STATUS REVIEW OF THE PACIFIC WALRUS (*Odobenus rosmarus divergens*)

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EXECUTIVE SUMMARY

This status review was compiled by a U.S. Fish and Wildlife Service (Service) Biological Review Team (BRT) in response to a petition filed by the Center for Biological Diversity to list the Pacific walrus (*Odobenus rosmarus divergens*) as threatened or endangered under the United States Endangered Species Act (ESA [16 U.S.C. 1531 et seq.]). The objectives of the status review were to obtain, synthesize, summarize and evaluate the best available scientific and commercial information on the status of the Pacific walrus and threats thereto. The interactions and cumulative effects of various threats acting on the Pacific walrus population were evaluated through the end of the 21st century.

Species Background: The Pacific walrus (*Odobenus rosmarus divergens*) is represented by a single population of animals that inhabits the shallow continental shelf waters of the Bering Sea and Chukchi Seas. The population ranges across the international boundaries of the United States and Russia and both nations share common interest in the conservation and management of this species. The distribution of Pacific walruses varies in response to seasonal patterns of sea-ice advance and retreat. During the late winter breeding season, walruses aggregate in the Bering Sea pack-ice in areas where ocean currents and upwelling's create areas of open water. In spring, as the sea-ice deteriorates in the Bering Sea, most of the population migrates north through the Bering Strait to summer feeding areas in the Chukchi Sea. In the fall, walruses return to winter feeding areas in advance of the sea-ice which forms rapidly across the Chukchi Sea.

Walruses are specialized predators of clams and other benthic invertebrates which are abundant in arctic ice covered waters. Although capable of diving to depths up 200 meters they are generally found in waters less than 100 meters because of the higher benthic productivity in these areas. Sea-ice habitats are used for resting between feeding bouts, breeding, calving, foraging and care of dependent young. Sea-ice is considered particularly important habitat for females and calves. When sea-ice is not available, walruses come to shore to rest on land. Since the mid-1990s, reductions of summer sea-ice cover have resulted in increased use of land-based haulouts along the Chukchi Sea coast. Disturbance events at densely packed coastal haulouts can result in injuries and mortalities.

Walruses have the lowest rate of reproduction of any pinniped species. The low birth rate of walruses is offset in by considerable maternal investment resulting in high survival rates of calves. The current size of the population is unknown. The Pacific walrus is an important subsistence resource in many coastal communities along the Bering and Chukchi Sea coasts of

Alaska (US) and Chukotka (Russia). Over the past fifty years the Pacific walrus population has sustained annual harvest mortalities ranging from 3,200 to 16,000 animals per year. While recent harvest levels are lower than historical highs, the lack of reliable information on population size and trend make it difficult to assess the impact of harvest levels.

Threats Assessment: The BRT organized and evaluated potential threats according to the 5-factor analysis outlined in Section 4(a)(1) of the ESA:

- (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, or
- (E) other natural or manmade factors affecting its continued existence

The interactions and cumulative effects of factors A, B, C, and E, were assessed using a Bayesian belief network (BBN) model. Existing regulatory mechanisms (Factor D) were assessed for each threat individually.

The present or threatened destruction, modification, or curtailment of the species' habitat or range: A warming climate is modifying the sea-ice habitats of the Pacific walrus. Projections of future ice conditions generated from global circulation models suggest that the Bering Sea will likely have sufficient amounts of sea-ice during the winter breeding season and spring calving season to support these activities at least through mid-century. By late-century, the location of favorable ice conditions for breeding and calving will likely shift further to the north. Observed and projected ice loss during the summer feeding season is more pronounced; and walruses are expected to become increasingly dependent on coastal haulouts along the Chukchi Sea coast. This shift in habitat use patterns is expected to result in increased rates of mortality from disturbance events along the coast and a reduction in the prey base within range of coastal haulouts. These factors are expected to result in a population decline over time; however, the timeframe and magnitude of the projected decline is unknown. As the Pacific walrus population becomes increasingly dependent on coastal habitats, interactions with humans are expected to increase. Human activities along the coast including aircraft over-flights, tourism and hunting have been identified as sources of disturbance related mortalities in recent years. The efficacy of future management efforts to protect walruses at coastal haulouts will likely be an important factor that will influence future population outcomes.

Overutilization for commercial, subsistence, recreational, scientific, or educational purposes: The utilization of Pacific walruses for recreational, scientific, and educational purposes occurs at very low levels and is not projected to increase significantly in the future. Although current harvest levels are likely within a sustainable range, observed and projected changes in sea ice habitats are expected to result in future population declines. Harvest levels may become unsustainable in the future if harvest levels do not adjust in concert with changes in population size. The subsistence walrus harvest in Alaska is not regulated under a quota system, however the Marine Mammal Protection Act (MMPA) provides for the development of co-management agreements with Alaska Natives for the subsistence use of marine mammals. Local hunting ordinances are also in development in some hunting communities, providing a potential mechanism for self-regulation of harvests. The MMPA also has a provision for establishing harvest quotas for marine mammals should a population be declared depleted.

Disease or predation: Diseases and predation do not appear to represent significant threats to the Pacific walrus population at the present time. Although a changing climate may increase exposure of walruses to new pathogens, the BRT considered the potential threats to walruses as low. As walruses and polar bears become increasingly dependent on coastal environments during ice-free periods we expect interactions between these two species to increase. Predation rates and associated disturbance related mortalities (particularly among calves and juveniles) are expected to increase in the future; however, the rate and extent of such an increase is unknown. The presence of polar bears stranded along the coast during the ice-free season is also likely to influence patterns of haulout use, and may play a significant role in the selection of coastal haulout sites in the future. How these interactions will translate into population level effects in the future is unknown.

Inadequacy of existing regulatory mechanisms: Our analysis of existing laws and regulations indicate that there is a diverse network of international, Federal, State and local laws and regulations that provide protection to Pacific walruses and their habitats. Currently, however, there are no effective mechanisms to regulate the global greenhouse gas emissions that are driving—via climate warming—the loss of sea-ice habitats. Our analysis of future sea-ice conditions is based on models and scenarios that do not include additional climate initiatives.

Other natural or human factors affecting the species' continued existence: Contaminants, oil and gas industry activities, fisheries, and shipping are presently occurring at modest levels within the range of the Pacific walrus, and do not represent a significant threat to the population at this time. Although all of these factors have potential to impact Pacific walruses in the future, we anticipate that future activities will be well regulated, and that any future impacts will be relatively localized. The threat of greatest concern is the potential for a large oil spill associated with oil and gas activities or shipping. While the probability of a large oil spill occurring is relatively low, the impacts of a large oil spill would likely be significant and could have long lasting consequences. The propensity of walruses to aggregate in large numbers along the Arctic coast makes them vulnerable to catastrophic events such as an oil spill.

Conclusions: We used BBN modeling to organize our threats assessment, examine interactions among threats, quantify expert opinions regarding cumulative effects of the listing factors, and determine which threats had the greatest effect on the population. We modeled 4 time periods and up to 3 scenarios (threat levels) for each time period. Modeling indicated that the cumulative effects of the threats increased over time. It is noteworthy that under best-case scenario's, where specified stressors such as harvest levels and disturbance related mortalities at coastal haulouts were set at low levels, the probability of negative population effects was significantly reduced. This suggests that effective mitigation of these stressors could influence future population outcomes. Sensitivity analyses indicated that harvest levels and GHG emissions had the largest effects on model outcomes. Compared to the observed and predicted habitat changes and harvest levels, the other threats analyzed had relatively minor influence on future population outcomes. The issue of greatest concern in Factor E (other factors) category is the potential effects of a large oil spill associated with oil and gas exploration and development, or shipping.

The Pacific walrus is experiencing habitat modification due to a warming climate and loss of summer sea-ice that has not occurred for several thousand years. Our review and analysis of potential threats suggests that the intensity of stressors will continue to increase in the future and will likely result in a population decline. The time frame over which population changes are likely to occur and the magnitude of population level impacts are uncertain. Continued monitoring and evaluation of population status and trends, as well as habitat assessment (availability and quality) will be critical to evaluate our assumptions, make adjustments as we gain increased understanding, and make direct links among the threats and population performance.

1 INTRODUCTION

On February 7, 2008, the Center for Biological Diversity (CBD) filed a petition with the Secretary of the Interior (Secretary) and the U. S. Fish & Wildlife Service (Service) to list the Pacific walrus (*Odobenus rosmarus divergens*) as threatened or endangered and to designate critical habitat for this species pursuant to the U.S. Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 et seq.).

Section 4(b)(3)(A) of the ESA requires the Secretary to determine, to the maximum extent practicable, within 90 days of receiving a petition to list a species under the ESA, whether the petition presents substantial scientific or commercial information indicating that the petitioned action may be warranted. On September 10, 2009 the Service published a positive 90-day finding in the *Federal Register* stating that the CBD petition presented substantial scientific or commercial information indicating that the petitioned action may be warranted.

To assist in determining whether listing the Pacific walrus under the ESA is warranted, the Service convened an expert panel (the Pacific Walrus Biological Review Team, or BRT) to prepare a status review for this species. The purpose of this status review is to synthesize, summarize and evaluate the best available scientific and commercial data on the status of the Pacific walrus and threats thereto. Information in this status review is intended to serve as a basis for the next finding the act requires the Service to make, the 12-month finding that the petitioned action is either: (1) warranted; (2) not warranted; or (3) warranted but precluded.

To assist with making this determination, the BRT evaluated the time frames over which future events can be reasonably said to be “foreseeable”, and assessed the risks of specific threats faced by the species identified under the 5 listing factors outlined in Section 4(a)(1) of the ESA:

(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, or

(E) other natural or manmade factors affecting its continued existence.

The interactions and cumulative effects of factors A, B, C, and E, were assessed using a Bayesian belief network (BBN) model. Existing regulatory mechanisms (Factor D) were assessed for each threat individually.

This document is a compilation of the best available scientific and commercial information concerning Pacific walruses, including information concerning past, present, and likely future threats to the population. It does not represent a decision by the Service on whether the Pacific walrus should be proposed for listing as threatened or endangered under the ESA. That decision will be made by the Service after reviewing this document, any other relevant biological and threat information not included herein, efforts being made to protect the species, and all relevant laws, regulations, and policies. The decision whether the Pacific walrus should be proposed for listing will be posted on the Service website (http://alaska.fws.gov/fisheries/mmm/walrus/reports.htm) and announced in the *Federal Register*.

2 SPECIES BACKGROUND

2.1 Taxonomy and Phylogeny

The walrus (*Odobenus rosmarus*) is the only living representative of the family Odobenidae, a group of marine carnivores that was highly diversified in the late Miocene and early Pliocene; 7-3 million years before present (YBP) (Kohno 2006; Harrington 2008). Fossil evidence suggests that the genus evolved in the North Pacific Ocean and dispersed throughout the Arctic Ocean and North Atlantic during interglacial phases of the Pleistocene; 2.5 million-12,000 YBP (Harington and Beard 1992; Dyke *et al.* 1999; Harrington 2008).

Three modern subspecies of walruses are generally recognized (Wozencraft 2005; ITIS 2010): the Atlantic walrus (*O. r. rosmarus*) ranges from the central Canadian Arctic eastward to the Kara Sea (Reeves 1978); the Pacific walrus (*O. r. divergens*) which ranges across the Bering and Chukchi Seas (Fay 1982) and the Laptev walrus (*O. r. laptevi*) which is represented by a small, geographically isolated population of walruses in the Laptev Sea (Heptner *et al.* 1976;Andersen *et al.* 1998; Rice 1998; Wozencraft 2005; Jefferson *et al.* 2008). Atlantic and Pacific walruses are genetically and morphologically distinct (Cronin *et al.* 1994), presumably as a result of range fragmentation and differentiation during periods of glacial maxima (Harrington 2008). Although geographically isolated and ecologically distinct, walruses from the Laptev Sea appear to be most closely related to Pacific walruses (Lindqvist *et al.* 2009).

Pacific walruses are geographically isolated and ecologically distinct from other walrus populations in the Arctic. Pacific walruses range across vast offshore areas of the shallow continental shelf waters of the northern Bering Sea and southern Chukchi Sea, relying principally on broken pack-ice habitat to access offshore feeding areas (Fay 1982). The Bering Strait affords Pacific walruses the opportunity to migrate significant distances between summer foraging areas in the Arctic (primarily the offshore continental shelf of the Chukchi Sea) and highly productive, seasonally ice covered waters in the Sub-arctic (northern Bering Sea) in winter (Fig. 1). Although many adult male Pacific walruses remain in the Bering Sea during the ice free season where they forage from coastal haulouts, most of the population migrates north in summer and south in winter following seasonal patterns of ice advance and retreat. In contrast, Atlantic walruses, which are represented by several discrete stocks of animals distributed across the Arctic, generally feed in coastal areas because of the narrow continental shelf over much of its range (Richard 1990; Laidre *et al.* 2008). Atlantic walruses occur predominately in Arctic waters, and the range and distributions of individual stocks is restricted to relatively small areas by natural barriers such as land masses and persistent sea-ice (Born *et al.* 1995). Because of the unique and favorable habitat and ecological conditions of the northern Bering and Chukchi Seas (broken pack-ice habitat juxtaposed over large areas of shallow continental shelf waters with high benthic production), the Pacific walrus population is significantly larger than any Atlantic walrus stocks which are represented by a few hundred - few thousand animals in other parts of the Arctic (Born *et al.* 1995).

Fossil evidence suggests that walruses occurred in the northwest Pacific during the last glacial maximum (20,000 YBP) with specimens recovered as far south as northern California (Gingras *et al.* 2007; Harrington 2008). More recently, commercial harvest records indicate that Pacific walruses were hunted along the southern coast of Russia in the Sea of Okhotsk and near Unimak Pass (Aleutian Islands) and the Shumigan Islands (Alaska Peninsula) of Alaska during the 17th Century (Elliott 1882). Today, Pacific walruses have a more northerly distribution; they generally range across the continental shelf waters of the northern Bering Sea and Chukchi Sea, occasionally ranging into the East Siberian and Beaufort Seas (Fay 1982) (Fig. 1). Walruses are rarely spotted south of the Aleutian archipelago; however migrant animals (mostly males) are occasionally reported in the North Pacific and at least one adult male walrus has been spotted regularly in Cook Inlet (south of the Alaska Peninsula) over the past 20 years (Alaska Public Radio, October 27, 2009, http://aprn.org/2009/10/27/talk-of-alaska-the-status-of-pacific-walrus/). Although (Jay *et al.* 2008) found some differences in the ratio of trace elements in the teeth of walruses sampled in winter from two breeding areas (southeast Bering Sea and St. Lawrence Island) suggesting that the sampled animals had a history of feeding in different regions, Scribner *et al.* (1997) found no difference in mitochondrial and nuclear DNA among Pacific walruses sampled from different breeding areas. Pacific walruses are presently identified and managed as a single panmictic (unstructured, random-mating) population (USFWS 2010).

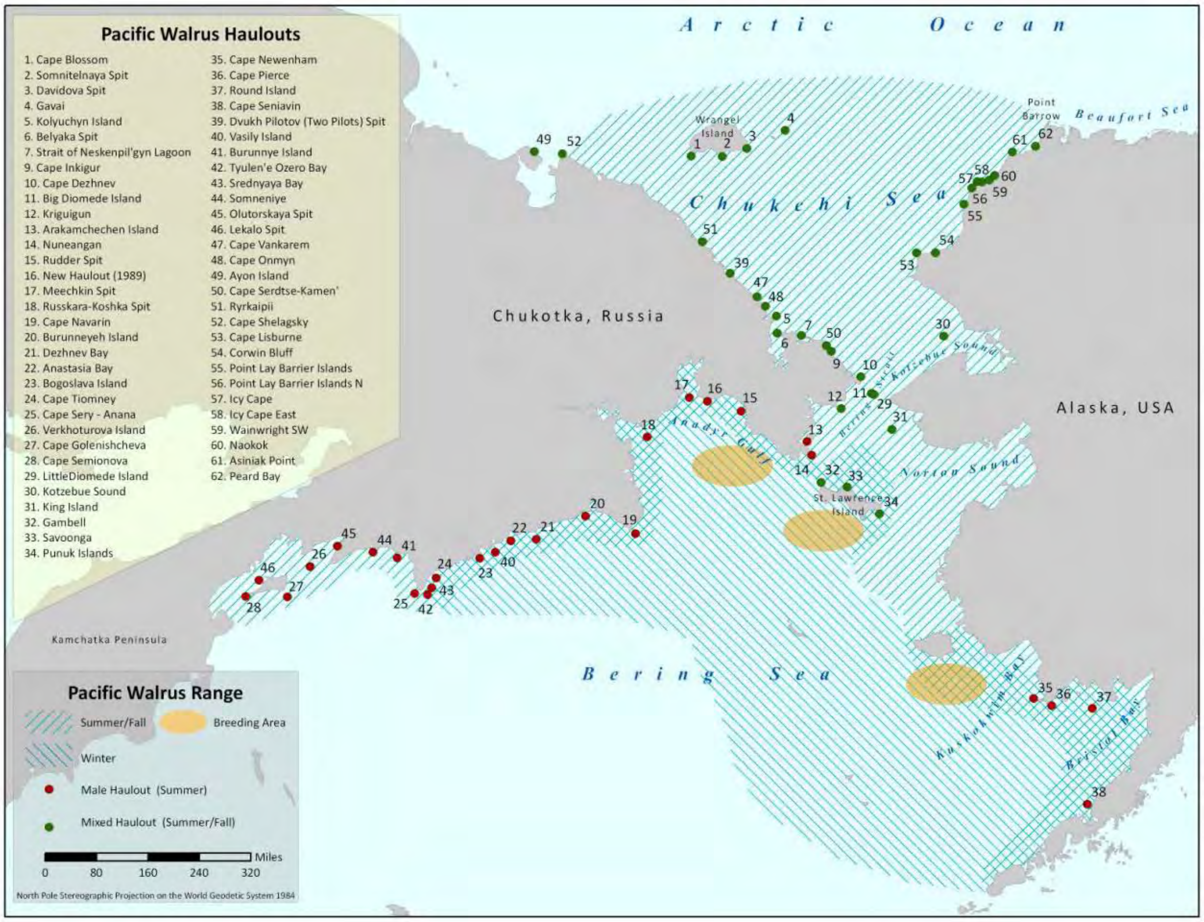


***Figure 1*. Distribution of the Pacific walrus in the Bering and Chukchi Seas in winter and summer. Modified from (Smith 2010).**

2.2 Species Description

Walruses are readily distinguished from other Arctic pinniped species by their enlarged upper canine teeth which form prominent tusks. The generic name *Odobenus* (tooth walker) is based on observations of walruses using their tusks to pull themselves out of the water. Males, which have relatively larger tusks than females also tend to have broader skulls (Fay 1982). Walrus tusks are used as offensive and defensive weapons (Kastelein 2002). Adult males use their tusks in threat displays and fighting to establish dominance during mating (Fay *et al.* 1984b) and animals of both sexes use threat displays to establish and defend positions on land or ice haulouts (Fay 1982). Walruses also use their tusks to anchor themselves to ice floes when resting in the water during inclement weather (Fay 1982; Kastelein 2002).

The walrus is the largest pinniped species in the Arctic. At birth, calves are approximately 65 kg and 113 cm long (Fay 1982). After the first few years of life, the growth rate of female walruses declines rapidly, and they reach a maximum body size by approximately 10 years of age. Adult females can reach lengths of up to 3 meters and weigh up to 1,100 kg. Male walruses tend to grow faster and for a longer period of time than females. They usually do not reach full adult body size until they are 15-16 years of age. Adult males can reach lengths of 3.5 meters and can weigh more than 2,000 kg (Fay 1982).

The first molt, in which a white lanugo (fetal hair) is shed, occurs *in utero* two to three months before birth. The coarse, dark, natal coat is shed in June and July of the first year. Adult animals have a short, sparse, tawny pelage, and molt annually during the summer months (Fay 1982).

2.2.1 Behavior

Walruses are social and gregarious animals. They tend to travel and “haul out” to rest on ice or land in densely packed groups. On land or ice, in any season, walruses tend to lie in close physical contact with each other. Young animals often lie on top of adults. Group size can range from a few individuals, up to several thousand animals (Gilbert 1999; Kastelein 2002; Jefferson *et al.* 2008). When disturbed, stampedes from a haulout can result in injuries and mortalities. Calves and young animals are particularly vulnerable to trampling injuries.

The mother-calf bond is strong. The calf normally remains with its mother for at least 2 years, sometimes longer, if not supplanted by a new calf (Fay 1982). The high degree of maternal investment is thought to result in much lower rates of mortality among calves than with other pinniped species (Fay *et al.* 1989; Chivers 1999). After separation from their mother, young females tend to remain with groups of adult females, while young males gradually separate from the females and begin to associate with groups of other males. Individual social status appears to be based on a combination of body size, tusk size, and aggressiveness. Individuals do not necessarily associate with the same group of animals and must continually reaffirm their social status in each new aggregation (Fay 1982).

Mating occurs primarily in January and February in broken pack-ice habitat in the Bering Sea. Breeding bulls follow herds of females and compete for access to groups of females hauled out onto sea-ice. Males perform visual and acoustical displays in the water. Sub-dominant males remain on the periphery of these aggregations and apparently do not display. Intruders into display areas are met with threat displays and physical attacks. Individual females leave the resting herd to join a male in the water where copulation occurs (Fay *et al.* 1984b; Sjare and Stirling 1996; NAMMCO 2004).

2.2.2 Foraging and Prey

Walruses consume mostly benthic invertebrates (Fay 1982, Bowen and Siniff 1999, Born *et al.* 2003, Dehn *et al.* 2007, Sheffield and Grebmeier 2009) although fish and other vertebrates are also occasionally reported (Fay 1982, Sheffield and Grebmeier 2009). Walruses root in the bottom sediment with their muzzles and use their whiskers to locate prey items. They use their fore-flippers, nose, and jets of water to extract prey buried up to 32 cm (12.6 in) (Fay 1982; Oliver *et al.* 1983; Kastelein 2002; Levermann *et al.* 2003). The foraging behavior of walruses is thought to have a major impact on benthic communities in the Bering and Chukchi Seas (Oliver *et al.* 1983; Klaus *et al.* 1990). Ray *et al*. (2006), estimated that walruses consume approximately 3 million metric tons (3,307 tons) of benthic biomass annually and that the area affected by walrus foraging is in the order of thousands of square kilometers (km^2) annually. Consequently, walruses play a major role in benthic ecosystem structure and function, which Ray *et al*. (2006) suggested increased nutrient flux and productivity.

The earliest food habits studies were based on examination of stomachs from walruses killed by hunters, and reports indicated that walruses were primarily feeding on bivalve mollusks (clams) and that non-bivalve prey was only incidentally ingested (Fay 1982; Sheffield *et al.* 2001). However, these early studies did not take into account the differential rate of digestion of prey items (Sheffield and Grebmeier 2009; Sheffield *et al.* 2001). Additional research indicates that stomach contents include over 100 taxa of benthic invertebrates from all major phyla, and while bivalve mollusks remain the primary component, walruses are not adapted to a diet solely of bivalves (Fay 1982; Sheffield and Grebmeier 2009). Other prey items have similar energetic benefits (Wacasey and Atkinson 1987). Based on analysis of the contents from fresh stomach of Pacific walruses collected between 1975 and 1985 in the Bering and Chukchi Seas, prey consumption likely reflects benthic invertebrate composition (Sheffield and Grebmeier 2009). There does not appear to be a significant difference in prey selection between male and female walruses (Sheffield and Grebmeier 2009).

Walruses typically swallow invertebrates without shells in their entirety (Fay 1982). Walruses remove the soft parts of mollusks from their shells by suction, and discard the shells (Fay 1982). Born *et al*. (2003) reported that Atlantic walruses consumed an average of 53.2 bivalves (range 34 to 89) per dive. Based on caloric need (kcal/kg) and observations of captive walruses, walruses require approximately 29 to 74 kg (64 to 174 lbs) of food per day (Fay 1982). Adult males forage little during the breeding period (Fay 1982; Ray *et al.* 2006). Calves up to one year depend primarily on their mother’s milk (Fay 1982) and are gradually weaned in their second year (Fisher and Stewart 1997).

Although walruses are capable of diving to depths of more than 250 m (820 ft) (Born *et al.* 2005), they usually forage in waters of 80 m (262 ft) or less (Fay and Burns 1988; Born *et al.*

2003; Kovacs and Lydersen 2008), presumably because of higher productivity of their benthic foods in shallow waters (Fay and Burns 1988; Carey 1991; Jay *et al.* 2001; Grebmeier *et al.* 2006 a,b). Walruses make foraging trips from land or ice haulouts that range from a few hours up to several days (Jay *et al.* 2001; Born *et al.* 2003; Ray *et al.* 2006; Udevitz *et al.* 2009). Walruses tend to make more frequent but shorter, both in duration and distance, trips when they are using sea-ice as a foraging platform compared to terrestrial haulouts (Udevitz *et al.* 2009). Satellite telemetry data indicates that walruses spend, on average, 46 hours in the water between resting bouts on ice (Udevitz *et al.* 2009). Male walruses appear to have greater endurance than females, with foraging excursions from land haulouts that can last up to 142 hours (about 6 days) (Jay *et al.* 2001).

2.2.3 Seasonal Distributions

The distribution of Pacific walruses varies markedly in response to seasonal and inter-annual variations in sea-ice cover. During the January to March breeding season, walruses congregate in the Bering Sea pack-ice in areas where open leads (fractures in the ice caused by wind drift or ocean currents), polynyas (enclosed areas of unfrozen water surrounded by ice) or thin ice allow access to water (Fay 1982; Fay *et al.* 1984b). While the specific location of winter breeding aggregations varies annually depending upon the distribution and extent of ice, breeding aggregations generally form southwest of St. Lawrence Island; south of Nunivak Island; and south of the Chukotka Peninsula in the Gulf of Anadyr (Fay 1982; Mymrin *et al.* 1990; Burn *et al.* 2009; Speckman *et al.* 2010) (Fig. 1).

In spring, as the Bering Sea pack-ice deteriorates, most of the population migrates northward through the Bering Strait to summer feeding areas over the continental shelf in the Chukchi Sea. Several thousand animals, primarily adult males, remain in the Bering Sea during the summer months foraging from coastal haulouts in the Gulf of Anadyr and in Bristol Bay during the ice-free season (Fig. 1).

Summer distributions in the Chukchi Sea vary annually depending upon the distribution and extent of sea-ice. When broken ice is abundant, walruses are typically found in patchy aggregations across the shallow continental shelf. Individual herds may range from < 10 to > 1000 animals (Gilbert 1999; Ray *et al.* 2006). Summer concentrations have been reported in loose pack-ice off the northwestern coast of Alaska between Icy Cape and Point Barrow and along the coast of Chukotka, Russia as far west as Wrangel Island (Fay 1982; Gilbert, *et al.* 1992; Belikov *et al.* 1996). The pack-ice of the Chukchi Sea usually reaches its minimum extent in September. In years when the sea-ice retreats beyond the continental shelf, walruses congregate in large numbers at terrestrial haulouts on Wrangel Island and other sites along northern coast of the Chukotka Peninsula (Fay 1982; Belikov *et al.* 1996; Kochnev 2004; Ovsyanikov *et al.* 2007; Kavry *et al.* 2008).

In late September and October, walruses that summered in the Chukchi Sea typically begin moving south in advance of the developing sea-ice. Large herds of southbound migrants often congregate for a period of time to rest at coastal haulout sites in the southern Chukchi Sea (e.g., Cape Lisburne, Cape Dezhnev and Cape Serdtze Kamen'(Fig. 1)), before moving to winter breeding areas in the Bering Sea. Large haulouts have also been reported intermittently in the Bering Strait Region (Big Diomede, King Island, and the Punuk Islands) in late fall and early winter, prior to the onset of ice formation (Fay and Kelly 1980) (Fig. 1). Satellite telemetry data indicates that male walruses that summered in the Bering Sea also begin to move northward towards winter breeding areas in November (Jay and Hills 2005). Breeding bulls apparently do not feed much during the winter breeding season and their movements and distributions appear to be driven primarily by the presence of females at this time of year (Freitas *et al.* 2009).

2.2.4 Habitat Requirements

Walrus habitat requirements include large areas of shallow water that support a productive bivalve community, the reliable presence of open water over these feeding areas, and suitable ice or land nearby upon which to rest.

2.2.4.1 Benthic Habitat

The shallow, ice covered waters of the Bering and Chukchi Seas support some of the highest densities of benthic invertebrates in the world (Grebmeier *et al.* 2006a,b). Sea-ice algae provide a highly concentrated and high quality food source for planktonic food webs in the spring (Grebmeier *et al.* 2006a; McMahon *et al.* 2006; Gradinger 2009). Because zooplankton populations are relatively low in areas where ice is present, much of this primary production falls to the sea floor where it is converted to benthic biomass (Grebmeier *et al.* 2006a).

Spatial variability in benthic biomass across the Bering and Chukchi Seas is influenced by a variety of ecological, oceanographic and geomorphic features. Within the Arctic region of the Bering Sea, marginal sea-ice zones and areas of persistent polynyas appear to be “hot spots” of high benthic diversity and productivity (Grebmeier and Cooper 1995). Benthic biomass is particularly high in the northern Bering Sea, the southern Chukchi Sea and in the Gulf of Anadyr while benthic communities are relatively sparse across the Alaskan Beaufort Sea shelf and areas of the eastern Chukchi Sea influenced by the nutrient poor Alaska coastal current (Fay *et al.* 1977; Grebmeier *et al.* 1989; Feder *et al.* 1994; Smith *et al.* 1995; Grebmeier *et al.* 2006a; Bluhm and Gradinger 2008).

In the sub-arctic region of the Bering Sea, benthic organisms are heavily preyed on by demersal fish and epifaunal invertebrates, whose distributions tend to be limited further to the north by cold water temperatures resulting from seasonal sea-ice cover. Differences in ocean temperatures, mediated by seasonal ice cover, form a temperature defined ecological boundary; in the colder Arctic region of the Bering Sea, predatory invertebrates, benthic feeding whales, walruses and sea-birds are the primary consumers of benthos (Grebmeier *et al.* 2006b).

2.2.4.2 Sea-ice Habitat

Walruses generally occupy first-year ice and are not found in areas of extensive, unbroken ice (Fay 1982; Richard 1990; Barber *et al.* 1991). Expansive areas of heavy ice cover are thought to play a restrictive role in walrus distributions across the Arctic and a barrier to the mixing of populations (Fay 1982; Dyke *et al.* 1999, Harington 2008). In winter, walruses tend to concentrate in areas of broken pack-ice associated with divergent ice flow or along the margins of persistent polynyas (Burns *et al.* 1981; Fay *et al.* 1984b; Richard 1990). These areas are also characterized by abundant benthic food (Ray *et al.* 2006). Females and their young spend the summer months along the southern margin of the Chukchi pack-ice; moving further into the ice pack during storms (Fay 1982; Richard 1990; Gilbert 1999). The size and topography of individual ice floes may be important features in the selection of ice haulouts, and animals have been observed returning to the same ice floe between feeding bouts (Ray *et al.* 2006). However, it has also been noted that walruses can and will exploit a fairly broad range of ice types and ice concentrations in order to stay in preferred forage or breeding areas (Freitas *et al.* 2009; Jay *et al.2010a*). Walruses tend to make shorter foraging excursions when they are using sea-ice rather than land haulouts, presumably because it is more energetically efficient for them to haulout on ice near productive feeding areas than forage from shore. Walruses generally do not occur farther south than the maximum extent of the winter pack-ice; possibly because of their reliance on sea-ice for breeding and rearing young (Fay *et al.* 1984b) and isolation from terrestrial predators (Kochnev 2004; Ovsyanikov *et al.* 2007) or because of the higher densities of benthic invertebrates in northern waters (Grebmeier *et al.* 2006b).

2.2.4.3 Terrestrial Habitats: Coastal Haulouts

When suitable sea-ice is not available, walruses haul out to rest on land. Factors thought to influence terrestrial haulout site selection include: proximity to food resources; isolation from disturbances and predators; social factors and learned behavior; and, protection from strong winds and surf (Richard 1990). Walruses tend to use established haulout sites repeatedly and exhibit some degree of fidelity to these sites (Jay and Hills 2005). A wide variety of substrates, ranging from sand to boulders, are used. Isolated islands, points, spits, and headlands are occupied most frequently. It has also been noted that the use of some coastal haulouts has fluctuated over time, possibly due to localized prey depletion (Garlich-Miller and Jay 2000). Human disturbance is also thought to influence the choice of haulout sites; many historic haulouts in the Bering and Chukchi Seas were abandoned in the early 1900s when the Pacific walrus population was subjected to high levels of exploitation (Fay 1982; Fay *et al.* 1984a).

Adult males use land-based haulouts more than females or young, and consequently, have a greater distribution through the ice-free season. Most female walrus and their young stay with the drifting ice pack throughout most of the year (Fay 1982), only coming to shore when sea-ice is completely absent. Females may avoid using terrestrial haulouts because their offspring are more vulnerable to trampling (Fay and Kelly 1980; Ovsyanikov *et al.* 1994; Kochnev 2004; Kavry *et al.* 2008; Fischbach *et al.* 2009) or predation (Kochnev 2004; Ovsyanikov *et al.* 2007; Kavry *et al.* 2008). Females may also have more difficultly foraging from coastal haulouts when encumbered by a young calf (Cooper *et al.* 2006; Jay and Fischbach 2008).

Bering Sea Haulouts

Coastal haulouts in the Bering Sea tend to be utilized primarily by adult males during the summer months. The most consistently used coastal haulout sites in the Bering Sea are located in Bristol Bay, Alaska and in the Gulf of Anadyr, Russia (Fig. 1). Intermittently used summer haulouts have also been reported at Big Diomede Island in the Bering Strait region, on St. Mathew and Hall Islands in the central Bering Sea and along the Koryak coast of Russia (Fig. 1).

The number of walruses using Bristol Bay haulouts during the summer months, and the relative use of the different haulout sites has varied over the past century. Harvest records indicate that walrus herds were once common at coastal haulouts along the Alaska Peninsula and the islands of northern Bristol Bay (Fay *et al.* 1984a). By the early 1950s, most of the traditional haulout areas in the Southern Bering Sea had been abandoned, presumably due to hunting pressure. During the 1950s and 1960s, Round Island was the only regularly used haulout in Bristol Bay. Peak counts of walruses at Round Island increased from 1,000-2,000 animals in the late 1950s to more than 10,000 animals in the early 1980s (Frost *et al.* 1983). Declining walrus counts at Round Island in the late 1980s may in part reflect a redistribution of animals to other coastal sites in the Bristol Bay region. Walruses have been observed regularly at the Cape Seniavin haulout on the Alaska Peninsula since the 1970s and at Cape Peirce and Cape Newenham in northwest Bristol Bay since the early 1980s. Less consistently used summer haulouts in Bristol Bay include Hagemeister Island, Crooked Island, Twin Islands, Amak Island, and Cape Constantine (Frost *et al.* 1983). Haulout counts at Cape Pierce and Cape Newenham declined markedly after 1999, while counts at Round Island have remained below the peak numbers observed in the early 1980s. Although individual animals with unique identifying characteristics such as tusk deformities or attached telemetry equipment have been observed at Bristol Bay haulouts in successive years, the degree of inter-annual fidelity to Bristol Bay haulouts is unknown. Large year to year fluctuations in haulout numbers suggest that animals do not necessarily return to the same haulout each year. Factors influencing walrus abundance in Bristol Bay are poorly understood, but may include the status of food stocks near the haulouts, changes in population size, disturbance levels, and winter/spring distributions (Jay and Hills 2005).

Traditional Bering Sea summer haulouts in Russia include sites along the Kamchatka Peninsula; the Gulf of Anadyr (most notably Rudder and Meechkin spits) and Arakamchechen Island (Fig. 1). The number of walruses using Bering Sea haulouts in Russia has declined substantially since the 1980s. Several of the southernmost haulouts along the coast of Kamchatka and the Koryak coast have been abandoned in recent years and the number of animals at the other sites is greatly reduced (Kochnev 2005). Although walrus continue to use terrestrial haulouts to the north in the Gulf of Anadyr the number of animals observed at these sites has also declined in recent years (Kochnev 2005).

Chukchi Sea Haulouts

Haulouts along the Chukchi Sea have been used less consistently during the summer months than those in the Bering Sea because of the presence of pack-ice (a preferred substrate) for much of the year. Since the mid-1990s reductions of summer sea-ice cover has coincided with an increased use of coastal haulouts along the coast of Russia (Kochnev 2004; Kavry *et al.* 2008). Large herds of walruses, up to several tens of thousands of animals, of various age and sex classes, have begun to use coastal haulouts on Wrangel Island and several locations along the northern Chukotka coastline (Fig. 1) in late summer (Kochnev 2004; Ovsyanikov *et al.* 2007; Kavry *et al.* 2008). In recent years (2007, 2009 and 2010) walruses have also been observed hauling out along the coast of Alaska in late summer (Thomas *et al.* 2009).

Monitoring studies conducted in association with oil and gas exploration in the eastern Chukchi Sea suggest that the use of coastal haulouts along the Arctic coast of Alaska is influenced by the availability of sea-ice. For example, in 2006 and 2008 walruses remained with the ice pack during the entire summer season, however in August 2007, 2009, and 2010, the pack-ice retreated beyond the continental shelf and walruses were observed hauled out on land at several locations between Point Barrow and Cape Lisburne (Thomas *et al.* 2009; COMIDA Survey Project: http://www.afsc.noaa.gov/NMML/cetacean/bwasp/flights_COMIDA_1-3.php; Fig. 1). Thomas *et al.* (2009) noted a lag of approximately 20 days between the disappearance of sea-ice in offshore areas and the formation of coastal haulouts along the Alaska Coast. Following the inshore-migration, subsequent movements of walruses back offshore and another movement returning to shore was inferred from vocalizations recorded on offshore hydrophones suggesting that animals may have moved offshore periodically to feed (Macrander 2009). Although summer sea-ice concentrations in the eastern Chukchi Sea were also low in 2008, small ice pans (undetectable by satellites) persisted in some areas and walruses were able to use this ice cover and remain offshore (Chad Jay, USGS, 2008 *pers.*

comm., based upon unpublished telemetry data). In September 2009, survey aircraft again reported large numbers of walruses hauled out along the coast of Alaska suggesting a similar scenario to 2007 when pack-ice retreated away from offshore feeding grounds (COMIDA Survey Project: http://www.afsc.noaa.gov/NMML/cetacean/bwasp/flights_COMIDA_1-3.php).

2.2.5 Vital Rates

Walruses have the lowest rate of reproduction of any pinniped species (Fay 1982). Although male walruses reach puberty at 6-7 years of age they are unlikely to successfully compete for females until they reach full body size at 15 years of age or older (Fay 1982; Fay *et al.* 1984). Female walruses attain sexual maturity at 4-7 years of age (Fay 1982; Garlich-Miller *et al.* 2006). Oestrus and mating occur from January through March. Pacific walruses typically give birth to a single calf in May the following year shortly before, or during, the spring migration (Fay 1982). Mothers and newborn calves stay on ice floes until calves develop sufficient energy reserves for thermoregulation. The calf is closely attended by the cow, and typically nurses for 1-2 years (Fay 1982; Fisher and Stewart 1997). Ovulation may be suppressed until the calf is weaned, raising the birth interval to 3 years or more (Garlich-Miller and Stewart 1999). The age of sexual maturity and birth rates may be density dependent (Fay *et al.* 1989; Fay *et al.* 1997; Garlich-Miller *et al.* 2006).

The low birth rate of walruses is offset in part by considerable maternal investment in offspring (Fay *et al.* 1997). Estimated survival rates through the first year of life range from 0.5 to 0.9 (Fay *et al.* 1997). Survival rates for juveniles and adults (e.g. 4-20 years old) are assumed to be as high as 0.96-0.99 (DeMaster 1984; Fay *et al.* 1997) declining to zero by 40-45 years of age (Chivers 1999). Chivers (1999) developed an individual-based model of the Pacific walrus population using published estimates of survival and reproduction. The model estimated a theoretical maximum population growth rate of 8%.

2.2.6 Abundance and Trends

The size of the Pacific walrus population has never been known with certainty. Based on large sustained harvests in the 18th and 19th centuries, Fay (1957) speculated that the pre-exploitation population was about 200,000 animals. Since that time, population size is believed to have fluctuated in response to varying levels of human exploitation. Large-scale commercial harvests are believed to have reduced the population to 50,000-100,000 animals in the mid-1950s (Fay *et al.* 1997). The population appears to have increased rapidly in size during the 1960s and 1970s in response to harvest regulations that limited the take of females (Fay *et al.* 1989). Between 1975 and 1990, aerial surveys were carried out by the United States and Russia at 5-year intervals, producing population estimates ranging from 201,039 to 290,000 (Table 1). In 2006, U.S. and Russian researchers surveyed walruses in the pack-ice of the Bering Sea using thermal imaging systems to detect walruses hauled out on sea-ice and satellite transmitters to account for walruses in the water (Speckman *et al.* 2010). The number of walruses within the surveyed area was estimated at 129,000 with 95% confidence limits of 55,000 to 507,000 individuals (Table 1).

Table 1. **Estimates of Pacific walrus population size, 1975-2006.**

Year	Population size[a]	Reference
1975	214,687	(Udevitz *et al.* 2001)
1980	250,000-290,000	(Johnson *et al.* 1982; Fedoseev 1984)
1985	242,366	(Udevitz *et al.* 2001)
1990	201,039	(Gilbert *et al.* 1992)
2006	129,000 (55,000-507,000)	(Speckman *et al.* 2010)

[a] Due to differences in methods, comparisons of estimates across years (population trends) are subject to several caveats and not reliable. The 2006 survey was the only one that allowed for a measure of precision (in parenthesis, 95% confidence interval).

Past survey results are not directly comparable among years due to differences in survey methods, timing of surveys, segments of the population surveyed, and incomplete coverage of areas where walruses may have been present (Fay *et al*. 1997); and do not provide a basis for determining trends in population size (Hills and Gilbert 1994; Gilbert 1999). Whether prior estimates are biased low or high is unknown, because of problems with detecting individual animals on ice or land, and in open water, and difficulties counting animals in large, dense groups (Speckman *et al.* 2010). In addition, no survey has ever been completed within a time frame that could account for the redistribution of individuals (leading to double counting or undercounting) or before weather conditions either delayed the effort or completely terminated the survey before the entire area of potentially occupied habitat had been covered (Speckman *et al.* 2010). Due to these general problems, as well as seasonal differences among previous surveys (fall or spring) and technological advancements that correct for some problems, we do not believe that past survey results provide a reliable basis for estimating population trend.

Based on evidence of changes in abundance, distributions, condition indices, and life-history parameters, Fay *et al.* (1989; 1997) concluded that the Pacific walrus population increased rapidly in size during the 1960s and 1970s, and postulated that the population was approaching, or had exceeded, the carrying capacity of its environment in the early 1980s.

Changes in the size, composition and productivity of the sampled walrus harvest in the Bering Strait Region of Alaska over this time frame are consistent with this hypothesis (Garlich-Miller *et al.* 2006). Increased reproductive rates and earlier maturation in females occurred in the 1990s, suggesting that the population was no longer constrained by density dependent mechanisms; however, it is not clear whether these changes reflect a decline in population size, changes in environment conditions or a combination factors (Garlich-Miller *et al.* 2006).

Although it is difficult to quantify recent changes in the status and trend of the population, resource managers in Russia have reduced harvest quotas in recent years in response to their perception that the population is in decline (Anatoli Kochnev, Chukot TINRO, 2010, *pers. comm.*). Factors considered in their decision to lower quotas include: the abundance estimate generated from the 2006 survey results (Speckman *et al.* 2010) is lower than the results of previous survey efforts; significant reductions in summer sea-ice habitats have occurred in recent years; and large numbers of mortalities (up to several thousand per year) have been reported at coastal haulouts in Russia (Nikiforov *et al.* 2007; Ovsyanikov *et al.* 2007; Kochnev 2008). It should be noted that the most recent abundance estimate is believed to be negatively biased to an unknown degree because inclement weather conditions precluded full coverage of available habitats (Speckman *et al.* 2010).

3 THREATS ASSESSMENT

The purpose of this threats assessment is to estimate the effect and magnitude of potential threats as part of a decision making process analyzing the status of the Pacific walrus relevant to the listing criteria of the ESA. The level of risk faced by a species depends on the number and severity of threats and the time frame considered in terms of the ability to forecast the effects of a threat and the ability to forecast the response of the species.

3.1 The Foreseeable Future

Making a determination of whether a species is threatened requires consideration of the time frame over which the population status and each potential threat is foreseeable. When a species is exposed to a variety of threats, each threat may be uniquely foreseeable.

3.1.1 Factors in the Foreseeability of Threats to Pacific Walruses

The petition to list the Pacific walrus under the ESA cited global warming as a primary concern, and others have also speculated that Pacific walruses are at risk from loss of sea-ice habitats in a warming climate (Tynan and DeMaster 1997; Kelly 2001; Jay and Fischbach 2008; Laidre *et al.* 2008; Moore and Huntington 2008). Other potential stressors, such as impacts to prey species, calf/juvenile mortality, and disease/parasitism/predation rates are also likely to be influenced by environmental changes associated with a warming climate driven by greenhouse gas (GHG) emissions. Therefore, the predictability of trends in GHG emissions is of primary consideration in the foreseeability of many threats to Pacific walruses.

The analysis and synthesis of information by the Intergovernmental Panel on Climate Change (IPCC) in its *Fourth Assessment Report* (AR4) identifies the most likely causes and future trends in climate change and has broad support within the scientific community. The IPCC AR4 used a range of future GHG emissions produced under various scenarios to project plausible outcomes with clearly stated assumptions about socio-economic factors that will influence GHG emissions. Conditional on each scenario, the best estimate and likely range of emissions were projected to the end of the 21st century. The factors that differ among the scenarios include assumptions about economic and population growth rates, technological development, and the mix of energy sources used to meet global needs. The IPCC did not assign likelihood to any of the six scenarios.

The IPCC AR4 model outputs have been used by several authors to forecast future sea-ice conditions in the Bering and Chukchi Seas through the end of the 21st century. Because of model to model differences in the way that physical processes are incorporated into the various IPCC AR4 models, predictions of future climate conditions are conditional to a certain extent on the choice of GCMs used. The most common approach to deal with the uncertainty and biases inherent in individual models is to use the median outcome of several predictive models (a model ensemble) for inference. Screening or deemphasizing the weight of those models that poorly simulate observational data is also a common approach to reducing uncertainty surrounding projections from multi-model ensembles. Although excluding models with persistent biases that grossly misrepresent observed results may result in more realistic model projections over the short term, it is important to recognize that the selected models do not necessarily result in better long-term projections (Douglas 2010).

Not all potential threats to Pacific walruses are climate related, or not all are foreseeable through the 21st century. As a simple example, an episodic outbreak of a novel disease or a catastrophic event such as an oil spill may be considered as potential threats to the Pacific walrus population, but the time frame of “foreseeability” of an inherently episodic or novel threat is difficult or impossible to establish.

3.1.2 Factors in the Foreseeability of the Response of Pacific Walruses to Threats

A threat to a species and its response to that threat are not, in general, equally foreseeable. Even though future warming is highly likely to occur, the demographic, ecological, and evolutionary responses of Pacific walruses to a warming climate are difficult to predict. Observations of the response of walruses to loss of summer sea-ice over the last several years is the most realistic scenario when evaluating future changes, but does not take into full account future changes in walrus and human behavior that may accompany the large environmental changes.

3.2 The Present or Threatened Destruction, Modification, or Curtailment of the Species' Habitat or Range

3.2.1 Global Climate Change

In 1988, the World Meteorological Organization and the United Nations Environmental Programme established the Intergovernmental Panel on Climate Change (IPCC) to provide an objective source of information about Global Climate Change. The IPCC has produced four assessment reports that represent syntheses of the best available and most comprehensive scientific information on climate change to date. The following excerpts from the IPCC's "Climate Change 2007: Synthesis Report, Summary for Policymakers" (IPCC 2007b) highlight some of the observed and projected changes in climate and their anticipated effects/impacts:

"Observed changes in climate and their effects:

- *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.*
- *Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases.*
- *There is medium confidence that other effects of regional climate change on natural and human environments are emerging, although many are difficult to discern due to adaptation and non-climatic drivers*".

"Projected climate change and its impacts:

- *There is high agreement and much evidence that with current climate change mitigation policies and related sustainable development practices, GHG emissions will continue to grow over the next few decades.*
- *Continued GHG emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century.*
- *There is now higher confidence than in the TAR* [Third Assessment Report] *in projected patterns of warming and other regional-scale features, including changes in wind patterns, precipitation and some aspects of extremes and sea-ice.*
- *Studies since the TAR have enabled more systematic understanding of the timing and magnitude of impacts related to differing amounts and rates of climate change.*
- *Altered frequencies and intensities of extreme weather, together with sea level rise, are expected to have mostly adverse effects on natural and human systems.*
- *Anthropogenic warming and sea level rise would continue for centuries due to the time scales associated with climate processes and feedbacks, even if GHG concentrations were to be stabilized*
- *Anthropogenic warming could lead to some impacts that are abrupt or irreversible, depending upon the rate and magnitude of the climate change*".

Both the observed and the projected effects of a warming global climate are most extreme in northern high latitude regions, in large part due to the ice-albedo feedback mechanism in which melting of snow and sea-ice lowers reflectivity and thereby further increases surface warming by absorption of solar radiation. A large and growing body of information documenting observed changes in environmental conditions in the Arctic and projections of future changes are available. Our focus in this section is to assess observed and projected changes in environmental conditions on Pacific walrus habitat.

3.2.1.1 Effects of Global Climate Change on Sea-ice Habitats

This section describes the past, present, and future projections of sea-ice conditions over continental shelf regions of the Bering and Chukchi Seas. To help put recent observations and future forecasts into context, information on climate reconstructions for the past 11,000-12,000 years are presented. We then examine sea-ice conditions during recent decades, with an emphasis on the period of passive microwave satellite retrievals (1979-present) and continue with a discussion of sea-ice projections through the end of the twenty-first century.

The Past:

The paleo-climate record for the Bering and Chukchi seas during the Holocene (the last 11,000-12,000 years) appears to be one of dynamic change, with great variations in sea-ice cover. For example, McKay *et al.* (2008) analyzed bottom sediment core samples taken from the Alaskan margin in the eastern Chukchi Sea; their results indicate a long-term decreasing trend in sea-ice cover has occurred over the past 9,000 years, with millennial-scale fluctuations characterized by periods of low ice with a frequency of about one every 2,500-3,000 years superimposed on the general trend. Sea-ice cover in the western Arctic Ocean appears to have fluctuated greatly throughout the Holocene, and there appears to have been times when sea-ice cover was much less extensive than it is today (McKay *et al.* 2008). In their literature review of past glacial and interglacial conditions in the Arctic Ocean and marginal seas, Darby *et al.* (2006) noted centennial to millennial-scale climate changes occurred across the Arctic during the Holocene.

Savinetsky *et al.* (2004) estimated the dynamics of summer sea-ice in the Bering Strait from buried peat layers in coastal deposits, and found that a period characterized by an increase in summer sea-ice began about 1,200-1,400 years before present (YBP) based on ^{14}Carbon dating. This period coincided with an increase in the number of bowhead whales and walruses in the region, based on remains found associated with ancient settlements (Savinetsky *et al.* 2004). Crockford and Frederick (2007) analyzed prehistoric skeletal remains from archaeological sites on Unalaska and interpreted the results as providing evidence "that Neoglacial (a cold period during the Holocene from approximately 4,700 to 2,500 YBP) sea-ice expansion in the Bering Sea was substantial enough to have altered the distribution of North Pacific pinnipeds and cetaceans." They suggest that the Bering Strait was ice-bound until late summer at the earliest during this time frame (Crockford and Frederick 2007).

How walruses responded to previous variations in Arctic climate and ice cover in the Bering and Chukchi Seas is unknown. The two oldest fossils of the modern species (*Odobenus rosmarus*) come from the Pacific coast (70,000 and ≈28,000 YBP), then there is a gap (28,000-2,000 YBP) in the fossil record for the North Pacific represented by a "few" early Holocene (10,000 YBP) archeological specimens (Dyke *et al.* 1999). In contrast, fossil and archeological specimens dating back 10-12,000 years are relatively common across the Canadian Arctic Archipelago (Dyke *et al.* 1999). It is unclear whether walruses in the Pacific migrated to the North Atlantic during the Pleistocene (126,000 YBP) (Cronin *et al.* 1994); went extinct and the region was repopulated from the Atlantic about 1 million YBP (Repenning 1976); or, persisted at low numbers during the early Holocene. The fossil record for walruses in the Atlantic suggests a pattern of range contraction and expansion in response to periods of glacial advance and retreat during the Pleistocene (Dyke *et al.* 1999) and walrus distributions in the Pacific may have responded in a similar fashion, based on their current seasonal migration patterns.

The Present:

At maximal sea-ice extent, in March-April, the Chukchi Sea is completely frozen, and the Bering Sea is typically frozen to latitude 58-60 degrees north. The Bering Sea spans the marginal sea-ice zone, where ice gives way to water at the southern edge, and around the peripheries of persistent polynyas. Sea-ice in the Bering Sea is highly dynamic and largely a wind-driven system (Sasaki and Minobe 2005). Ice cover is comprised of a variety of first year ice thicknesses, from young, very thin ice to first year floes that may be upwards of 1.0 m (3.3 ft) thick (Burns *et al.* 1980; Zhang *et al.* 2010). Depending on wind patterns, there is a variable (but relatively minor) fraction of ice that drifts south through the Bering Strait which could be comprised of some thicker ice floes that originated in the Chukchi and Beaufort Seas (Kozo *et al.* 1987).

Ice melt usually begins in April and accelerates in May, with the edge of the ice moving northward until it passes through the Bering Strait, typically in June. The Bering Sea remains ice-free for the duration of the summer. Ice continues to retreat northward through the Chukchi Sea until September, when minimal sea-ice extent is reached (Boveng *et al.* 2008). Sea-ice has withdrawn completely from the continental shelf waters of the Chukchi Sea in six years (between 1999 and 2008) with periods of little to no ice cover ranging from a few weeks up to several months. In contrast, during the preceding 20 years (1979-1998), broken sea-ice habitat persisted over continental shelf areas of the Chukchi Sea through the entire summer melt season (Jay and Fischbach 2008).

Freeze-up begins in October, with the ice edge progressing southward across the Chukchi Sea. The ice edge usually reaches the Bering Strait in November and advances through the Strait in December. The ice edge continues to move southward across the Bering Sea until its maximal extent is reached in March. There is considerable year to year variation in the timing and extent of ice retreat and formation (Boveng *et al.* 2008).

In the Bering Sea, statistically significant monthly reductions in the extent of sea-ice have been documented (1979-2005) for March (-4.8 percent), October (-42.9 percent), and November (-20.3 percent), but the overall annual decline (-1.9 percent) is not statistically significant (Meier *et al.* 2007). The Bering Sea declines have been greatest in the months of October and November. In the Chukchi Sea, statistically significant monthly reductions have also been documented for the same period for May (-0.19 percent), June (-4.3 percent), July (-6.7 percent), August (-15.4 percent), September (-26.3 percent), October (-18.6 percent), and November (-8.0 percent), and the overall annual reduction (-4.9 percent) is statistically significant (Meier *et al.* 2007). In essence, the Chukchi Sea has shown declines in sea-ice extent in all months when it is not completely ice-covered, with the greatest declines occurring in months of maximal melt and early freeze-up (August, September, and October).

Markus *et al.* (2009) reported that between 1979 and 2007, there was a general trend toward earlier onset of ice melt and later onset of freeze-up in both the Bering and Chukchi Seas. For the Bering Sea, the onset of ice melt has occurred 1.0 day earlier per decade, while in the Chukchi/Beaufort Seas ice melt has occurred 3.5 days earlier per decade (Markus *et al.* 2009). The onset of freeze up in the Bering Sea has occurred 1.0 day later per decade, while freeze up in the Chukchi/Beaufort Seas has occurred 6.9 days later per decade.

The Future:

The Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment Report (AR4) produced several general circulation models (General Circulation Models (GCMs) are simulations of energy transfer between the earth's oceans, atmosphere, biosphere, geosphere, and cryosphere) that project, conditional upon underlying assumptions regarding future greenhouse gas emissions, future climate conditions through the end of the 21st century. These GCM outputs are available through the World Climate Research Program's Coupled Model Intercomparison Project-Phase 3 (CMIP3), and have been used by several authors to forecast future sea ice conditions in the Bering and Chukchi Seas through the end of the 21st century. It should be noted that sea-ice extent has been decreasing at a rate faster than predicted by most IPCC recognized GCMs (Stroeve *et al.* 2007; Overland and Wang 2007; Wang and Overland 2009) suggesting that GCM projections may portray 21st century sea-ice losses on a conservative time frame (Douglas 2010).

Boveng *et al.* (2008) used the observation record and a constrained subset of IPCC AR4 GCM models (selected for accuracy in simulating observations of recent ice conditions) to project spring (April-June) sea ice conditions in the Bering Sea out to 2050. Their analysis suggested that by mid-century, a modest decrease in the extent of sea ice cover in the Bering Sea is expected during the month of April. Bering Sea observations for May show a considerable number of years in recent decades with markedly reduced sea ice cover. Sea ice projections suggest that this pattern is likely to continue; the large range of model projections suggest that large inter-annual variability will result in some years with considerable sea ice cover in May and some years with reduced ice cover. Since the 1970s, sea-ice cover in the Bering Sea has been consistently low or absent during the month of June; there have been only one or two years per decade with greater than 0.05 million km^2 of ice cover in June. Model projections out to 2050 suggest that ice cover in the Bering Sea will essentially disappear in June, with only a rare year when the ice cover exceeds 0.05 million km^2 (Boveng *et al.* 2008).

In a subsequent analysis, Boveng *et al.* (2009) used IPCC AR4 models to project sea ice coverage in the eastern Bering Sea, the Bering Strait, and the Chukchi Sea out to 2070. For the eastern Bering Sea, they predicted that sea ice coverage would decline in the spring and fall, with fall declines exceeding those of spring. Their model projections suggest that, by 2050, the average sea ice extent in the eastern Bering Sea during November and December would be approximately 14 % of the present-day (1980-1999) mean; and sea ice extent in March to May would be about 70 percent of the present-day mean. By 2070, the fall extent of sea ice in the eastern Bering Sea would be only 6 % of the present-day mean, while the spring ice extent would be reduced to 50 % of present-day mean. For the Bering Strait region, model projections indicate a longer ice-free period by 2050 and 2070, largely as a result of decreasing ice coverage in November and December. By 2050, March-May sea ice extent in the Bering Strait region are projected to be 80 % of the present-day mean value (1980-1999), while November ice extent would be 20 % of the present. By 2070, the spring ice extent would be 78 % of present, while November extent would be 10 % of present-day value. For the Chukchi Sea, their modeling results showed a reduction in sea ice extent for November by 2050, a slight decline for June by 2070, and a clear reduction for November and December by 2070 (Boveng *et al.*(2009).

Douglas (2010) quantified IPCC AR4 sea ice projections (A2 and A1B scenarios) by 18 GCM models prepared for the IPCC fourth reporting period, as well as two GCM subsets which excluded models that poorly simulated the 1979-2008 satellite record of Bering and Chukchi sea ice conditions. His analyses focused on the annual cycle of sea ice extent within the range of the Pacific walrus population, specifically the continental shelf waters of the Bering and Chukchi Seas. Models were selected for the 2 subsets, respectively, when their simulated mean ice extent and seasonality during 1979-2008 were within 2 standard deviations (SD2) and 1 standard deviation (SD1) of the observed means. In consideration of observations of ice-free conditions across the Chukchi Sea in recent years in late summer, any models that failed to simulate at least 1 ice free month in the Chukchi Sea were also culled from the Chukchi Sea model ensemble. Ice observations and the projections of individual GCMs were averaged over decadal periods to integrate intrinsic natural variability (Douglas 2010).

To quantify projected changes in monthly sea ice extent, Douglas (2010) compared future monthly sea ice projections for the Bering and Chukchi Seas at mid-century (2045-2054) and late-century (2090-2099) with two decades from the observational record (1979-1988 and 1999-2008). The earliest observational period (1979-1988), which coincides with a timeframe when the Pacific walrus population was occupying most of its historical range (Fay *et al.* (1989, 1997) provides a useful baseline for examining predicted changes in sea-ice habitats.

The analysis of Douglas (2010) suggests that by mid-century, sea ice extent in the Bering Sea will decline for all months when sea ice has historically been present (November through June, Fig. 2). The most pronounced changes in Bering Sea ice extent are expected in June (-63% of the 1979-1988 baseline level) and November (-88 % of the baseline level). By late-century, substantial declines in Bering Sea ice extent are projected for all months (November through June) (Fig. 2), with losses ranging from 57 % in April, to 100 % loss of sea ice in November

(Douglas 2010). Late-century projections suggest that the onset of freezing in the Bering Sea will be delayed until January, and maximum winter extent (typically occurring in March) will be 60 % less than contemporary observations. Ice is also expected to melt rapidly in the spring, with little or no ice remaining in the month of May by the end of the century (Douglas 2010).

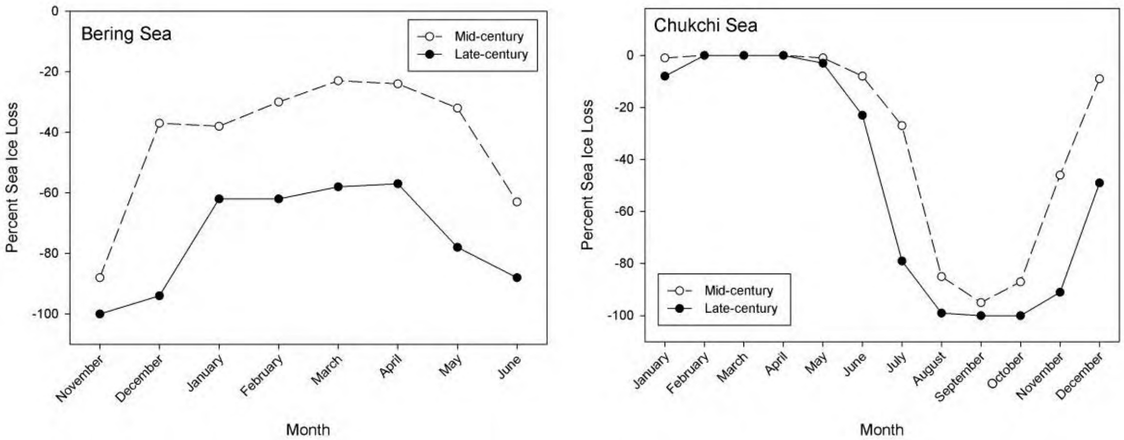


***Figure 2.* Percent loss in the average monthly proportion of sea-ice extent over continental shelf regions of the Bering, and Chukchi Seas, between the earliest decade of satellite observations (1979-1988) and two future decades (2045-2054 and 2090-2099). Sea-ice projections were based on medians of monthly decadal averages for eleven GCMs forced with the A1B emission scenario. Values for graphed data are from Douglas (2010, Table 2).**

Historically, sea-ice cover has persisted over continental shelf waters of the Chukchi Sea all twelve months of the year. A pattern of extensive sea-ice cover (approaching 100 %) in late winter and early spring (January-April) is expected to persist through the end of the century (Fig. 2). Projections of sea-ice loss during the months of May and June are relatively modest (Fig. 2) however sea-ice is expected to retreat rapidly during the month of July (Douglas 2010). By mid-century, the continental shelf waters of the Chukchi Sea are projected by most models to be sea-ice free for about three months (August-October). By the end of the 21st century, some models project that ice free conditions could persist for up to five months. In the most recent observational decade, the southern extent of the arctic ice pack has retreated and advanced through the Bering Strait in the months of June and November. By the end of the century, these transition months may shift to May and January respectively (Douglas 2010).

3.2.1.2 Effects of Changing Sea-ice Habitats on Pacific Walruses

Pacific walruses are an ice dependent species that rely on sea-ice for many aspects of their life history. Walruses must periodically haul out onto land or ice to rest between feeding bouts (Fay 1982). Floating pack-ice is also used as a substrate for breeding behavior (Fay *et al.*

1984b), giving birth (Fay 1982), and nursing and care of young (Kelly 2001). Sea-ice provides access to offshore feeding areas over the continental shelf of the Bering and Chukchi Seas; passive transportation among feeding areas (Ray *et al.* 2006); isolation from terrestrial predators (Ovsyanikov *et al.* 2007; Kelly 2001), and shelter from high waves and heavy surf (Richard 1990). Sea-ice situated over productive feeding areas allows females to forage intensively between bouts of resting and suckling their young (Kelly 2001). Fay (1982) also cites the importance of sea-ice in isolating walruses from human hunting pressure, noting that that during the 18th century most walrus herds using terrestrial haulout sites in the Bering and Chukchi sea were extirpated by hunters, while those that stayed in the sea-ice survived.

This section examines the likely responses and demographic effects of projected changes in sea-ice conditions in the Bering and Chukchi Sea on the Pacific walrus population and explores potential mechanisms of resilience to observed and projected changes in ice conditions. Our analysis focuses on how projected changes in seasonal ice conditions are likely to impact key walrus life history events. Here we examine the potential effects of changing ice conditions in winter (December–March) when breeding occurs, spring (April-June) during which time calving occurs; and the summer/fall period (June-November) when walruses are nursing their dependent young. The demographic and ecological responses of Pacific walruses to a warming climate are difficult to predict. To help inform our analysis, we considered the observed responses of Pacific walruses to recent losses of summer sea-ice from continental shelf regions of the Chukchi Sea, and looked for environmental and ecological correlations with the Atlantic walrus.

3.2.1.2.1 Winter (December-March)

During the winter months, the entire Pacific walrus population occupies the broken pack-ice of the Bering Sea. Our review of future sea-ice forecasts suggests that seasonal pack-ice will continue to form in the northern Bering Sea, primarily in January-March, and persist in most years through April (Fig. 2). There will be less ice, on average; freeze-up is expected to occur later, and spring retreat earlier (Douglas 2010). In association with a general long-term warming trend, we expect to see changes in the frequency of years with extensive sea-ice, and the duration of ice persistence that could potentially impact ice conditions in areas that walruses presently occupy. Ice cover across the Bering Sea will likely continue to be highly dynamic as broken ice is driven by winds and currents, resulting in a mixture of thin, newly formed ice and thicker rafted ice.

The distribution of walruses during the winter months will likely shift in the future in response to changing patterns of sea-ice development. By mid-century, the onset of sea-ice formation in the northern Bering Sea is expected to occur later than at present (Fig. 2). By the end of the century, sea-ice is not expected to form in the Bering Sea until January (Douglas 2010). There are relatively few islands or other coastal haulout areas within range of traditional winter forage areas. Haulouts on St. Lawrence Island, the Punuk Islands and St. Mathews Island (Fig. 1) have been used when suitable winter sea-ice was not available (Fay and Kelly 1980). Large coastal haulouts also form along the Chukchi Sea coast of Russia in late fall, and in recent years, some of these haulouts (e.g. Cape Deznev and Cape Sedtze Kamen, Fig. 1) have been occupied into December (Anatoli Kochnev, Chukot TINRO, 2010, *pers. comm*). If the formation of sea-ice across the Bering Sea is delayed into December or January, it is likely that this observed trend of increasing dependence on coastal haulouts in the fall and early winter will continue.

Sea-ice is expected to form rapidly across the Bering Sea in January and February. Through mid-century, only modest decreases in sea-ice extent in the Bering Sea are expected during the January-March breeding seasons (Fig. 2). Because of the dynamic nature of sea-ice, it is unlikely that walrus breeding behavior is tied to specific geographic locations (Fay *et al.* 1984b), rather we expect breeding behavior to occur in areas where animals are already concentrated by suitable ice and forage conditions. Core areas of winter abundance south of St. Lawrence Island and the Gulf of Anadyr (Fig. 1) will likely continue to have adequate ice cover to support breeding aggregations through mid-century. Walruses currently wintering in Northern Bristol Bay, will likely have to shift their distribution northward in response to the absence of sea-ice in this region. By the end of the century, winter sea-ice extent across the Bering Sea is expected to be greatly reduced (Fig. 2). Under this scenario, core areas of winter abundance and breeding aggregations would likely shift further north to areas of heavier ice, potentially even into areas north of the Bering Strait in the southern Chukchi Sea.

3.2.1.2.2 Spring (April-June)

Female walruses typically give birth to a single calf in May shortly before, or during, their northward spring migration through the Bering Strait (Fay 1982). Mothers and newborn calves stay mostly on ice floes during the first few weeks of life until calves develop sufficient energy reserves for thermoregulation (Fay and Ray 1968). Observations from hunters on St Lawrence Island suggest that when sea-ice disappears early, or is broken up by storms, walruses may encounter difficulties finding suitably stable ice platforms for newborn calves, which can result in calf mortalities (Jim Wilder, Service, 2010, *pers. comm.*). By mid-century, ice extent in the Bering Strait Region is expected to be markedly reduced during the May calving season (Boveng *et al.* (2009). End of century predictions suggest that the Bering Sea may be largely sea-ice free during the month of May (Douglas 2010). Whether rates of calf mortality are likely to increase in the future in response to earlier spring break up in the Bering Sea is difficult to predict. As is the case with breeding, the birth of a calf is probably not tied to specific geographic locations. It is reasonable to assume that suitable ice conditions for calving will persist into the foreseeable future, even if the location of these favorable ice conditions were to shift to further to the north over time.

3.2.1.2.3 Summer/Fall (June-November)

Sea-ice has historically persisted in the Chukchi Sea through the entire melt season, although the extent of sea-ice cover over continental shelf areas during the summer and fall has been highly variable. Over the past decade, sea-ice has begun to retreat beyond shallow continental shelf waters in late summer. This trend of rapid ice loss from continental shelf regions in July and August is expected to persist, and perhaps accelerate into the foreseeable future (Fig. 2). The onset of ice formation in the fall over continental shelf regions in the Chukchi and Bering Seas is also expected to be delayed in the future due to warmer ocean temperatures. By mid-century, ice free conditions over most continental shelf regions of the Chukchi Sea are expected to persist from August through October. By late century, ice free conditions across continental shelf waters of the Chukchi Sea may persist for up to 4-5 months, conditional upon the underlying assumptions associated with the AIB forcing scenario (Douglas 2010).

When sea-ice recedes beyond shallow feeding areas on the continental shelf to the deep waters of the Polar Basin, walruses must relocate to coastal areas where they can rest on land. The number of walruses using land based haulouts along the Chukchi Sea coast during the summer months, and the duration of haulout use has increased over the past decade, with up to several tens of thousands of animals hauling out at some locations along the coast of Russia (Fig. 1). Coastal walrus haulouts have also begun to form along the coast of Alaska during the summer months in recent years (2007, 2009, and 2010).

As sea-ice withdraws from offshore feeding areas, walruses can be expected to become increasingly dependent on coastal haulouts as a foraging base during the summer months. Warming ocean temperatures are also expected to delay the onset of ice formation in the fall, and in the absence of sea-ice cover in the southern Chukchi Sea and northern Bering Sea, walruses will likely remain at coastal haulouts for longer periods of time until sea-ice cover develops in these regions. By the end of the century the dependence on coastal haulouts as a foraging base may extend into early winter (December –January). This hypothesis is consistent with observations made by Russian scientists that some of the coastal haulouts along the southern Chukchi sea coast of Russia have persisted in recent years into December (Anatoli Kochnev, Chukot TINRO, 2010, *pers. comm*). Based upon future sea-ice predictions for the Bering and Chukchi Seas, this pattern of increased reliance on coastal haulouts from mid-summer through early winter will likely persist in the future.

2007: A warm year analog for the Chukchi Sea.

During the record sea-ice retreat in the summer of 2007, ice conditions in the Chukchi Sea were similar to those forecast by climate based models by mid-century and may serve as a useful analog for predicting how Pacific walruses are likely respond to future losses of summer sea-ice habitats in the region. Although the 2007 melt season in the Chukchi Sea began relatively slowly, sea-ice retreat accelerated rapidly in July and August. The continental shelf of the Chukchi Sea was completely sea-ice free by mid-August, and the ice edge eventually retreated hundreds of miles north of the shelf and ice did not reform over the continental shelf until late October (NSIDC, 2007).

In Chukotka, Russia, walruses began coming to shore in mid-July, a month earlier than has been previously recorded. Biologists reported that adult males arrived first, and were joined by females and young starting in mid-August (Kochnev 2008). Coastal aggregations in Chukotka ranged in size from 4,500 to 70,000 animals, depending on location and month (Ovsyanikov *et al.* 2007; Kochnev 2008; WWF 2010). Russian biologists attached satellite telemetry devices to 12 female walruses at Cape Vankarem to investigate foraging and haulout behavior from coastal haulouts. The animals made several offshore excursions (presumably to feed) generally within 60 km (37 miles) of the shore (Fischbach *et al.* 2010). Small herds of walruses, ranging in size from a few animals up to 3,500 animals were also reported in along the Chukchi Sea coast of Alaska in August and September 2007 (Thomas *et. al.* 2009). Although herds of walruses have been observed in the past along the Arctic Coast of Alaska (notably at Cape Lisburne), these haulouts have typically formed during the fall migration (October-November).

Ovsyanikov *et al.* (2007) reported that many of the walruses arriving at Wrangel Island, Russia, in August 2007 were emaciated and weak, some too exhausted to flee or defend themselves from polar bears patrolling the coast. The authors attributed the poor condition of these animals to the rapid retreat of sea-ice off of the shelf in July to waters too deep for them to feed, followed by a long multi-day migration to land through stormy seas. Hunters from the Russian coastal villages of Vankarem and Ryrkaipii reported more than 1,000 walrus carcasses (mostly calves of the year and aborted fetuses) at coastal haulouts near the communities in September 2007 (Nikiforov *et al.* 2007; Kochnev 2008; WWF 2010). Noting the near absence of calves amongst the remaining animals, Kochnev 2008, speculated that most of the 2007 cohort along the Chukchi Sea coast had been lost. Approximately 1,500 walrus carcasses (predominately adult females) were also reported near Cape Dezhnev in late October (Anatoli Kochnev, Chukot TINRO, 2007, *pers. comm.*). Russian investigators estimate that between 3,000-10,000 animals died along the Chukotka coastline during the summer and fall of 2007, primarily from intra-specific trauma (trampling) associated with disturbance events at the haulouts (WWF 2010). Although a few sick and dead animals were observed by hunters along the Alaska coast in 2007, no significant mortality events were reported in this region, perhaps because the relatively small sizes of the groups reduced the potential for large scale mortality events.

Observations in subsequent years:

Summer ice loss over continental shelf regions of the Chukchi Sea in 2008, 2009, and 2010 was not as extreme as conditions experienced in 2007 and there was considerable regional variation in sea-ice extent and coastal haulout use between years.

In 2008, sea-ice persisted in the western Chukchi Sea late into the season, and walruses did not begin to arrive at coastal haulouts in Chukotka until late August. Observed mortality rates at the coastal haulouts in Chukotka were also lower than those observed in 2007 (Anatoli Kochnev, Chukot TINRO, 2010, *pers. comm.*). Although the eastern Chukchi Sea was mostly sea-ice free by the end of August, walruses were apparently able to find and exploit small scattered ice floes off the coast of Alaska through the entire melt season (Chad Jay, USGS, 2008 *pers. comm.*, based on unpublished telemetry data), and no walrus haulouts were reported by aerial survey crews along the coast of Alaska during the 2008 open water season (COMIDA Survey Project: http://www.afsc.noaa.gov/NMML/cetacean/bwasp/flights_COMIDA_1-3.php).

In the summer of 2009, large numbers of walruses once again occupied coastal haulouts in Chukotka, Russia from mid-August through October. In the eastern Chukchi Sea, sea-ice persisted over continental shelf regions through August, and coastal haulouts did not form along the Alaska coast until September. The coastal haulouts that did form in Alaska were relatively small (3-5,000 animals in some locations) and only persisted for 3-4 weeks (COMIDA Survey Project: http://www.afsc.noaa.gov/NMML/cetacean/bwasp/flights_COMIDA_1-3.php). Some trampling related mortalities (primarily calves) were reported at coastal haulouts in Alaska in the summer of 2009 however most of the animals observed at the haulouts appeared to be in relatively good condition (Fischbach *et al.* 2009).

In the summer of 2010, sea-ice persisted late into the season in the western Chukchi Sea and haulout numbers along the Chukotka coast during the summer months were greatly reduced. In Alaska, ice concentrations were relatively light, and a large coastal haulout (10-50,000 animals) formed near the community of Point Lay in late-August. Mortalities at the Point Lay haulout were relatively modest, likely due in part to the efforts of local villagers in keeping disturbance to a minimum (Garlich-Miller 2010, *pers. observ.)*.

3.2.1.2.4 Population Effects

Observations of the responses of walruses to periods of low ice conditions over continental shelf regions of the Chukchi Sea in recent years provides a basis for evaluating likely responses and potential effects on the Pacific walrus population to projected losses of sea-ice habitats. Observations by Russian scientists and hunters at coastal haulouts in Chukotka suggest that rates of calf-mortality and poor body condition of adults are inversely related to the persistence of sea-ice over offshore feeding areas and the length of time that animals occupy coastal haulouts (Nikiforov *et al.* 2007; Ovsyanikov *et al.* 2007; Kochnev 2008; WWF 2010).

As noted in the previous section, summer ice conditions across the Chukchi Sea and the associated responses of walruses, have shown considerable inter-annual and regional variability over the past several years. Projected losses of summer sea-ice over continental shelf waters of the Chukchi Sea are not likely to be linear or uniform. We expect considerable inter-annual and regional variability in the duration and extent of summer sea-ice cover will occur (Douglas 2010). However, in association with a general long term warming trend, we expect that the frequency of years of “adequate” ice cover to maintain offshore foraging through the summer melt season will decrease over time, and the duration of ice-free periods in the Chukchi Sea will also increase, resulting in increased dependency on coastal haulouts as a foraging base. Over time, reduced access to traditional offshore foraging areas can reasonably be expected to result in increased intra-specific competition for food in remaining habitat areas. Information regarding the density of walrus prey items in the near shore zone accessible from coastal haulouts is limited; however, some of these areas have supported sizable concentrations of animals (up to several tens of thousands of animals) in recent years for periods of up to four months (Anatoli Kochnev, Chukot TINRO, 2010, *pers. comm.*). Many walrus prey species are slow growing and potentially vulnerable to over-exploitation (Ray *et al*. 2006) and intensive foraging from coastal haulouts by large numbers of animals may eventually lead to localized prey depletion within range of the coastal haulout. The most likely response to localized prey depletion will be for walruses to seek out and colonize other terrestrial haulouts with better foraging opportunities. However, prey densities along the Arctic coast are not uniform (Feder *et al*. 1994; Grebmeier *et al*. 1989; Grebmeier and Dunton 2000; Grebmeier *et al*. 2006a), and many coastal areas which provide the physical features of a suitable haulout, may not be situated near areas of abundant food resources. A visual comparison of areas of high benthic production (e.g. Grebmeier and Dunton 2000; Grebmeier *et al*. 2006b; Springer *et al*. 1996) and areas that have supported large terrestrial haulouts of walruses (e.g., Cape Inkigur, Cape Serdtse-Kamen) indicates that walruses have historically selected sites near areas of very high benthic productivity. Benthic productivity along part of the western shore of Alaska (i.e., along the eastern edge of the Chukchi Sea) is low because of the nutrient- poor waters of the Alaska Coastal Current (Dunton *et al*. 2005; Dunton *et al.* 2006; Grebmeier *et al*. 2006a).

Consequently, the number of sites with adequate food resources to support large aggregations of walruses is likely limited.

Energetic costs to walruses will increase if they have to travel greater distances to locate prey, or foraging efficiency is reduced as a consequence of lower prey densities (Sheffield and Grebmeier 2009; Jay *et al*. 2010b). Females with dependent young are likely to be disproportionally affected by the increased reliance on coastal haulouts as a foraging base. Females with dependent young require two to three times the amount of food needed by non-lactating females (Fay 1982). During the summer months, females typically nurse their calves between short foraging forays from sea-ice platforms situated over productive forage areas. If food resources in proximity to coastal haulouts become limited, females encumbered by young calves during foraging excursions from coastal haulouts could have difficulties finding sufficient foraging opportunities near the haulouts to meet the energetic demands of lactation. Females forced to swim long distances between forage areas and haulout locations may also be forced to abandon their calves (Cooper *et al*. 2006). The degree to which food resources near the haulouts becomes a limiting factor in the future, will depend on a variety of factors including: the location of coastal walrus haulouts, the number of animals utilizing the haulouts, the duration of time walruses occupy the haulouts, and the robustness of the prey base within range of those haulouts.

Walruses at coastal haulouts become vulnerable to terrestrial predators and intra-specific trauma (trampling) associated with disturbance events (Fay 1982; Fay and Kelly 1980; Nikiforov *et al.* 2007; Ovsyanikov *et al.* 2007; Kochnev 2008; WWF 2010) Sources of disturbance are expected to be greater at terrestrial haulouts than in offshore pack ice habitats, because the level of human activity such as hunting, fishing, boating, and air traffic is much greater along the coast, and there is a greater chance of disturbance from terrestrial animals (Kochnev 2004; WWF 2010). While disturbance related mortalities at all-male haulouts in the Bering Sea are relatively uncommon, calves and pregnant females appear to be more susceptible to intra-specific trauma and predation by polar bears, which can occasionally result in high mortality rates, particularly amongst calves. Large episodic mortality events such as those reported along the Russian coast in the fall of 2007 have been previously reported. For example, Fay and Kelly (1980) examined several hundred walrus carcasses at coastal haulouts on St. Lawrence Island and the Punuk Islands in the fall of 1978. Approximately 15 percent of those carcasses were aborted fetuses, 24 percent were calves, and the others were older animals (mostly females) ranging in age from 1 to 37 years old. The principal cause of death was identified as intra-specific trauma, possibly from disturbance related stampedes or battling bulls. The authors noted that mortality levels at coastal haulouts are highly variable from year to year depending upon a variety of factors including the size and composition of the herds.

The impact of episodic mortality events at coastal haulouts on the Pacific walrus population will depend upon the frequency and magnitude of such events. Long-lived species with overlapping generations can withstand relatively high rates of offspring mortality and still maintain population size provided that the breeding female cohort is maintained (Eberhardt 1977). The loss of mature, breeding females is a more serious concern, but appears to be a relatively small proportion of haulout mortalities at the present time. Rates of juvenile mortality, due to trampling at coastal haulouts, may also be density-dependent and as herd sizes diminish (either via dispersal or declining abundance) so will levels of mortalities associated with disturbances, predation, or both.

In evaluating the response of Pacific walruses to projected losses of summer sea-ice, we also considered corollaries with other walrus populations. Some populations of Atlantic walruses appear to utilize coastal haulouts to a greater extent during the summer months than Pacific walruses. Most Atlantic walrus populations (which range in size from a few hundred, to a few thousand animals) occupy areas characterized by a relatively narrow continental shelf, or utilize isolated offshore islands that provide access to off shore feeding area during ice free periods (Born *et al.* 1995). These conditions are analogous to conditions that Pacific walruses are likely to experience in the future. It is reasonable to assume that the prey base accessible from coastal or insular haulouts will be much smaller than the broad continental shelf areas occupied by Pacific walruses today. Because near-shore food resources are unlikely to be able to support the current population, the loss of access to offshore feeding areas will likely result in a population decline over time.

Although the loss of summer sea-ice habitat can reasonably be expected to result in a population decline, it is difficult to predict the rate and magnitude of population changes. The Pacific walrus population is large relative to other walrus populations, with a recent minimum abundance estimate of 129, 000 animals (Speckman *et al.* 2010). Productivity also appears to be high, consistent with a population presently below its carrying capacity (Garlich-Miller *et al.* 2006). Research and monitoring efforts leading to a better understanding of population size and trend will be critical in evaluating the future risk of extinction. As the Pacific walrus population becomes increasingly dependent on coastal haulouts, interactions with humans along the coast are also expected to increase. Human activities at the haulouts including aircraft over flights, tourism and hunting have been identified as sources of disturbance related mortalities in recent years (e.g. Nikiforov *et al.* 2007; Kochnev 2008; WWF 2010). The efficacy of future management efforts to protect walruses at coastal haulouts will be an important factor that will influence future population outcomes.

3.2.1.3 Effects of Global Climate Change on Walrus Prey Species

3.2.1.3.1 Ocean Warming

For the last several decades, surface air temperatures throughout the Arctic, over both land and water, have warmed at a rate that exceeds the global average, and they are projected to continue on that path (Comiso and Parkinson 2004; Christensen *et al*. 2007; Lawrence *et al*. 2008; Serreze *et al*. 2009). In addition, the subsurface and surface waters of the Arctic Ocean and surrounding seas, including the Bering and Chukchi Seas have warmed (Steele and Boyd 1998; Zhang *et al.* 1998; Overland and Stabeno 2004; Stabeno *et al.* 2007; Steele *et al.* 2008; Mueter *et al.* 2009). There are several mechanisms working in concert to cause these increases in ocean temperature, including: warmer air temperatures (Comiso and Parkinson 2004; Overland and Stabeno 2004), an increase in the heat carried by currents entering the Arctic from both the Atlantic (Drinkwater *et al.* 2009; Zhang *et al.* 1998) and Pacific Oceans (Stabeno *et al.* 2007; Woodgate *et al.* 2010), and a shorter ice season, which decreases the albedo (reflective property) of ice and snow (Comiso and Parkinson 2004; Moline *et al.* 2008; Markus *et al.* 2009). Due to their biological characteristics which include tolerance of considerable variations in temperature, direct effects to walrus are not anticipated with warmer ocean temperatures. Nevertheless, changes in the thermal dynamics of ocean conditions may affect walrus indirectly through impacts to their prey base. Changes to density, abundance, distribution, food quality, and species of benthic invertebrates may occur primarily through changes in habitat related to sea-ice.

Walruses are the top predator of a relatively simple food web in which the primary constituents are bacteria, sea-ice algae, phytoplankton (tiny floating plants), and benthic invertebrates (Horner 1976; Lowry and Frost 1981; Grebmeier and Dunton 2000; Dunton *et al.* 2006; Aydin and Mueter 2007). Sea-ice is important to the Arctic food webs because: (1) it is a substrate for ice algae (Horner 1976; Kern *et al.* 1983; Grainger *et al.* 1985; Melnikov 2000; Gradinger 2009); (2) it influences nutrient supply and phytoplankton bloom dynamics (Lovvorn *et al.* 2005); and (3) it determines the extent of the cold-water pool on the southern Bering shelf (Aydin and Mueter 2007; Coyle *et al.* 2007; Stabeno *et al.* 2007; Mueter and Litzow 2008).

In the spring, ice algae form up to a 1-cm- (0.4-in-) thick layer on the underside of the ice, but are also found at the ice surface and throughout the ice matrix (Horner 1976; Cota and Horne 1989; Gradinger *et al.* 2005; Gradinger 2009). Ice algae can be released into the water through water turbulence below the ice, through brine drainage through the ice, or when the algal mats are sloughed as the ice melts (Cota and Horne 1989; Renaud *et al.* 2007). As noted above, sea-ice algae provide a highly concentrated food source for the benthos and the plankton (organisms that float or drift in the water) food web that is initiated once the ice melts (Grebmeier *et al.* 2006b; McMahon *et al.* 2006; Renaud *et al.* 2007; Gradinger 2009). Areas of high primary productivity support areas of high invertebrate mass, which is food for walruses (Grebmeier and McRoy 1989; Grebmeier *et al.* 2006b; Bluhm and Gradinger 2008).

Spring ice melt plays an important role in the timing, amount, and fate of primary production over the Bering Sea shelf, with late melting (as occurs now) leading to greater delivery of food from primary production to the benthos and earlier melting (as is projected to occur in the future) contributing food primarily to the pelagic system (Aydin and Mueter 2007; Coyle *et al.* 2007). When ice is present from late March to May (as occurs now), cold surface temperatures, thinning ice, and low-salinity melt water suppress wind mixing, and cause the water column to stratify, creating conditions that promote a phytoplankton bloom. The burst of phytoplankton, seeded in part by ice algae, persists until ocean nutrients are drawn down. Because it is early in the season and water temperatures are cold, zooplankton populations are still low. Consequently, the pulse of phytoplankton production is not consumed by zooplankton, but instead sinks to the sea floor, where it provides abundant food for the benthos (Coyle and Cooney 1988; Coyle and Pinchuk 2002; Hunt and Stabeno 2002; Lovvorn *et al.* 2005; Renaud *et al.* 2007). Blooms form a 20- to 50-km- (12–31 mi-) wide belt off the ice edge and progress north as the ice melts, creating a zone of high productivity. In colder years in the Bering Sea, when the ice extends to the shelf edge, there is greater nutrient resupply through shelf-edge eddies and tidal mixing, creating a longer spring bloom (Tynan and DeMaster 1997).

The blooms that occur near the ice edge make up approximately 50 to 65 percent of the total primary production in Arctic waters (Coyle and Pinchuk 2002; Bluhm and Gradinger 2008). High benthic abundance and biomass correspond to areas with high deposition of phytodetritus (dead algae) (Grebmeier *et al.* 1989; Grebmeier and McRoy 1989; Tynan and DeMaster 1997). Regions with the highest masses of benthic invertebrates occur in the northern Bering Sea southwest of St. Lawrence Island, Alaska; in the central Gulf of Anadyr, Russia, north and south of the Bering Strait; at a few offshore sites in the East Siberian Sea; and in the northeast sector of the Chukchi Sea (Grebmeier and Dunton 2000; Dunton *et al.* 2005; Carmack *et al.* 2006; Grebmeier *et al.* 2006b; Aydin and Mueter 2007; Bluhm and Gradinger 2008). As noted above, the biomass of benthic invertebrates is much less in the eastern Chukchi Sea, which is under the influence of the nutrient-poor Alaska Coastal Current (Dunton *et al.* 2006).

When the ice melts early (before mid-March, as projected for the future), conditions that promote the phytoplankton bloom do not occur until late May or June (Stabeno *et al.* 2007). The difference in timing is important, because when the bloom occurs later in the spring the surface water temperatures are 2.2 °C (3.6 °F) to more than 5 °C (9.4 °F) warmer (Hunt and Stabeno 2002); this, in turn, is an important influence on the metabolism of zooplankton. In cold temperatures zooplankton consume less than 2 percent of the phytoplankton production (Coyle and Cooney 1988; Coyle and Pinchuk 2002). Warmer temperatures result in increased zooplankton growth rates, reduction in time to maturity, and increased production rates (Coyle and Pinchuk 2002; Hunt and Stabeno 2002). Zooplankton are efficient predators of phytoplankton, and when they are abundant, they can remove nearly all the phytoplankton available (Coyle and Pinchuk 2002). Zooplankton are the primary food for walleye pollock (*Theragra chalcogramma*) and other planktivorous fishes (Hunt and Stabeno 2002). Consequently, when zooplankton populations are high, instead of the primary production being transmitted to the benthos, it becomes tied up in pelagic food webs. While this may be beneficial for fish-eating mammals, it reduces the amount of food delivered to the benthos and, thus, may reduce the amount of prey available to walrus (Tynan and DeMaster 1997; Carmack *et al.* 2006; Grebmeier *et al.* 2006a). Most models project that sea-ice melt in the Bering Sea will occur increasingly early in the future, and will be 1 month earlier by the end of the century (Douglas 2010). This is consistent with recent trends over the past two decades, and particularly in the past few years. Based on our current understanding of food web dynamics in the Bering Sea, this shift in timing would favor a shift to pelagic food webs over benthic production, consequently reducing the amount of prey available to walrus.

The importance of ice algae is not only in its role in seeding the spring phytoplankton bloom, but also in its nutritional value. As food supply to the benthos is highly seasonal, synchrony of reproduction with algal inputs insures adequate high-quality food for developing larvae or juveniles of benthic organisms (Renaud *et al.* 2007). Ice algae have high concentrations of essential fatty acids, some of which cannot be synthesized by benthic invertebrates and, therefore, must be ingested in their diet (Arrigo and Thomas 2004; Klein-Breteler *et al.* 2005; McMahon *et al.* 2006). Fatty acids in marine fauna play an integral role in physiological processes, including reproduction (Klein-Breteler *et al.* 2005). Because ice algae are a much better source of essential fatty acids than phytoplankton, a loss in sea-ice could change the quality of food supplied to areas that currently support high levels of benthic biomass. These changes may affect the success of invertebrate reproduction and recruitment, which, in turn, may affect the quantity and quality of food available to walrus (Witbaard *et al.* 2003; McMahon *et al.* 2006). By the end of the century, the March (winter maximum) extent of sea-ice is projected to be approximately half of contemporary conditions (Douglas 2010). We expect ice algae will persist where ice is present; however, because of the reduced ice extent, current areas of high benthic productivity may be reduced or shift northward.

The eastern and western Bering Sea shelves are fueled by nutrient-rich water supplied from the deep water of the Bering Sea (Sambrotto *et al.* 1984; Springer *et al.* 1996). Concentrations of nitrate, phosphate, and silicate are among the highest recorded in the world's oceans and contribute to the high benthic productivity (Sambrotto *et al.* 1984; Grebmeier *et al.* 2006a; Aydin and Mueter 2007). High productivity on the northern Bering-Chukchi shelf is supported by the delivery of nutrient-rich water via the Anadyr Current that flows along the western edge of the Bering Sea and through the Bering Strait (Springer *et al.* 1996; Aydin and Mueter 2007). Thus, the movement of highly productive water onto the northern Bering Sea shelf supports persistent hot spots of high benthic productivity, which in turn support large populations of benthic-feeding birds, walrus, and gray whales (Aydin and Mueter 2007). This contrasts with the southern subarctic region of the Bering Sea, which is south of the current range of the Pacific walrus, where the benthic mass is largely consumed by upper tropic-level demersal fish and epifaunal invertebrates whose northern distribution is limited by a pool of cold, near-freezing water in the northern region of the Bering Sea.

Benthic productivity on the northern Bering Sea shelf has decreased over the last two decades, coincident with a reduction of northward flow of the Anadyr current through the Bering Strait (Grebmeier *et al.* 2006a). Because of recent warming trends, the northern Bering Sea shelf may be undergoing a transition from an Arctic to a more subarctic ecosystem with a reduction in benthic prey populations and an increase in fish populations (Overland and Stabeno 2004; Grebmeier *et al.* 2006a). The Bering Sea is a transition area between Arctic and subarctic ecosystems, with the boundary between the two loosely concurrent with the extent of the winter sea-ice cover (Overland and Stabeno 2004). In the eastern Bering Sea, reductions in sea-ice have been responsible for shrinking a large subsurface pool of cold water with water temperatures less than 2 °C (3.6 °F) (Stabeno *et al.* 2007; Mueter and Litzow 2008). The southern edge of the cold pool, which defines the boundary region between the Arctic and subarctic communities, has retreated approximately 230 km (143 mi) north since the early 1980s (Mueter and Litzow 2008).

The northward expansion of warmer water has resulted in an increase in pelagic species as subarctic fauna have colonized newly favorable habitats (Overland and Stabeno 2004; Mueter and Litzow 2008). Walleye pollock, a species common in the subarctic, which avoid temperatures less than 2° C (3.6 °F), have now moved northward into the former Arctic zone. Arctic cod (*Boreogadus saida*), which prefer cold temperatures, have also moved north to remain in colder temperatures (Stabeno *et al.* 2007). Because of the redistribution of these species, benthic fauna will be facing a new set of predators (Coyle *et al.* 2007). The evidence suggests that warming on the Bering Sea shelf could alter patterns of energy flow and food web relationships in the benthic invertebrate community, leading to overall reductions in biomass of benthic invertebrates (Coyle *et al.* 2007).

Continued changes in the extent, thickness, and timing of the melt of sea-ice are expected to create shifts in production and species distributions (Overland and Stabeno 2004). Because some residents of the benthos are very long lived, it may take many years of monitoring to observe change (Coyle *et al.* 2007). Many simultaneous changes (e.g., ocean currents, temperature, sea-ice extent, and wind patterns) are occurring in walrus-occupied habitats, and thus may impact walrus' prey base. Rapid warming might cause a major restructuring of regional ecosystems (Carmack and Wassmann 2006; Mackenzie and Schiedek 2007). Mobile species such as fishes have the ability to move to areas of thermal preference and follow key forage species (Mueter *et al.* 2009); immobile species such as bivalves must cope with the conditions where they are.

Projections by Douglas (2010) indicate that the March (yearly maximum) sea-ice extent in the Bering Sea will be about 25 percent less than the 1979–1988 average by mid-century, and 60 percent less by the end of the century. In addition, spring melt will occur increasingly earlier, and on average will be one month sooner by the end of the century (Douglas 2010). As described above, the earlier spring melt may lead to a change in the food web dynamics that favors pelagic predators, which feed on zooplankton, over the delivery of high quantities of quality food to benthic invertebrates. In addition, reductions in the extent of the winter sea-ice cover may lead to a further or more permanent expansion of the subarctic ecosystem northward into the Arctic. Although there is uncertainty about the specific consequences of these changes, the best available scientific information suggests that because of the likely decreases in the quantity and quality of food delivered to benthic invertebrates, and because of a potential increase in predators from the south, the amount and distribution of preferred prey (bivalves) available to walrus in the Bering Sea will likely decrease in the foreseeable future as a result of the loss of sea-ice and ocean warming. The extent to which this decrease may result in a curtailment of the range of the Pacific walrus or limit the walrus population in the future is unknown, and at this time we do not have sufficient information to predict it with reliability. The implications of the available information, however, are that impacts may include modification of habitat that could contribute to a reduction in the range of the Pacific walrus at the southern edge of its current distribution, as well as a possible reduction in the walrus population because of reduced prey. Although our conclusion is based on the best available science, we recognize that its validity rests on ecological hypotheses that are currently being tested.

3.2.1.3.2 Ocean Acidification

Since the beginning of the industrial revolution in the mid-18th century, the release of carbon dioxide (CO_2) from human activities ("anthropogenic CO_2") has resulted in an increase in atmospheric CO_2 concentrations, from approximately 280 to approximately 390 ppm currently, with 30 percent of the increase occurring in the last three decades (Scripps 2011).

The global atmospheric concentration of CO_2 is now higher than experienced for more than 800,000 years (Lüthi *et al.* 2008; Scripps 2011). Over the industrial era, the ocean has been a sink for anthropogenic carbon emissions, absorbing about one-third of the atmospheric CO_2 (Feely *et al.* 2004; Canadell *et al.* 2007). When CO_2 is absorbed by seawater, chemical reactions occur that reduce seawater pH (a measure of acidity) and the concentration of carbonate ions, in a process known as "ocean acidification."

Ocean acidification is a consequence of rising atmospheric CO_2 levels (Denman *et al*. 2007; Doney *et al.* 2008). Seawater carbonate chemistry is governed by a series of chemical reactions (CO_2 dissolution, acid/base chemistry, and calcium carbonate dissolution) and biologically mediated reactions (photosynthesis, respiration, and calcium carbonate precipitation) (Wootton *et al.* 2008; Bates and Mathis 2009). The marine carbonate reactions allow the ocean to absorb CO_2 in excess of potential uptake based on carbon dioxide solubility alone (Denman *et al*. 2007). Consequently, the pH of ocean surface waters has already decreased (become more acid) by about 0.1 units since the beginning of the industrial revolution (Caldeira and Wickett 2003; Orr *et al.* 2005).

The absorption of carbon dioxide by seawater changes the chemical equilibrium of the inorganic carbon system and reduces the concentration of carbonate ions. Carbonate ions are required by organisms like clams, snails, crabs, and corals to produce calcium carbonate, the primary component of their shells and skeletons. Decreasing concentrations of carbonate ions may place these species at risk (Green *et al.* 2004; Orr *et al.* 2005; Gazeau *et al.* 2007; Fabry *et al.* 2008; Comeau *et al.* 2009; Ellis *et al.* 2009). Two forms of calcium carbonate produced by marine organisms are aragonite and calcite. Aragonite, which is 50 percent more soluble in seawater than calcite, is of greatest importance in the Arctic region because clams, mussels, snails, crustaceans, and some zooplankton use aragonite in their shells and skeletons (Fritz 2001; Fabry *et al.* 2008; Steinacher *et al.* 2009).

When seawater is saturated with aragonite or calcite, the formation of shells and skeletons is favored; when undersaturated, the seawater becomes corrosive to these structures and it becomes physiologically more difficult for organisms to construct them (Fabry *et al.* 2008) Gazeau *et al.* 2007; Fabry *et al.* 2008; Talmage and Gobler 2009; Findlay *et al*. 2010). The waters of the Arctic Ocean and adjacent seas are among the most vulnerable to ocean acidification, with undersaturation of aragonite projected to occur locally within a decade (Orr *et al.* 2005; Chierici and Fransson 2009; Steinacher *et al.* 2009). To date, aragonite saturation has decreased in the top 50 m (164 ft) in the Canadian Basin (Yamamoto-Kawai *et al.* 2009), and undersaturated waters have been documented from areas investigated to date in different parts of the Arctic region, including outside the range of the Pacific walrus on the Mackenzie shelf (Chierici and Fransson 2009), and within the range of the species in the Chukchi Sea (Bates and Mathis 2009), and Bering Sea (Fabry *et al*. 2009).

Factors that contribute to undersaturation of seawater with aragonite or calcite are: upwelling of carbon dioxide–rich subsurface waters; increased carbon dioxide concentrations from anthropogenic CO_2 uptake; cold water temperatures; and fresher, less saline water (Feely *et al*.

2008; Chierici and Fransson 2009; Yamamoto-Kawai *et al.* 2009). The loss of sea-ice (causing greater ocean surface to be exposed to the atmosphere), the retreat of the ice edge past the continental shelf break that favors upwelling, increased river runoff, and increased sea-ice and glacial melt are forces that favor undersaturation (Yamamoto-Kawai *et al.* 2009; Bates and Mathis 2009). The projected increase of 3 to 5 months of ice-free conditions in the Bering and Chukchi Seas by Douglas (2010) indicates the potential for increased CO_2 absorption in the Arctic over the next century beyond what would occur from predicted CO_2 increases alone. However, there are opposing forces that may mitigate undersaturation to some extent, including photosynthesis by phytoplankton that may increase with reduced sea-ice, and warmer ocean temperatures (Bates and Mathis 2009). However, according to Steinacher *et al.* (2009) the question is not whether undersaturation will occur in the Arctic, but how large an area will be affected, how many months of the year it will occur, and how large its magnitude.

Because acid-base balance is critical for all organisms, changes in carbon dioxide concentrations and pH can affect reproduction, larval development, growth, behavior, and survival of all marine organisms (Green *et al.* 1998; Kurihara and Shirayama 2004; Berge *et al.* 2006; Fabry *et al.* 2008; Kurihara 2008; Pörtner 2008; Ellis *et al.* 2009; Talmage and Gobler 2009; Findlay *et al*. 2010). Pörtner (2008) suggests that heavily calcified marine groups may be among those with the poorest capacity to regulate acid-base status. Although some animals have been shown to be able to form a shell in undersaturated conditions, it comes at an energetic cost which may translate to reduced growth rate (Talmage and Gobler 2009; Findlay *et al*. 2010; Gazeau *et al*. 2010), muscle wastage (Portner 2008), or potentially reduced reproductive output. Because juvenile bivalves have high mortality rates, if aragonite undersaturation inhibits planktonic larval bivalves from constructing shells (Kurihara 2008) or inhibits them from settling (Hunt and Scheibling 1997; Green *et al.* 1998; Green *et al.* 2004; Kurihara 2008), the increased mortality would likely have a negative effect on bivalve populations.

The effects of ocean acidification on walrus may be through changes in their prey base, or indirectly through changes in the food chain upon which their prey depend. Walruses forage in large part on calcifying invertebrates (Ray *et al*. 2006; Sheffield and Grebmeier 2009; also see discussion of diet, above). Aragonite undersaturation has been documented in the area occupied by Pacific walrus (Bates and Mathis 2009; Fabry *et al*. 2009), and it is projected to become widespread in the future (Steinacher 2009; Frölicher and Joos 2010). Also, it is possible that mollusks and other calcifying organisms may be negatively affected through a variety of mechanisms, described above. While the effects of observed ocean acidification on the marine organisms are not yet documented, the progressive acidification of oceans is expected to have negative impacts on marine shell-forming organisms in the future (Society 2005; Doney *et al*. 2009; Kroeker *et al*. 2010).

Uncertainty regarding the general effects of ocean acidification has been summarized by the Royal Society (Society 2005): "Organisms will continue to live in the oceans wherever nutrients and light are available, even under conditions arising from ocean acidification. However, from the data available, it is not known if organisms at the various levels in the food web will be able to adapt or if one species will replace another. It is also not possible to predict what impacts this will have on the community structure and ultimately if it will affect the services that the ecosystems provide." Consequently, although we recognize that effects to calcifying organisms, which are important prey items for Pacific walrus, will likely occur in the foreseeable future from ocean acidification, we do not know which species may be able to adapt and thrive, or the ability of the walrus to use alternative prey items. As noted in the introduction, the prey base of walrus includes over 100 taxa of benthic invertebrates from all major phyla (Sheffield and Grebmeier 2009). Consequently, although walruses are highly adapted for obtaining bivalves, they also have the potential to switch to other prey items if bivalves and other calcifying invertebrate populations decline. Whether other prey items would fulfill walrus nutritional needs over their life span is unknown (Sheffield and Grebmeier 2009), and there also is uncertainty about the extent to which other suitable non-bivalve prey might be available, due to uncertainty about the effects of ocean acidification and the effects of ocean warming.

3.2.1.4 Effects of Global Climate Change on Terrestrial Haulouts

Recent events suggest that a warming climate could potentially impact existing terrestrial walrus haulout areas through physical alteration of the coastline, or by changing the patterns of use of the coastline by walruses, humans and other predators. Erosion rates on the Chukchi Sea Coast are increasing, likely because of declining sea-ice, increasing sea surface temperature, rising sea-level, and increases in storm power (Mars and Houseknecht 2007; Jones *et al.* 2009). Many walrus haulouts form on beaches and barrier islands that are shaped by erosion, deposition, waves and currents. Other haulout areas are composed of boulders and rock ledges resistant to erosion. Loss of some habitat could potentially be offset by creation of new habitat or isolation of parts of existing coastline that might be currently unsuitable because of high levels of predation or disturbance by human activities.

3.2.2 Summary: Effects of Global Climate Change on the Pacific Walrus Population

The Bering Sea is expected to have reduced, although still substantial amounts of sea-ice in winter through mid- and late-century. Because of the dynamic nature of sea-ice, breeding behavior and calving do not appear to be tied to specific geographic locations, and it is reasonable to assume that suitable sea-ice habitat to carry out these life history functions will persist into the future, even if the location of these favorable ice conditions were to shift to other regions. The presence of the Bering Strait provides walruses with the prospect of adjusting their current winter range north into the Chukchi Sea. Shorter periods of ice cover, and thinner ice that is more susceptible to breakage into the types of floes preferred by walruses, could potentially lead to new areas of breeding and feeding habitats north of the Bering Strait that are near or over foraging areas currently used during the spring and early-summer.

Observed and projected changes in sea-ice habitats in the Chukchi Sea will likely result in significant changes in distribution and habitat use patterns by mid-century. As the population becomes increasingly dependent on coastal haulouts during the summer months, juvenile mortality at coastal haulouts and limited prey within range of coastal haulouts can reasonably be expected to result in a population decline. Although the general response of the Pacific walrus population to changing ice conditions can be predicted, the time frame over which these predictions will occur, and the magnitude of population level impacts is uncertain. Poor ice conditions would not necessarily present a significant population impact in any given year. Rather, the overall magnitude of the impact will be a function of the frequency of occurrence, the proportion of the population over which it occurs, and adjustments made by the population. The population is likely sufficiently robust at present, to withstand many years of moderate reductions before abundance becomes a concern for population persistence. However, given the historical reliance on seasonal pack-ice habitats in the Chukchi Sea, and the many advantages that summer ice pack provides female and young walruses, there is likely some threshold for ice free conditions, beyond which the population may not be able to endure. A major influence on that threshold will be the amount of prey resources available from coastal haulouts. Research leading to a better understanding of walrus/sea-ice relationships and foraging patterns near coastal haulouts is underway; programs designed to quantify prey dynamics near haulouts and track changes in population status are needed to help identify this threshold. It is also noted that as walruses become increasingly dependent on coastal haulouts they are likely to face increased interactions with humans and terrestrial predators. The efficacy of management efforts to mitigate sources of anthropogenic disturbances and associated mortality at coastal haulouts will be an important factor influencing future population outcomes.

Warming ocean temperatures and reductions in sea-ice cover in the Bering Sea are likely to cause a shift from a benthic dominated system to a more pelagic dominated ecosystem over time. This anticipated ecological shift could potentially result in a reduced forage base for Pacific walruses over time, however the rate and magnitude of ecological changes is difficult to predict. Additionally, increased levels of atmospheric CO_2 are resulting in increased CO_2 loading and acidification of the world's oceans. Lower pH levels in the marine environment can decrease the amount of calcium carbonate available to marine invertebrates (walrus prey) to construct their shells or exoskeletons. Although the potential consequences of ocean warming and ocean acidification on walrus prey species is a growing concern, our current understanding of these climate-induced changes is rudimentary at best, and the long-term consequences on walrus prey species in the Bering and Chukchi Seas remain speculative at this time.

3.3 Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

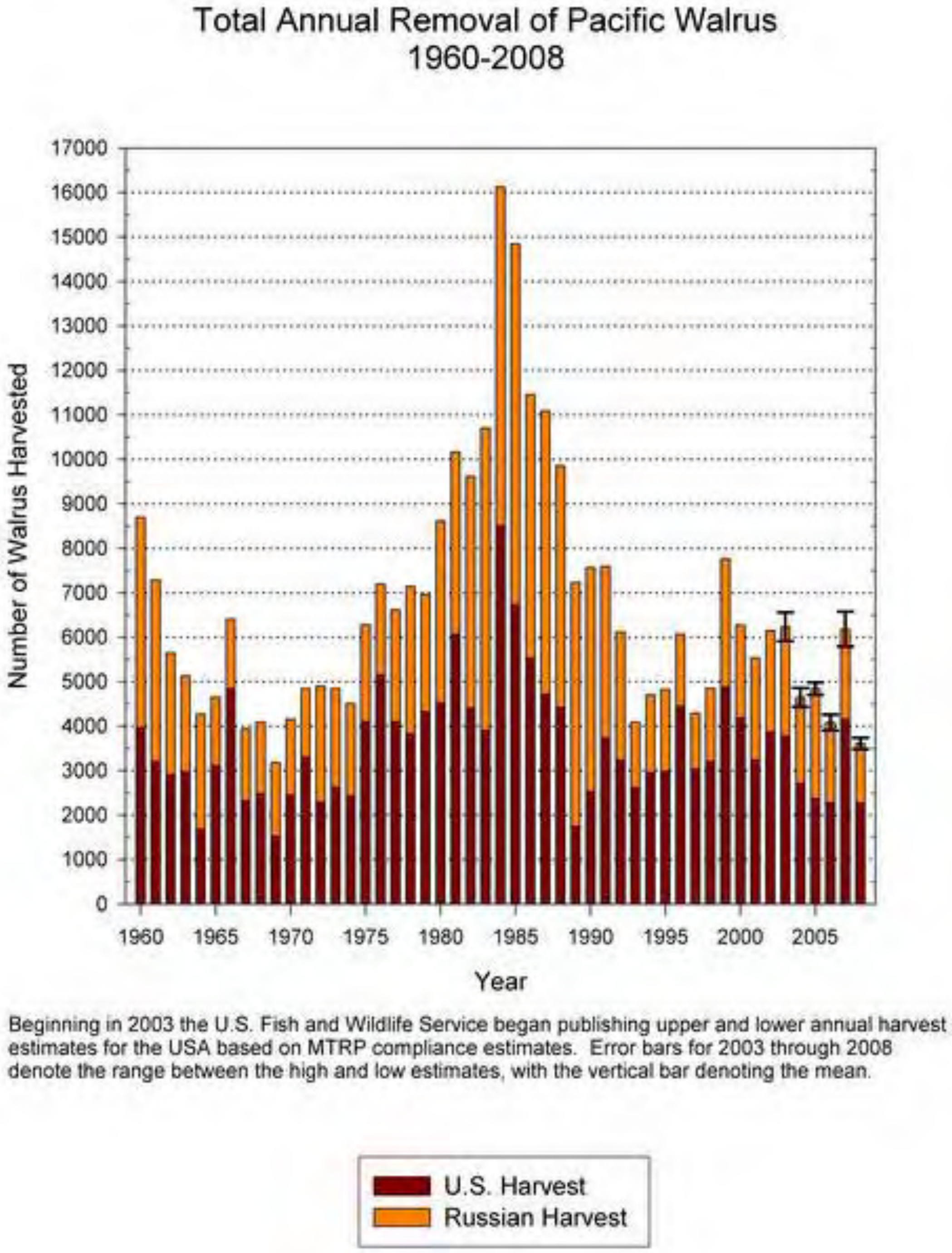
3.3.1 Commercial and Subsistence Harvests

For thousands of years walrus hunting has been an important component of the economy and culture of Native communities along the Bering and Chukchi Sea coasts (Ray 1975). Today, the Pacific walrus remains a valuable subsistence resource in many coastal communities as a source of food and raw materials for traditional equipment and handicrafts. The Pacific walrus has also been exploited as a commercial resource since the seventeenth century (Fay 1957). Based on large sustained harvests in the 18th and 19th centuries, Fay (1982) speculated that the pre-exploitation population was represented by a minimum of 200,000 animals. Since that time, population size has fluctuated in response to varying levels of human exploitation.

3.3.1.1 History of Harvest

It is unlikely that walrus hunting had any appreciable effect on the Pacific walrus population prior to the arrival of European explorers in the 17th century, when for the first time, walruses were killed in large numbers for tusks, hides, and oil that could be sold or traded on the world market (Fay 1982). Fay (1957) estimated that between 5-6 thousand walruses were harvested annually by aboriginal and non-aboriginal hunters between 1650 and 1790. In the early 1800's, harvest levels increased to approximately 10 thousand walruses/year (Elliott 1882). The most intense period of exploitation took place in the late 1800s, primarily by American whalers who targeted bowhead whales and walruses in the Bering Sea. Scammon (1874) reported that from 1868 to 1872 a minimum of 60 thousand walruses were taken in conjunction with the Bering Sea whale fishery. Fay (1957) estimated that 15-20 thousand walruses were harvested annually from 1860 to 1880. In response to the large commercial harvests in the late 1800s the population was soon depleted, declining to an estimated 80,000 animals by 1880 (Fay 1957). Walrus harvests associated with the whale fishery dropped dramatically in the 1890s, presumably in response to a population decline. Bockstoce and Botkin (1982) report a harvest of less than 100 walruses annually from 1885 until the collapse of the whaling industry in 1914. Fay (1957) estimated annual harvest levels of 5 to 7 thousand animals from all sources occurred during the period 1910 to 1950. By the mid-1950's the population was likely within a range of 50,000–100,000 animals (Fay *et al.* 1997). In 1960, in an effort to accelerate recovery of the population, the State of Alaska restricted the harvest of female walruses to seven per hunter per year. Concurrently, the Union of Soviet Socialist Republics (USSR) also implemented harvest restrictions and shooting animals in the water was prohibited (Fay *et al.* 1989). In 1961, the State of Alaska further reduced the subsistence walrus harvest quota to 5 females/hunter/year, while continuing to allow an unlimited harvest of males. This quota remained in effect until passage of the MMPA in 1972 (Fay *et al.* 1997). The management measures taken by the State of Alaska and USSR in the 1960's markedly reduced harvest rates, and the composition of the harvest shifted from predominately females to predominately males (Fay *et al.* 1989; Garlich-Miller *et al.* 2006). By the 1980's, the population had recovered to its pre-exploitation level (Fay *et al*. 1989).

Total annual harvest removals for the period 1960 through 2008 are presented in Fig. 3. These data represent the combined commercial and subsistence harvests in the United States and Russia. Reported subsistence harvests are corrected for struck and lost animals (42%) according to Fay *et al.* 1994. Total harvest removals for the 1960's and 1970's averaged 5,331 and 5,747 walruses per year for each decade respectively. The 1980's saw an increase in harvest with a total removal estimate averaging 10,970 walruses per year (Fig. 3). The increased harvest rates in the 1980's are thought to reflect several factors including removals associated with a ship-based (commercial) harvests in Russia, and increased availability to subsistence hunters coinciding with the Pacific walrus population peaking and reaching carrying capacity (Fay *et al.*1989; Fay *et al.* 1997). Between the years 1976 and 1979 the State of Alaska managed the walrus population under a federally imposed subsistence harvest quota of 3,000 walruses per year. Relinquishment of management authority back to the Service in 1979 lifted this harvest quota, which may have also contributed to the increased harvest rates in subsequent years (USFWS 1994). The increased harvest levels of the 1980's was also accompanied by an increase in the proportion of harvested females, which likely had a depleting effect on the population (Fay *et al.* 1997). The 1990's saw much lower total removal levels than the previous decade, with an average of 5,787 walrus per year. Total annual removal levels have continued to drop since that time. The average annual removal estimate for the most recent decade (2000-2008) is 5,285 walruses/year (Fig. 3).



Beginning in 2003 the U.S. Fish and Wildlife Service began publishing upper and lower annual harvest estimates for the USA based on MTRP compliance estimates. Error bars for 2003 through 2008 denote the range between the high and low estimates, with the vertical bar denoting the mean.

Figure 3. **Total annual harvest removals for the Pacific walrus population from 1960 to 2008. Reported subsistence harvests corrected for struck and lost animals (42%) according to Fay *et al.* 1994.**

3.3.1.2 Harvest Management

Commercial (and recreational) harvesting of marine mammals in U.S. waters has been prohibited since the passage of the MMPA in 1972. Commercial walrus harvests in Russian waters carried out through the 1980's, accounting for up to 45% of the total Russian harvest, however, commercial harvests ended in 1991 due to the economic collapse of the industry (Garlich-Miller and Pungowiyi 1999). Although Russian legislation allowing for a commercial harvest still exists; an annual decree from the Russian Fisheries Ministry allocating a quota would be needed prior to resumption of the harvest (Anatoli Kochnev, Chukot TINRO, 2010, *pers. comm.*).

In the United States, the MMPA provides for the harvest of walruses and other marine mammals by Alaska Natives for subsistence and the creation of authentic Native handicrafts. There are no harvest quotas or seasons at the present time; however subsistence harvests must not be conducted in a wasteful manner. Although there are no State-wide harvest quotas in Alaska, some local harvest management programs have been developed in recent years. For example, subsistence walrus hunting at Round Island, within the Walrus Island- State Game Sanctuary, is regulated by a cooperative agreement with an annual quota of up to 20 walruses per year (including struck and lost animals), and a defined hunting season to limit the potential for disturbances at the haulout. Also, the communities of Gambell and Savoonga on St. Lawrence Island have recently formed Marine Mammal Advisory Committees and have implemented local ordinances establishing a limit of four adult/sub-adult walruses per hunting trip (struck and lost animals and walrus calves accompanying adult animals do not count against the trip limit).

In Russia the "Law of Fisheries and Preservation of Aquatic resources" provides for subsistence harvest of Pacific walruses by aboriginal peoples. Under the USSR regime, subsistence hunting was accomplished by professional hunting brigades employed by community cooperatives. Hunting equipment was supplied by the cooperatives and all edible meat and byproducts were turned over to the cooperative. This system of hunting still continues today with each community having one to several professional hunting teams to supply the community with subsistence foods. With the collapse of the USSR, the concept of individuals hunting for their own subsistence needs was realized and has become more prevalent in Chukotka (Anatoli Kochnev, Chukot TINRO, 2010, *pers. comm.*). Subsistence harvest in Chukotka is regulated through a quota system. An annual subsistence quota is issued through a decree by the Russian Federal Fisheries Agency. Quotas are based in part on recommendations of Pacific Research Fisheries Center (Chukotka Branch-ChukotTINRO) scientists. Quota recommendations are based on what is thought to be a sustainable removal level based on the total population and productivity estimates. In recent years this level is thought to be approximately 4% of the population. With the population being shared with the U.S., Russian quota recommendations have generally been 2% or less of the estimated total population (Garlich-Miller and Pungowiyi 1999; Kochnev 2010*, pers. comm.*). For the years 1997 to 2003 the Russian Federation issued an annual subsistence quota of 3,000 walruses per year (Garlich-Miller and Pungowiyi 1999; Kochnev 2010). In 2004 this quota was reduced to 2,000 walruses and remained at that level for 2005. In 2006, the quota was further reduced to 1,500 and remained at that level for 2007. In 2008 the quota was increased to 1900, then decreased to 1500 in 2009 and further decreased to 1300 for 2010 (Anatoli Kochnev, Chukot TINRO, 2010, *pers. comm.*).

3.3.1.4 Regional Harvest Patterns

In recent (2004-2008) years, the United States has accounted for approximately 60% of the total (US/Russia) harvest (Fig. 3). The sex ratio of the US harvest over this time period was approximately 1.55:1 males to females. Although subsistence walrus hunting in Alaska is carried out in coastal communities stretching from Bristol Bay to the Arctic Slope, the bulk of the harvest occurs in the Bering Strait region. Between 2004 and 2008, the average annual harvest from St Lawrence Island (Gambell and Savoonga) was 988 walruses; accounting for approximately 84 % of the reported U.S. harvest. During this same time period, annual subsistence harvests in the Bristol Bay and the Yukon Kuskokwim Delta regions averaged 5 and 18 walruses per year respectively, and subsistence harvest in the North Slope region of Alaska averaged 48 walruses per year (US Fish and Wildlife Service, Unpublished data). For the years 2004-2008, Russia accounted for approximately 40% of the total (US/Russia) harvest (Fig. 3), with the communities of Lorino, Inchoun, and Enurmino accounting for approximately 50-60% of the Russian reported harvest (Anatoli Kochnev, Chukot TINRO, 2010, *pers. comm.*). Current sex ratio data from the Russian harvest is not available; however data collected in 2003 and 2005 indicate a sex ratio of 3.76:1 males to females. Current harvest practices in both countries primarily involve targeting walruses hauled out on sea-ice using small skiffs. Some hunting also occurs at coastal haulouts in the fall, primarily in Chukotka Russia.

3.3.1.4.1 Climate Change

Changing ice conditions in the Bering and Chukchi Seas are expected to result in changes in the distribution, habitat use patterns and ultimately, the size of the Pacific walrus population over time (Section 3.2.2). Projected changes in sea-ice habitats and walrus abundance will likely influence the availability of walruses for subsistence hunting in some regions. In general, in we anticipate that the availability of walruses will: decline in the southern part of their range (e.g. Bristol Bay, Kamchatka Peninsula); increase along the Arctic coast (northern Chukotka coastline, and Alaska's North Slope); and remain relatively stable in the Bering Strait region (section 3.2.1.2).

In Alaska, we expect that declining sea ice habitats in the southern Bering Sea (e.g. Bristol Bay) will result in a northward shift of winter aggregations from this region over time (Section 3.2.2). However, many adult male walruses occupy coastal haulouts in Bristol Bay during the ice-free summer months and these animals will likely continue to be available to hunters in the Bristol Bay region. The reported walrus harvest in Bristol Bay is quite low at the present time (approximately 5-18 walruses per year), and does not appear to be limited by the availability of walruses to hunters, therefore we do not anticipate any significant changes in harvest patterns will occur in this region. Although Russian scientists have reported that the number of walruses occupying coastal haulouts in the southern Bering Sea (e.g. Kamchatka and the Koryak coast (Fig. 1)) has declined significantly over the past decade (Kochnev, 2010, *pers. comm.*), walruses are not hunted in the Kamchatka region, therefore any further changes in walrus abundance (availability) in this region is not expected to influence regional harvest levels.

Walruses are expected to become increasingly dependent on coastal haulouts along the Chukchi Sea coast in the fall (Section 3.2.2). This is expected to increase the availability of walruses to hunters along the northern Chukotka coastline and in the North Slope region of Alaska. Increased availability of walruses at coastal haulouts in this region will not necessarily translate into significant increases in future harvest levels. In Chukotka Russia, walrus harvests are regulated through a regional quota system based upon principals of sustainable harvests. The total allocated harvest for the Chukotka region is distributed across coastal communities in the region based upon historical use patterns and community need (WWF 2010). Despite the dramatic increase in the availability of walruses along the northern Chukotka coast in recent years, harvest levels have declined because harvest allocations have been reduced in response to the perception that the population is in decline (Anatoli Kochnev, Chukot TINRO, 2010, *pers. comm.*). In the North Slope Region of Alaska, the formation of coastal haulouts during the summer months is a relatively new phenomenon. In the summer of 2010, a large haulout formed within 2 miles of the community of Point Lay. Despite the accessibility of walruses at the nearby haulout, hunters from the community harvested only 5 walruses that season, similar to harvest levels reported for previous years (Willard Neakok Sr., EWC, 2011 *pers. comm.*). It is noted that North Slope coastal communities have traditionally relied heavily on other marine mammal species (notably bowhead and beluga whales) as well as seabirds, fish and terrestrial mammals to meet their subsistence needs (MMS 2007a, p. IV–186). North Slope communities also appear to have a stronger economic base than many Bering Strait communities, and do not rely as heavily on ivory carving as a source of cash in the local economy.

Even if harvest levels along the Arctic coast of Chukotka and Alaska do not increase appreciably in the future, the potential for hunting activity at crowded coastal haulouts to create stampedes resulting in injuries or mortalities, or displace animals from preferred forage areas is an emerging concern (Kochnev 2004; WWF 2010). Awareness of the sensitivity of walruses to disturbance events at coastal haulouts is growing, and the prospects for developing local conservation and management initiatives to address disturbance related mortalities along the Arctic coast appears to be good (Kavry *et al.* 2008; WWF 2010). In 2008, the Eskimo Walrus Commission passed a resolution urging coastal communities to implement ordinances and guidelines regarding hunting and disturbance of groups of walrus while they rest on shore (EWC 2008). In Chukotka, hunters have revived a traditional practice of hunting animals at coastal haulouts with spears rather than rifles to minimize disturbances on the haulouts (WWF 2010). Some communities have also appointed a haulout steward that directs hunting activity at the haulouts to minimize impacts and disturbances (WWF 2010).

Most of the US walrus harvest occurs in the Bering Strait region of Alaska, principally from the St. Lawrence Island communities of Gambell and Savoonga. Walrus hunting has been a significant part of the culture and economy for coastal communities in this region for thousands of years (Ray 1975). Walrus harvest levels in the Bering Strait region of Alaska are primarily influenced by the availability of walruses to hunters (Fay *et. al.* 1989) and the influence of environmental conditions (e.g. ice conditions and weather patterns) on hunting conditions (Benter and Kanooka 2011). Winter sea-ice is expected to continue to form in the Bering Strait region in the future (Douglas 2010), and winter breeding aggregations are expected to persist in the region at least through mid-century (section 3.2.1.2). Pacific walruses will likely continue to be locally abundant near coastal communities during the spring migration, although poor ice conditions for hunting (e.g. thin ice floes, rapid spring melt) may impact spring hunting success (Leonard Apangalook 2004, in EWC 2004). Moderating fall/winter ice conditions could however increase opportunities for additional harvests during the winter months which may compensate for some of the lost opportunity in the spring (Benter and Robards 2009; Winnie James 2011, *pers comm.*). There is considerable year to year variation in harvest levels in the Bering Strait region presumably mediated by the influence of environmental factors (primarily weather and ice conditions) on hunting success (Benter and Koonooka 2011). We anticipate that the observed stochasticity in hunting conditions and success in the Bering Strait region will continue and potentially amplify in the future, however the overall availability of walruses to hunters, and the number of walruses harvested in the region is not expected to change appreciably in the future.

3.3.1.5 Harvest Sustainability

The size of the Pacific walrus population has fluctuated markedly over the past 200 years in response to various levels of exploitation. Although recent harvest levels are lower than historic highs, a lack of information on population status and trend make it difficult to quantify sustainable removal levels. Recent (2003–2007) annual harvest removals in the United States and Russia have ranged from 4,960 to 5,457 walrus per year, representing approximately 4 percent of a minimum population estimate of 129,000 animals (Speckman *et al.* 2010). These levels are lower than those experienced in the early 1980s (8,000–10,000 per year) that may have contributed to a population decline (Fay *et al.* 1989). Chivers (1999) modeled walrus population dynamics and estimated the maximum net productivity rate (*Rmax*) for the Pacific walrus population at 8 percent per year. Wade (1998), notes that one half of *Rmax* (4 percent for Pacific walruses) is a reasonably conservative (i.e. sustainable) potential biological removal (PBR) level for marine mammal populations below carrying capacity, because it provides a reserve for population growth or recovery. The PBR level, as defined under the MMPA, is the maximum number of animals, not including natural mortalities that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population.

Although current harvest levels are likely within a sustainable range, observed and projected changes in sea ice habitats are expected to result in future population declines. Harvest levels may become unsustainable in the future if harvest levels do not adjust in concert with changes in population size (Jay *et al.* 2010b). In Chukotka Russia harvest levels are established based upon the best available information concerning population size and trend. Russian managers have lowered subsistence quotas in recent years in response to concerns that the population is in decline. There are no state-wide harvest regulations in Alaska and harvest levels are not expected to change appreciably in the future. One of the most promising mechanisms for ensuring that the harvest levels in Alaska remain sustainable is the development of co-management agreements with the Alaska Native subsistence communities. The Tribal Governments of Gambell and Savoonga on St. Lawrence Island, where the majority of the walrus harvest occurs, recently adopted local ordinances establishing Marine Mammal Advisory Councils (MMAC). These MMACs have been granted the power to regulate the hunting practices of Tribal members. This is an extremely promising method of working with subsistence users to ensure that the harvest of Pacific walruses remains sustainable.

3.3.2 Utilization for Recreational, Scientific, or Educational Purposes

Overutilization for recreational, scientific, or educational purposes is currently not considered a threat to the Pacific walrus population. Recreational (sport) hunting has been prohibited in the United States since 1979. Russian legislation also prohibits sport hunting of Pacific walruses. The Marine Mammal Protection Act of 1972, as amended (16 U.S.C. 1361, *et seq.)* (MMPA), allows the Service to issue a permit authorizing the “take” (harass, capture, or kill) of walruses for scientific purposes in the United States, provided that the research will further a bona fide and necessary or desirable scientific purpose. No permits authorizing lethal take of walruses for scientific purposes have been requested in the United States since the early 1990s. Prior to issuing an authorization for scientific take, the Service must consider the benefits to be derived from the proposed research and the effects of the taking on the stock, and must consult with the public, experts in the field, and the United States Marine Mammal Commission.

Similarly, any take for an educational purpose is allowed by the MMPA only after rigorous review and with appropriate justification. No permits authorizing the take of walruses for educational and public display purposes have been requested in the United States since the 1990s. The Service has worked with the public display community to place stranded animals, which the Service has determined cannot be returned to the wild, at facilities for educational and public display purposes. By placing stranded walruses, which would otherwise be euthanized, at facilities that are able to care for and display the animals, we believe needs for the domestic public display community in the United States have been, and will continue to be, met. The Russian Federation does intermittently authorize the taking of walruses from the wild for scientific and educational purposes. For example, in 2009, a collection permit was issued for take of up to 40 walrus calves from the wild to be used for public display. This take is included in the subsistence harvest quota, and considered by Russian biologists to be sustainable. We have no information that would lead us to believe that the utilization (take) of Pacific walruses for recreational, scientific, or educational purposes in either the United States or Russia will increase in the foreseeable future.

3.3.3 Summary: Effects of Overutilization on the Pacific Walrus Population

Over the past fifty years the Pacific walrus population has sustained annual harvest removals ranging from 3,200 to 16,000/year. Over the past decade, harvest removals in the U.S. and Russia have averaged approximately 5,000/year. Recent harvest levels are significantly lower than historic highs and likely within a sustainable range. However, anticipated changes in population size in response to losses in sea-ice habitats, underscores the need for reliable population information as a basis for evaluating the sustainability of current and future harvest levels. Research leading to a better understanding of population responses to changing ice conditions and modeling efforts to examine the impact of various removal levels are needed. Harvest levels in Russia are presently subject to a quota system based upon the best available population information. Although the subsistence walrus harvest in Alaska is not regulated under a quota system, the MMPA provides for the development of co-management agreements with Alaska natives for the subsistence use of marine mammals. Local hunting ordinances have also recently been developed in some hunting communities, providing a potential mechanism for self regulation of harvests. The MMPA also has a provision for establishing harvest quotas for marine mammals should a population be declared depleted. Under the MMPA provisions for stock assessments (§117), the status of the Pacific walrus population will be updated at least every 3 years. Recreational, scientific, and educational utilization of walruses is currently at low levels and is not projected to increase.

3.4 Disease or Predation

3.4.1 Disease

3.4.1.1 Viruses and Bacteria

Infectious viruses and bacteria have the capacity to impact marine mammals, particularly when presented to a naïve population (Duignan *et al.* 1994; Osterhaus *et al.* 1997; Ham-Lamme and King 1999; Calle *et al.* 2002; Burek *et al.* 2008). Viruses, such as caliciviruses, are known to cause vesicular lesions, abortion, encephalitis, and pneumonitis in pinnipeds (Skilling *et al.* 1987), and have been a suspected cause for reproductive failure in Pacific walruses (*Fay et al.* 1984a). Bacteria, such as the spirochete *Leptospira*, may cause Leptospirosis resulting in renal disease (Calle *et al.* 2002).

Pacific walruses have endured and recovered from exposure to caliciviruses, as indicated by San Miguel sea lion virus and walrus calicivirus antibodies isolated from walruses in the Bering and Chukchi Seas (Smith *et al.* 1983; Barlough *et al.* 1986). While the transmission pathway for these viruses is poorly understood (Barlough *et al.* 1986), the primary route is likely via the food chain (Smith, *et al.* 1976; Smith *et al.* 1981; Smith *et al.* 1983; Barlough *et al.* 1986). Food chain transmission of calicivirus has been demonstrated with the opal eye-California sea lion (*Girella nigricans-Zalophus californianus*) relationship (Smith *et al.* 1981; Barlough *et al.* 1986). Accordingly, fishes in the North Pacific may be reservoirs of the virus, or perhaps intermediate hosts (Barlough *et al.* 1986). Alternative vectors may include filter-feeders such as bivalves that efficiently concentrate water-borne microbial agents (e.g., enteroviruses; (Sobsey 1982)). Walruses shed calicivirus for many months after exposure (Madin 1975), and it is possible that they may act as primary reservoir hosts (Smith *et al.* 1976; Smith and Latham 1978; Duignan *et al.* 1994), passing caliciviruses directly to conspecifics (Barlough *et al.* 1986).

Influenza A virus, that can cause death (Webster *et al*. 1981), has been detected in Pacific walruses (Calle *et al*. 2002). It has been postulated that there may be an interchange of the Influenza A virus between marine mammals and aquatic birds (Hinshaw *et al.* 1984; Callan *et al.* 1995; Danner and McGregor 1998). This exchange may occur via the food chain, as Pacific walruses may consume sea birds (Fay *et al.* 1990). Alternatively, exposure may occur indirectly, since many terrestrial walrus haulout sites are adjacent to sea bird colonies (Calle *et al.* 2002).

Introduction of viruses to naïve populations of marine mammals may occur as the result of changing distribution patterns of the host (Dobson and Carper 1993; Duignan *et al.* 1994). For example, phocine distemper virus (PDV) was recently introduced to the North Pacific, presumably through intraspecific transmission from seal populations in the Atlantic to the Pacific via the Arctic Ocean (Goldstein *et al.* 2009). Antibodies to PDV have been found in

Atlantic walruses (Nielsen *et al.* 2000), but, as yet, there has been no evidence of exposure in Pacific walruses (Osterhaus *et al.* 1988). Thus, exposure of Pacific walruses to PVD could have severe results given their naïve immune systems. A closely related pathogen, canine distemper virus (CDV), was introduced to marine mammals possibly from infected dogs (Harvell *et al.* 1999). CDV has stricken marine mammals that were naïve to the virus and has caused mass mortalities (i.e., 10,000 Caspian seals died in 2000; (Kuiken *et al.* 2006)).

Leptospirosis is caused by a bacterial infection from the spirochete *Leptospira interrogans*. Within hosts adapted to the disease, mild illness or abortion may occur, but introduced to a naïve host, the bacteria can cause acute illness including severe renal disease (Colagross-Schouten *et al.* 2002). A wide range of terrestrial mammals host these bacteria, and the presence of antibodies to *L. interrogans* has been reported in marine mammals from the North Pacific. Walruses from Round Island have a relatively high prevalence of *Leptospira* antibodies, and may be exposed to it from Steller sea lions that also carry the bacteria (Calle *et al.* 2002). Zuerner *et al.* (2009) postulated that Steller sea lions can transport and distribute *L. interrogans* over great distances during their seasonal migrations.

3.4.1.2 Parasites

Parasites are common among pinnipeds, and their infestations have various effects on individuals and populations (Fay 1982; Dubey *et al.* 2003). For example, the ectoparasite, *Antarctophthirus trichchi*, is an anopluran louse that lives in the skin folds of walruses (Fay 1982). Although it apparently causes external itching, no serious health issues are associated with this endemic insect (Fay 1982).

Of greater concern are the endoparasites; protozoa and helminthes that invade suitable hosts to complete all or part of their life cycle. Of the 17 species of helminthes known to parasitize Pacific walrus, two species are endemic (Fay 1982; Rausch 2005). The cestode *Diphyllobothrium fayi* is found only in the small intestine and is transmitted through ingestion of infected fish (Rausch 2005), and the nematode *Anisakis rosmari* is found only in stomachs (Heptner *et al.* 1976).

Trichinella spiralis nativa (Rausch *et al.* 2007) infects Pacific walruses at a low rate (1.5%, Bukina and Kolevatova 2007). This nematode infests the muscle tissue, and as is the case with walrus-eating indigenous people, is transmitted through the ingestion of infested meat (Rausch *et al.* 2007). Pacific walruses occasionally prey on seals (Lowry and Fay 1984; Rausch *et al.* 2007), which is the most likely source of *Trichinella*. Most Alaskan Eskimos agree that seal eating is a result of walrus calves losing their mothers before they learn to forage on benthic prey. This behavior may also be adopted by other walruses if benthic foods become less available (Lowry and Fay 1984). As sea-ice is reduced, access to benthic invertebrates may become limited

(Section 3.2.1.4), forcing walruses to find alternative food sources (Rausch *et al.* 2007). The prevalence of *Trichinella* may increase if walruses switch to a diet consisting of larger amounts of seals.

The intracellular parasite, *Toxoplasma gondii*, has been isolated from at least 10 species of marine mammals including walruses (Dubey *et al.* 2003). Of the 53 Pacific walruses tested between 1976 and 1998, 5.6% were positive for *T. gondii* (Dubey *et al.* 2003). *T. gondii* can be transmitted either by ingestion or through the placenta (Dubey *et al.* 2003). In the terrestrial environment, cats host *T. gondii* oocytes (Fayer and Trout 2005) and a hypothesis for transmission to the marine environment is through surface runoff or sewage discharges (Buergelt and Bonde 1983; Miller *et al.* 2002; Dubey *et al.* 2003). While direct intake of *T. gondii* suspended in contaminated seawater has been implicated for herbivorous marine mammals (Buergelt and Bonde 1983), ingestion of oocyst-contaminated bivalves may be a more plausible transmission pathway for walruses (Lindsay *et al.* 2004). In the Arctic, however, cold temperatures inhibit oocyst viability and felids are rare (Fayer and Trout 2005; Simon *et al.* 2009) so this is an unlikely source. An additional potential vector for *T. gondii* transmission to walruses may be fish (Massie and Black 2008; Jensen *et al.* 2009), however, walruses rarely consume fish. Because their diet is variable (Fay *et al.* 1984a) and *T. gondii* has been documented in some of their prey (e.g., seals and bivalves; (Fay 1982; Lowry and Fay 1984; Dubey *et al.* 2003; Lindsay *et al.* 2004; Jensen *et al.* 2009)), walruses may have limited exposure to this endoparasite, but it will not likely play a significant role in the health of Pacific walrus.

Neospora caninum is a protozoan parasite, and until the late 1980's was misdiagnosed as *T. gondii* (Dubey *et al.* 2007). Exposure to *N. caninum* is inferred due to antibodies that were found in 3 of 53 walruses (Dubey *et al.* 2003). The only known host for *N. caninum* is domestic dogs (Dubey *et al.* 2003) and coyotes, but foxes may also be a vector (Dubey *et al.* 2007). The health implication for *N. caninum* exposure in walruses is unknown and the potential for exposure appears low.

3.4.1.2 Future Scenarios For Disease and Parasite Transmission

Climate warming has changed the distribution of some diseases, disease vectors (Harvell *et al.* 1999), and parasites (Dobson and Carper 1993) which could expose walruses to new pathogens. Decreased ice cover over shallow, benthic habitat could result in a shift in the frequency of predation on marine mammals and an increased probability of disease transmission to walruses (Rausch *et al.* 2007). Additionally, increased use of terrestrial haulouts may escalate the risk of transmission of disease (Fay 1974). However, none of these scenarios have been documented. While we acknowledge the potential for disease and parasites to play a significant role in the health of the Pacific walrus population, the probability that such epizootics will actually occur appears low due to apparently limited potential transmission vectors.

3.4.2 Predation

Pacific walruses are one of the largest animals of the Bering and Chukchi Seas. As such, they have relatively few natural predators. The principal natural predators of Pacific walruses are polar bears (*Ursus maritimus*) and killer whales (*Orcinus orca*).

3.4.2.1 Polar Bears

The distribution of Pacific walruses overlaps with that of the polar bear (Derocher *et al.* 2004; Durner *et al.* 2004). Polar bears usually forage in areas where there are high concentrations of ringed seals, their primary prey (Stirling and McEwan 1975; Larsen 1985), although bearded seals, walruses, and beluga whales also are taken (Fay 1982; Amstrup and DeMaster 1988). Typically, polar bears are no match for healthy adult walruses in direct confrontations (Fay 1982); although some bears appear to become quite adept at preying on walruses (Iverson *et al.* 2006).

When suitable sea-ice platforms are not available, Pacific walruses will haul out on land. Many walruses can die in stampedes at coastal haulout sites (section 3.2.1.2.3) which, in turn, provide scavenging opportunities for bears (Ovsyanikov 2003). The abundance and predictable nature of food resources at coastal walrus haulouts contributes to the aggregations of polar bears at those sites (Kochnev 2006).

Polar bears first appear near walrus haulouts on Wrangel Island in early August, about a month prior to the arrival of walruses (Kochnev 2002). The number of bears coming ashore on Wrangel Island peaks in late October, averaging 50 bears (Kochnev 2002). However, during 2007 approximately 500-600 polar bears were estimated to be on Wrangel Island (Ovsyanikov and Menyushina 2007), along with herds of walruses (up to 15,000 in one group), which appeared weak (Ovsyanikov *et al.* 2007). Because the walruses were in poor condition, polar bears simply approached dying walruses and killed them with little resistance. At least 11 cases of polar bear predation on calves were also observed (Ovsyanikov *et al.* 2007). Walrus carcasses represent the most important resource for bears on the island in autumn and early winter (Kochnev 2002).

It seems reasonable to assume that increased walrus residency at terrestrial haulouts will result in increased exposure to polar bears. Because the fall open water period is predicted to increase in the foreseeable future, polar bears are also predicted to spend more time on land. As a result, terrestrial walrus haulouts may become increasingly important feeding areas for polar bears. Anecdotal information suggests that brown bears (*Ursus arctos*) also occasionally target walruses at coastal haulouts (Fay 1982; Smirnov *et al.* 2002).

Polar bears and brown bears are opportunistic predators and scavengers, and it is reasonable to assume that predictable food resources of the magnitude represented by walrus haulouts will be targeted by bears of both species. It is also reasonable to assume that bear cubs will learn these predation/scavenging strategies from their mothers. Such a scenario could result in direct effects from predation and trampling deaths, and possibly decreased condition of surviving walruses as a result of chronic disturbance from bear predation attempts.

3.4..2.2 Killer Whales

The killer whale is regarded as the Pacific walruses principal natural predator (Fay 1982). Although sea-ice habitats provide some protection against killer whales, which have limited ability to penetrate the ice pack, numerous accounts of killer whale predation on walrus observed by Russian scientists and Alaska Natives are contained in Fay (1982). Some observers suggest that killer whales primarily prey upon the youngest animals, although instances of killer whale predation on adult walruses have also been documented (Fay 1982). The mortality level from killer whale predation is unknown, but an examination of 52 walrus carcasses which washed ashore on St. Lawerence Island in 1951 determined that 17 (33%) died from injuries consistent with killer whale predation (Fay 1982). Reduced availability of sea-ice may lead to increased time spent by walruses in the water where they would be more susceptible to predation by killer whales. One uncertainty is the amount of time that might elapse before killer whales extend their foraging range northward into the Chukchi Sea.

3.4.3 Summary: Effects of Disease or Predation

Disease and predation are not considered to represent a significant stressor on the Pacific walrus at this time. As walruses and polar bears become increasingly dependent on coastal haulouts, predation rates and associated disturbance related mortalities could increase. The presence of polar bears along the coast during the ice free season will likely influence patterns of haulout use by walruses and may play a significant role in the selection of coastal haulout sites. Other terrestrial predators and scavengers such as brown bears, wolverines, and feral dogs may also contribute to levels of disturbances at coastal haulouts and influence the choice of haulout sites (WWF 2010). Programs have been established in recent years at some coastal haulouts in Chukotka, to mitigate disturbance related mortalities that include collection of walrus carcasses and establishment of polar bear feeding areas away from the haulouts and villages. Although predation levels and associated disturbance related mortalities can reasonably be expected to increase in the future, it is difficult to quantify the net effect on the population.

3.5 Inadequacy of Existing Regulatory Mechanisms

Regulatory mechanisms directed at managing many of the threats to Pacific walruses are in place in the United States, primarily through the MMPA. In addition, there are several international agreements that provide some conservation benefit to this species.

3.5.1 International Agreements

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

CITES is a treaty aimed at protecting species at risk from unregulated international trade. CITES lists species in one of three appendices which determines the level of monitoring and control applied to a species. Appendix I list species threatened with extinction. Trade of Appendix I species is only allowed in exceptional circumstances. Appendix II includes species not necessarily threatened with extinction now, but for which trade must be regulated in order to avoid overutilization. Appendix III includes species that are subject to regulation in at least one country, and for which that country has asked other CITES Party countries for assistance in controlling and monitoring international trade. In 1975, walrus were placed on Appendix III of CITES at the request of Canada. Global trade in walrus ivory is restricted according to a CITES Appendix III listing.

In a public comment associated with the listing petition, the Humane Society International urged the Service to examine trade in walrus ivory, specifically with Indonesia, to determine whether trade is in compliance with the MMPA, and whether such trade constitutes a significant risk factor for walruses. The Service has determined that the majority of the trade is in parts and derivatives, including ivory jewelry, ivory carvings, bone carvings, ivory pieces and tusks. In 2008 more than 16,000 specimens were imported or exported and over 98% of those specimens originated in the United States. Most of the specimens were identified as fossilized bone and ivory shards, principally dug from historic middens on St. Lawerence Island. As such, the specimens are pre–MMPA and exempt from the provisions of Section 102 of the MMPA. As a result, this trade does not constitute a significant risk factor to Pacific walruses. Post-MMPA ivory can only be imported or exported after it has been legally harvested, and substantially altered to qualify as a handicraft. Trade in post-MMPA walrus ivory will continue to be closely monitored.

The International Union for the Conservation of Nature and Natural Resources (IUCN) Red List

The IUCN Red List identifies and documents species in need of conservation attention, and is widely recognized as the most comprehensive, apolitical global approach for evaluating the conservation status of plants and animals. In order to produce Red Lists of threatened species worldwide, the IUCN Species Survival Commission draws on a network of scientists and partner organizations, which use a scientifically rigorous approach to determine a species risk of extinction. Because current abundance and population trends are unknown, the Pacific walrus is currently classified as “Data Deficient” on the IUCN Red List (Lowry and Burkanov 2008).

3.5.2 Domestic Regulatory Mechanisms

Marine Mammal Protection Act of 1972, as Amended

The MMPA was enacted in response to growing concerns among scientists and the general public that certain species and populations of marine mammals were in danger of extinction or depletion as a result of human activities. The MMPA set forth a national policy to prevent marine mammal species or populations (stocks) from diminishing to the point where they are no longer a significant functioning element of the ecosystems.

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

The MMPA includes a general moratorium on the taking and importing of marine mammals, which is subject to a number of exceptions. Some of these exceptions include take for scientific purposes, public display, subsistence use by Alaska Natives, and unintentional incidental take coincident with lawful activities. Take is defined in the MMPA to include the harassment of marine mammals. Harassment includes any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild (Level A harassment), or has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering (Level B harassment). The Secretaries of Commerce and of the Interior have primary responsibility for implementing the MMPA.

The MMPA exempts Alaska Natives from the prohibitions on taking for subsistence purposes. Section 119 of the MMPA provides for the adoption of cooperative agreements with Alaska Native organizations to conserve marine mammals and provide co-management of subsistence uses. In addition, sections 101(b)(3) and 103 of the MMPA provide for the adoption of subsistence harvest regulations for stocks designated as depleted, after notice and administrative hearings.

The Service signed a formal co-management agreement under the Section 119 authority with the Eskimo Walrus Commission (EWC) in 1997 and has maintained a formal working relationship since that initial agreement. The EWC was institutionalized in 1978 by Kawerak, Inc. of Nome, AK and represents Alaska's walrus hunting communities. Initially formed as a consortium of Native hunters, EWC is a recognized statewide entity working on resource co-management issues, on behalf of Alaska Natives. The EWC is comprised of 19 member communities throughout the range of the walrus in Alaska. The EWC's mission is to "Encourage self regulation of walrus hunting and management of walrus stock by Alaska Natives who use and need walrus to survive" (http://www.kawerak.org/servicedivisions/nrd/ewc/index.html). The EWC board and the Service meet on a regular basis, to exchange information and work on various projects; including harvest monitoring, collection of biological samples, developing harvest related ordinances, and helping to reduce human disturbance at coastal haulouts (http://www.kawerak.org/servicedivisions/nrd/ewc/index.html).

U.S. citizens who engage in a specified activity other than commercial fishing (which is specifically and separately addressed under the MMPA) within a specified geographical region may petition the Secretaries to authorize the incidental, but not intentional, taking of small numbers of marine mammals within that region for a period of not more than five consecutive years (16 U.S.C. 1371(a)(5)(A)). The Secretary shall allow the incidental taking if the Secretary finds that the total of such taking during each 5 year (or less) period concerned will have a negligible impact on such species or stock and will not have an immitigable adverse impact on the availability of such species or stock for taking for subsistence uses. If the Secretary makes the required findings, the Secretary also prescribes regulations that specify; (1) permissible methods of taking, (2) means of affecting the least practicable adverse impact on the species, their habitat, and their availability for subsistence uses, and (3) requirements for monitoring and reporting. The regulatory process does not authorize the activities themselves, but authorizes the incidental take of the marine mammals in conjunction with otherwise legal activities described within the regulations.

On August 23, 2002, the Alaska Oil and Gas Association (AOGA) filed a Petition for the Promulgation of Regulations Pursuant to Section 101 (a) (5) of the MMPA for the Beaufort Sea. Similarly, on August 5, 2005, AOGA filed a Petition for the Promulgation of Regulations Pursuant to Section 101 (a) (5) of the MMPA for the Chukchi Sea. These petitions were for regulations for the unintentional taking of Pacific walruses and polar bears, incidental to oil and gas exploration, development, and production operations and all associated activities on the North Slope for the period of five years. In response to these petitions, FWS issued Incidental Take Regulations for both the Beaufort and Chukchi Seas (USFWS 2006; USFWS 2008; USFWS 2009). On April 30, 2009, the AOGA filed a renewal Petition for the Promulgation of Regulations Pursuant to Section 101 (a) (5) of the MMPA for the Beaufort Sea.

The Service has concluded in the Incidental Take Regulations issued for the Beaufort and Chukchi Seas that Alaska oil and gas activities in the Arctic, including exploration, development (USFWS 2006; USFWS 2008) and production, do not pose a threat to Pacific walruses or their habitat. The Service found "that the total takings of Pacific walruses during oil and gas industry exploration, development and production activities will have a negligible impact on these species" (USFWS 2006).

Similar to promulgation of incidental take regulations, the MMPA also established a process by which citizens of the United States can apply for an authorization to incidentally take small numbers of marine mammals where the take will be limited to harassment (16 U.S.C. 1371(a)(5)(D)). These authorizations are limited to one-year and, as with incidental take regulations, the Secretary must find that the total of such taking during the period will have a negligible impact on such species or stock and will not have an immitigable adverse impact on the availability of such species or stock for taking for subsistence uses. The Service refers to these authorizations as Incidental Harassment Authorizations.

To reduce human caused disturbances on terrestrial haulouts, the Service in conjunction with the Federal Aviation Administration (FAA) has issued guidelines to pilots operating aircraft in the vicinity of known walrus haulouts in Bristol Bay and along the Northwest coast of Alaska. Pilots are requested to remain 2,000 feet AGL within 1/2 mile of Cape Seniavin and the Togiak National Wildlife Refuge boundary in the vicinity of Capes Peirce and Newenham (FAA 2008). To avoid disturbance from marine vessels, the Service has coordinated with the National Ocean Service to place a notice to mariners in the Coast Pilot Volume 9, requesting that marine vessel operators avoid transiting or anchoring within 0.5 mile of the Capes Newenham, Pierce, and Seniavin walrus haulouts. Mariners are further advised that "operating a watercraft in a manner which results in disturbing, harassing, herding, hazing or driving of walruses is prohibited under provisions of the MMPA". To minimize disturbance along the northwest coast, guidelines for pilots recommend fixed wing aircraft remain at altitudes greater than 1,000 feet AGL while within 1/2 mile of walrus group, and helicopters should remain at altitudes greater than 3,000 feet AGL when traveling within one nautical mile of a haulout (www.fooa.gov/about/office_org/Headquarters_offices/ato/service_units/systemops/fs/

Alaskan/advisories/walrus/media/lisburnewalrus-psa.pdf).

Clean Air Act of 1970

The Clean Air Act of 1970 (42 U.S.C. 7401 *et seq.*), as amended, requires the Environmental Protection Agency (EPA) to develop and enforce regulations to protect the general public from exposure to airborne contaminants hazardous to human health. In 2007, the Supreme Court ruled that gases that cause global warming are pollutants under the Clean Air Act, and that the EPA has the authority to regulate carbon dioxide and other heat-trapping gases (Massachusetts *et al*. v. *EPA* 2007 [Case No. 05-1120]). The EPA published a regulation to require reporting of greenhouse gas emissions from fossil fuel suppliers and industrial gas suppliers, direct greenhouse gas emitters and manufacturers of heavy duty and off-road vehicles and engines (EPA 2009). The rule, effective December 29, 2009, does not require control of greenhouse gases; rather it requires only that sources above certain threshold levels monitor and report emissions (EPA 2009). On December 7, 2009, the EPA found under section 202(a) of the Clean Air Act that the current and projected concentrations of six greenhouse gases in the atmosphere threaten public health and welfare. The finding itself does not impose requirements on any industry or other entities but is a prerequisite for any future regulations developed by the EPA. At this time, it is not known what regulatory mechanisms will be developed in the future as an outgrowth of the finding or how effective they would be in addressing climate change.

National Environmental Policy Act (NEPA)

The NEPA requires federal agencies to consider the environmental impacts of their proposed actions, including actions of others requiring a federal permit, and reasonable alternatives to those actions. To meet this requirement, federal agencies conduct environmental reviews, including Environmental Impact Statement and Environmental Assessments. NEPA does not specifically regulate Pacific walruses, but it does require full evaluation and disclosure of information regarding the effects of contemplated federal actions on Pacific walruses and their habitat.

Outer Continental Shelf Lands Act (OCSLA)

The OCSLA (43 U.S.C. 331 et seq.) established federal jurisdiction over submerged lands on the outer continental shelf (OCS) seaward for 3 miles in order to expedite exploration and development of oil and gas resources. Implementation of OCSLA is delegated to the Bureau of Ocean Energy Management, Regulation, and Enforcement (formerly Minerals Management Service [MMS]) of the Department of the Interior. OCS projects that could adversely impact the coastal zone are subject to federal consistency requirements under terms of the Coastal Zone Management Act, as noted below. OCSLA also mandates that orderly development of OCS energy resources be balanced with protection of human, marine, and coastal environments. Through consistency determinations, OCSLA helps to ensure that OCS projects do not adversely impact Pacific walruses or their habitats.

Oil Pollution Act (OPA) of 1990

Oil spill response in Alaska is regulated by the 1990 OPA, which requires the U.S. Coast Guard (USCG) and the EPA to develop a statewide oil spill response plan, and by Alaska Statute 46.04, which requires the Alaska Department of Environmental Conservation (ADEC) to develop a statewide response plan and individual response plans for ten geographic subareas spanning the State of Alaska (Oil Pollution Act of 1990 (33 U.S.C. 2701-2761). Finally, Alaska Statute 46.04 requires that the oil industry develop oil discharge prevention and contingency plans. The MMPA requires the Service to complete contingency planning for response to the stranding and unusual mortality of protected marine mammals. While oil spills are considered a cause of unusual mortality, the MMPA defers to the OPA and Alaska Statutes for oil spill response planning.

Coastal Zone Management Act (CZMA)

The CZMA (16 U.S.C. 1451 et seq.) was enacted to ``preserve, protect, develop, and where possible, to restore or enhance the resources of the Nation's coastal zone.'' The CZMA is a state program subject to federal approval. The CZMA requires that federal actions be conducted in a manner consistent with a state's coastal zone management plan to the maximum extent practicable. Federal agencies planning or authorizing an activity that affects any land or water use or natural resource of the coastal zone must provide a consistency determination to the appropriate state agency. The CZMA applies to Pacific walrus habitats of Alaska.

Alaska National Interest Lands Conservation Act

The Alaska National Interest Lands Conservation Act (ANILCA) of 1980(16 U.S.C. 3101 *et seq.*) created or expanded National Parks and National Wildlife Refuges in Alaska, including the expansion of the Togiak National Wildlife Refuge (TNWR). One of the establishing purposes of the TNWR is to conserve fish and wildlife populations and their habitats, including marine birds and mammals. Walrus haulouts at Cape Peirce and Cape Newenham are located within TNWR. Access to the Cape Peirce is tightly controlled through a permitted visitor program. Refuge staff requires that visitors must remain out of sight, downwind, and a minimum of 100 yards from walruses. Cape Newenham has no established refuge visitor program as public access is extremely limited due to the presence of Department of Defense lands surrounding the Cape.

Marine Protection, Research and Sanctuaries Act (MPRSA)

The Marine Protection, Research and Sanctuaries Act (MPRSA, 33 U.S.C. 1401 et seq.) was enacted in part to ``prevent or strictly limit the dumping into ocean waters of any material that would adversely affect human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities.'' The MPRSA was designed to protect the quality of marine habitats that Pacific walruses rely upon.

Magnuson-Stevens Fishery Conservation and Management Act

The North Pacific Fishery Management Council (NPFMC) is one of eight regional councils established by the Magnuson Fishery Conservation and Management Act in 1976 (which has been renamed the Magnuson-Stevens Fishery Conservation and Management Act) to oversee management of the nation's fisheries. With jurisdiction over the 900,000 square mile Exclusive Economic Zone (EEZ) off Alaska, the Council has primary responsibility for groundfish management in the Gulf of Alaska (GOA) and Bering Sea and Aleutian Islands (BSAI), including cod, pollock, flatfish, mackerel, sablefish, and rockfish species harvested mainly by trawlers, hook and line longliners and pot fishermen. In 2009 the NPFMC released its Fishery Management Plan for Fish Resources of the Arctic Management Area, covering all U.S. waters north of the Bering Strait. Management policy for this region is to prohibit all commercial harvest of fish until sufficient information is available to support the sustainable management of a commercial fishery (NPFMC 2009).

3.5.2.1 State of Alaska Regulations

Several State of Alaska regulatory programs contribute to the conservation for walruses and their habitats. For example, oil and gas lease permits in state managed waters contain specific requirements designed to protect Pacific walruses and their habitats. Walruses and their habitats are also protected in various State of Alaska special areas, e.g., Round Island (see Section 3.5.3.1), where regulations are in place to protect the haulout on Round Island located within the Walrus Islands State Game Sanctuary in Bristol Bay. Round Island is managed by the Alaska Department of Fish & Game (ADF&G), and access to the sanctuary is tightly controlled. Boat access within a three mile radius of the island is prohibited, although direct access to the island is authorized by permit and restricted to a designated travel corridor. Pilots are requested to avoid flights below 5000’above ground level (AGL). ADF&G staff is present on the island during the visitor season and visitors are prohibited from accessing the beaches.

3.5.3 Evaluation of Mechanisms to Limit Green House Gas Emissions

As noted in section 3. 2*,* global climate change is impacting the sea-ice habitats of the Pacific walrus. GHG emissions at or above current rates are expected to cause further warming and reductions in sea-ice habitats through the 21st century. The observed and projected loss of sea-ice habitats is expected to result in significant changes in walrus distributions and habitat use patterns in the foreseeable future, and these changes are expected to have negative consequences for the Pacific walrus population.

There are currently no legal mechanisms regulating GHGs in the U.S. In 2003, the EPA rejected a petition urging it to regulate GHG emissions from automobiles under the U.S. Clean Air Act (CAA). In 2007, the U.S. Supreme Court overturned the EPA's refusal to regulate these emissions and remanded the matter to the agency for further consideration. On April 17, 2009, the EPA issued a proposed finding that GHGs contribute to air pollution that may endanger public health and welfare. The proposed finding did not include any proposed regulations. Before taking any steps to reduce GHGs under the CAA, the EPA was required to conduct an appropriate process and consider public comment on the proposed finding. On December 7, 2009, the EPA announced that GHGs threaten the health and welfare of the American people, and that GHG emissions from vehicles contribute to that threat. The finding does not impose any emission reduction requirements but rather allows EPA to finalize the GHG standards proposed for new light-duty vehicles as part of the joint rulemaking with the Department of Transportation (EPA 2009).

The American Petroleum Institute cited the passage of a bill by the U.S. House of Representatives on June 26, 2009 that would dramatically limit the future emissions of GHGs as an example of an intervening action. However, the bill was never passed by the Senate and cannot be considered an existing regulatory mechanism, and mitigating factor in offsetting the likely consequences of future climate change.

3.5.4 Summary: Inadequacy of Existing Regulatory Mechanisms

Our analysis of existing regulatory mechanisms, indicate that there is a diverse network of international and domestic laws and regulations that provide conservation benefits and protections to the Pacific walrus population. In the United States, key protections to walruses and other marine mammals are provided by the MMPA, which prohibits the unauthorized take of marine mammals in US waters. Specific protections to walruses on terrestrial haulouts in the U.S. are provided through protected status for some areas, notably the haulouts on Togiak NWR, Round Island State Game Refuge, and specific prohibitions of harassment contained within the MMPA. Russian haulouts also have a variety of protections, with some haulouts occurring on protected lands and others protected by local conservation organizations. Walrus harvests in Russia are managed for sustainability. Harvest in the United States is well monitored and limited to subsistence activities by Alaska Natives with restrictions on use and sale; however, the U.S. harvest is not directly limited by quota. Emerging local harvest management efforts offer a promising approach to developing voluntary harvest limitations. Effectiveness of such measures can be evaluated with existing harvest monitoring and reporting programs.   While the Service is committed to working with the Alaska Native community to ensure that the subsistence harvest of Pacific walrus remains sustainable, the MMPA also provides a mechanism for the service to develop limits to the take of Pacific walrus, if we find that such limits are necessary and appropriate to ensure that taking, including subsistence harvest, will not be to the disadvantage of the Pacific walrus. Other human activities occurring within the range of the Pacific walrus including oil and gas explorations and commercial fishing, appear to have sufficient regulations in place to avoid, minimize and mitigate potential effects on walruses.

As noted in Section 3.2, the loss of summer sea-ice due to increasing temperatures related to greenhouse gas emissions is negatively affecting the Pacific walrus population. While the Clean Air Act of 1970 (42 U.S.C. 7401 *et seq.*), as amended, requires the EPA to develop and enforce regulations to protect the general public from exposure to airborne contaminants that are known to be hazardous to human health, the EPA does not have regulations in place to control the emissions of greenhouse gases. The EPA’s December 7, 2009 endangerment finding signals that regulations might be developed in the future; however, the effectiveness of any such regulation is uncertain. Therefore, there are no known existing regulatory mechanisms currently in place at the local, state, national, or international level that effectively address greenhouse gas emissions.

3.6 Other Natural or Human Factors Affecting the Species’ Continued Existence

3.6.1 Pollution and Contaminants

A 2006 assessment of contaminants in Pacific walruses summarized the available data, and concluded that existing data suggest Pacific walruses contain generally low contaminant levels, (Robards *et al.* 2009). However, at that time data were few or dated, and precluded any assumptions about current contaminant effects in Pacific walruses. Although more recent data exist, this new information still does not allow firm conclusions about contaminant concentrations, exposure, or effects in Pacific walruses.

Therefore, in addition to a data review, we addressed threats to the Pacific walrus population from contaminants by evaluating both potential exposure and effects; essentially, a risk assessment. Where inadequate data exist we looked to similar taxa for exposure and effects assessment. We evaluated exposure based on spatial and temporal trends of contaminants in the Arctic, and on walrus biology (e.g. diet, trophic status, and range). These contaminants included persistent organic pollutants (POPs), metals (especially mercury and cadmium), radionuclides, tributyltin (TBT; from ship anti-fouling paints), and petroleum products from resource extraction activities and spills. Each contaminant class has different sources, transport, and accumulation patterns; vary in temporal and spatial trends; and vary in concentrations in Arctic biota.

3.6.1.1 Exposure

Of particular concern in the Arctic are POPs, named because they don't break down in the environment and are toxic. Legacy POPs (no longer used in the United States) include polychlorinated biphenyls (PCBs) and organochlorine pesticides such as DDT, chlordanes, toxaphene, and mirex, as well as some with continued use, such as hexachlorocyclohexanes (HCHs). When use is stopped or curtailed, these pollutants generally decrease in the environment (AMAP 2009). For example, total PCBs decreased in Greenland polar bears from 1990 to 2000, and total HCHs decreased in Arctic seals since 1994 (Riget *et al.* 2004). Not all persistent organochlorines have been banned; some are still used as pesticides, including lindane (gamma-HCH) and endosulfan (AMAP 2009).

Emerging POPs include brominated flame retardants (BFRs) and fluorinated compounds. Most studies report increases of both classes in the Arctic, but recent data may indicate stabilization or declines (AMAP 2009), as many countries are phasing them out.

While there are numerous other POPs that have been detected in the Arctic environment, few have been found (or even assessed) in walruses. This may be because trophic status plays a large role in the exposure potential for these compounds. In general, POPs tend towards greater concentrations in high trophic levels (biomagnification). Walruses in general and Pacific walruses in particular, are lower on the food chain compared to other pinnipeds and other Arctic marine mammals (Norstrom and Muir 1994; Pauly *et al*. 1998; Hobson *et al.* 2002). They rarely consume fish and seals. Concentrations of POPs in Pacific walruses are relatively low (Seagars and Garlich-Miller 2001) and recent data show walruses had much lower levels of brominated compounds and perfluorinated sulfonates (PFSA) than other Arctic marine mammals (Letcher *et al.* 2010). Some walruses appear to make greater use of pelagic fish and ringed seals (*Phoca hispida*), and this trophic elevation can result in greater POP concentrations (Muir *et al.* 1995; Dietz *et al.* 2000).

Many POPs in marine mammals and other arctic biota are elevated in the eastern Canadian Arctic, Greenland, Svalbard, and northern Europe and Russia compared to Alaska including in walrus (Muir *et al.* 1995). Variation is caused by wind patterns, climate, ocean currents, and proximity to point sources. Heavy metals may be more directly related to point sources, but atmospheric and oceanic transport, underlying geology, and abiotic and biotic mobilization also contribute to spatial differences.

Heavy metals of concern in Arctic marine mammals include mercury, cadmium, and lead. Mercury behaves as a metal, (with underlying geology serving as point sources), and as an organic contaminant in the form of methyl mercury, which is persistent and concentrates up food chains. Defining mercury trends is complicated by mercury's complex environmental chemistry, although in general anthropogenic mercury is increasing in the arctic, as it is globally (AMAP 2004), primarily due to combustion processes. Conversion to the toxic form, methyl mercury, may also be greater in the marine water column than previously thought (Sunderland et al. *2009*), although demethylation also occurs in marine waters and marine mammals (Van-Oostdam *et al.* 2005).

Mercury concentrations in fossil and fresh walrus teeth collected at Nunavut in the Eastern Canadian Arctic were no higher in the 1980s and 1990s compared to 1200-1500, indicating an absence of industrial Hg in the species at this location, while increases were seen in beluga teeth from the Beaufort Sea over the same time span (Outridge *et al.* 2002). There was also no change in mercury in walruses from Greenland from 1973-2000 (Riget *et al.* 2007). Mercury concentrations increase with trophic level in marine mammals (Dietz *et al.* 2000), and Born *et al.* (1981) found low methyl mercury accumulation in Atlantic walruses compared to seals in Greenland and the eastern Canadian Arctic (Born *et al.* 1981).

Cadmium has been of concern in Pacific walruses because walrus are used as subsistence food, not because of effects on walrus health. Mollusks accumulate cadmium, so it is not surprising that walruses had relatively high levels, but Lipscomb (1995) found no histopathological effects in Pacific walrus liver and kidney tissues although liver concentrations were great enough to cause concern had those occurred in other species. Marine animals may possess detoxification mechanisms for metals, having evolved in the ion-rich ocean environment (Dietz *et al.* 1998). Thus, cadmium and mercury concentrations that may be toxic to freshwater or terrestrial organisms may not be so in marine ones.

Radionuclide sources include atmospheric fallout from Chernobyl, nuclear weapons testing, and nuclear waste dumps in Russia (Hamilton *et al.* 2008). Pacific walrus muscle had non-naturally occurring ^{137}Cs activity lower than sympatric bearded seal (*Erignathus barbatus*), and lower than seals from Greenland sampled one to two decades earlier (Hamilton *et al.* 2008). With decay of anthropogenic radionuclide fallout, improved regulation and cleanup of waste sources, and barring new major accidents or releases, radionuclide levels are expected to continue to decline in Arctic biota (AMAP 2009).

Spilled oil, fuel, and TBT are the major contaminants associated with shipping. TBT is ubiquitous in the marine environment (Takahashi *et al.* 1999; Strand and Asmund 2003); at greatest concentrations in harbors and near shore shipping channels (Takahashi *et al.* 1999; Strand and Asmund 2003). Indeed, sea otters (*Enhydra lutris*) from Alaska and Kamchatka had lower organotin concentrations than those from California (Murata *et al.* 2008). Oil spills are associated with major shipping channels, such as the reliably ice-free southern Bering Sea, which covers only a small portion of Pacific walrus range. Pacific walruses will likely see increased exposure to these two contaminant classes with increased shipping in their habitats as a result of longer ice-free seasons due to climate change.

3.6.1.2 Effects

Due to their trophic status and distribution, Pacific walruses would be expected to, and have demonstrated relatively low concentrations of contaminants of concern. However, even low concentrations of contaminants are not necessarily non-toxic. While there is no evidence of population-level effects in walruses from contaminants of any type, there are no studies on this subject. Therefore, we evaluated the potential effects of POPs in walruses by comparing concentrations to toxicity thresholds in other pinnipeds. We further evaluated exposure and effects to contaminants that do not typically biomagnify, especially those that are found in walrus prey species. For example, mollusks accumulate TBT to a much greater degree than other marine invertebrates and fish (Takahashi *et al.* 1999).

Pinnipeds have shown decreased reproduction from an experimental diet study using fish contaminated with a mixture of persistence chlorinated contaminants. Reproductive impairment, immunotoxicity, and hormone alterations occurred in adult harbor seals (*Phoca vitulina*) at total PCB concentrations of 17-25 parts per million (ppm, lipid basis), and reduced harbor seal neonate immune responses with an average total PCB concentration of 3.3 ug/g (lipid basis) (Shaw *et al.* 1999). Seals of the Baltic Sea demonstrated a disease complex associated with high PCB and DDT levels (Norstrom and Muir 1994). All these concentrations were greater, sometimes by orders of magnitude, than those that have been reported, in adult male Atlantic walruses (e.g., average 2 ug/g lipid basis total PCBs) (Wolkers *et al.* 2006). Further, walruses may be more efficient at metabolizing PCBs than ringed seal, based on PCB congener patterns in each species (Norstrom and Muir 1994). Regarding immune dysfunction, Calle *et al.* (2002) acknowledge, “Fortunately, the Pacific walrus population has low levels of PCB, DDT, dieldrin, chlordanes, and related compounds…Thus this population may be less susceptible to an epizootic than more highly contaminated pinniped populations.”

3.6.1.3 Effects of Climate Change

Climate change may alter all aspects of the preceding analysis, resulting in potentially greater exposure to, and effects of, environmental contaminants in Pacific walruses. These could include changes in walrus biology, and changes in distribution, such as expansion into contaminated areas of western Siberia (Metcalf and Robards 2008).

Climate related change will affect long-range and oceanic transport of contaminants, and may provide additional sources. Increasing water temperatures may increase methylation of mercury (Sunderland *et al.* 2009) and release contaminants from melting pack-ice (Metcalf and Robards 2008). ^{137}Cesium from nuclear weapons testing fallout and Chernobyl may be liberated from storage in trees with projected increasing forest fires (AMAP 2009). An increase in shipping through previously ice-bound waters will increase the potential for shipping-related contamination of walruses and their prey.

Although few data exist with which to evaluate the status of the Pacific walrus population in relation to contaminants, past data combined with knowledge of walrus ecology leads us to conclude that current threats to walruses from contaminants are not likely to affect walrus populations. Climate change, with projected increases in mobilization of contaminants to and within the Arctic, combined with potential changes in Pacific walrus prey base, may lead to increased exposure. However, projections regarding specific effects of contaminants on Pacific walruses in light of climate change are uncertain, given our lack of current data on contaminant exposure and effects.

3.6.2 Offshore Oil and Gas Exploration, Development, and Production

The Arctic may hold as much as a quarter of the world's undiscovered oil and gas reserves. These extensive reserves coupled with rising global demand make it very likely that oil and gas activity will increase in the Arctic in the future. Climate change is expected to reduce sea-ice extent, thickness, and seasonal duration, improving access to offshore oil and gas reserves around the margins of the Arctic Basin (AMAP 2007).

3.6.2.1 Past and Present Oil and Gas Activities

Oil and gas exploration, development and production activities have been conducted in the Beaufort and Chukchi since the late 1960s, with most activity occurring in the Beaufort Sea (USFWS 2008). Three offshore oil fields are currently in production in the Beaufort Sea, with drilling occurring from artificial islands in state waters. The *Endicott* oil field has been in production since October 1987; the *Northstar* field since October 2001; and the *Ooogurük* field since June 2008. Two additional offshore oil fields in the Beaufort Sea are currently under development: the *Liberty* field, with ultra extended-reach wells drilled from the existing Endicott facility; and the *Nikaitchuq* oil field, with plans for production from a gravel island near Spy Island.

The Outer Continental Shelf (OCS) region of the eastern (US) Chukchi Sea experienced a modest level of oil and gas exploration activity in the late 1980s and early 1990s. Five offshore exploratory wells were ultimately drilled; however no oil fields were subsequently developed.

There has been renewed interest in the exploration and development of oil and gas reserves from OCS regions of the eastern Chukchi Sea over the past few years. Three offshore oil and gas lease sales have occurred in the eastern Chukchi Sea since 1988, with the latest (Sale 193 in 2008) being the most successful OCS lease sale in Alaska's history (MMS 2008). Several offshore seismic surveys have been carried out in the eastern Chukchi Sea in recent years, and in December 2009, the Department of the Interior approved plans for drilling at five potential sites within three prospects known as Burger, Crackerjack, and Southwest Shoebill in the Chukchi Sea (Fig. 4). However, following events surrounding the explosion of the *Deepwater Horizon* drilling platform in the Gulf of Mexico in April 2010, plans for drilling at these sites were suspended until at least 2011, pending further review (USDOI 2010).

Although there are no existing oil and gas development or production activities in the Russian sector of Chukchi Sea, the region is thought to contain significant oil and gas reserves. In 2006, 3,700 km of seismic surveys were conducted in Russia's North and South Chukchi basins to explore for economically viable oil and gas reserves. Preliminary results were described as "very encouraging" (Frantzen 2007).

Pacific walruses do not normally range into the Beaufort Sea, although individuals and small groups have occasionally been reported. From 1994-2004, industry monitoring programs recorded a total of nine walrus sightings involving 10 animals; two of these sightings were of individual animals that hauled-out onto *Northstar* Island. Because of the small numbers of walruses encountered by past and present oil and gas activity in the Beaufort Sea, impacts to the Pacific walrus population appear to have been minimal (USFWS 2008). Oil and gas activities occurring in the Chukchi Sea are more likely to interact with Pacific walruses. However, in consideration of the limited scale and intermittent nature of previous exploration activities in this region, it is unlikely that significant impacts to the Pacific walrus population have occurred.

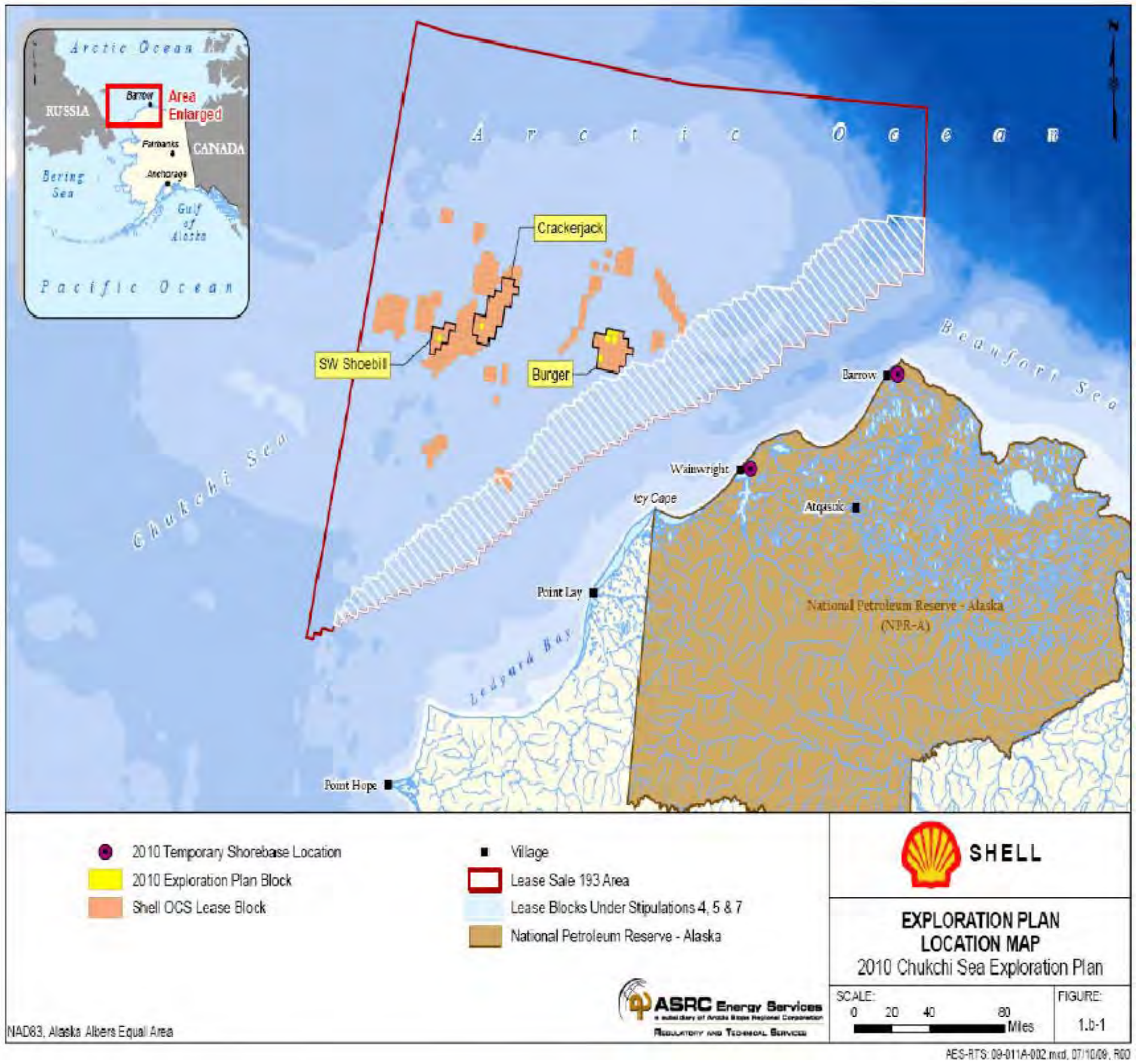


Figure 4. **Chukchi Sea sale 193 lease blocks in relation to the Alaska coastline, including locations of three prospects (Burger, Crackerjack, and Southwest Shoebill) identified as potential drill sites by Shell for their 2010 exploratory drilling program.**

3.6.2.2 Future Oil and Gas Activities

In the United States, OCS oil and gas lease sales are typically announced in 5-year “programs” that indicate the size, timing, and location of proposed leasing activity for each 5-year period. In 2007, The US Department of the Interior, Minerals Management Service (MMS) (now Bureau of Ocean Energy, Management, Regulation and Enforcement (BOEMRE) released the 2007-2012 OCS Oil and Gas Leasing Program, which included proposed lease sales in the Chukchi Sea in

2008, 2010, and 2012; in the Beaufort Sea in 2009 and 2011; and in the Bering Sea (North Aleutian Basin) in 2011 (MMS 2007b). In February, 2008, MMS conducted Chukchi Sea Lease Sale 193, receiving bids on 488 offshore blocks representing 2.7 million acres (Sale day statistics: http://alaska.boemre.gov/cproject/Chukchi193/193Saleday/Sale193SaleDayStats.htm). Two lawsuits were filed challenging the Leasing Program, and in April 2009, the U.S. Court of Appeals for the District of Columbia vacated and remanded the program and directed MMS to conduct a more thorough environmental review of proposed leasing activity. In 2010, MMS released a revised 2007-2012 leasing schedule which did not include any further lease sales in the Alaska OCS (MMS 2010a). MMS (now BOEMRE) has initiated the development of the next 5 year (2012-2017) OCS Oil and Gas Leasing Program, which includes proposed lease sales in the Beaufort and Chukchi Seas, but not the Bering Sea (MMS 2010b). On April 20, 2010, an explosion of the *Deepwater Horizon* drilling platform in the Gulf of Mexico resulted in a catastrophic oil blowout that released an estimated 4.9 million barrels of oil (Deepwater Horizon Response 2010). The accident in the Gulf of Mexico will likely impact future oil and gas activities in OCS regions of the United States, including proposed activities in Alaska.

3.6.2.3 Effects of Future Oil and Gas Activities

Future offshore oil and gas exploration, development and production activities may include: geophysical seismic surveys; the drilling of exploratory, delineation, and production wells; construction of artificial-islands and pipelines; and vessel and aircraft support operations. These activities have the potential to impact Pacific walruses, primarily through noise and physical disturbances; and through oil spills.

3.6.2.3.1 Noise and Physical Disturbances

Noise and physical disturbances associated with oil and gas exploration and development activities could potentially interfere with the ability of walruses to function normally in their environment with potential consequences to their health. Potential effects of prolonged or repeated disturbances include displacement of animals from preferred feeding areas, increased stress levels, increased energy expenditure, masking of communication, and the impairment of thermoregulation of neonates that are forced to spend too much time in the water (USFWS 2008: Chukchi Sea ITR EA: http://alaska.fws.gov/fisheries/mmm/itr.htm).

Offshore oil and gas exploration and development activities typically involve the use of numerous ships, airplanes and helicopters. Disturbances caused by vessel and air traffic can cause walrus groups to abandon ice haulouts. Severe disturbance events could result in trampling injuries or cow-calf separations, both of which are potentially fatal. The potential for disturbance events to result in animal injuries, mortalities or mother-calf separations tend to increase with the size of affected walrus aggregations. Reactions of walruses to aircraft are thought to vary with aircraft type, range, and flight pattern, as well as the age, sex, and group size of exposed individuals. Helicopters are more likely to elicit responses than fixed-wing aircraft, and walruses are particularly sensitive to changes in engine noise and are more likely to stampede when aircraft turn or bank overhead. Researchers conducting aerial surveys for walruses in sea-ice habitats have reported little reaction to small fixed-winged aircraft above 305 m (1,000'). (USFWS, Chukchi Sea ITR EA: http://alaska.fws.gov/fisheries/mmm/itr.htm). Conversely, it has been reported that walruses have stampeded from Round Island in the Walrus Islands State Game Sanctuary as a result of airliners flying overhead at approximately 30,000' (Okonek 2009, *pers. comm.*).

The reaction of walruses to vessel traffic appears to be dependent upon vessel type, distance, speed, and previous exposure to disturbances. Underwater noise from vessel traffic could "mask" ordinary communication between individuals. Ice management operations are expected to have the greatest potential for disturbances since these operations typically require the vessel to accelerate, reverse direction, and turn rapidly thereby maximizing propeller cavitations and resulting noise levels. Previous monitoring efforts suggest that icebreaking activities can displace some walrus groups up to several kilometers away; however most groups of hauled out walruses showed little reaction beyond 800 m (0.5 mi) (Brueggeman *et al.* 1990). Environmental variables such as wind speed and direction are also thought to contribute to variability in detection and response (USFWS, Chukchi Sea ITR EA: http://alaska.fws.gov/fisheries/mmm/itr.htm).

Seismic surveys are a particularly intense source of noise, and thus warrant further consideration as a potential threat to walruses. Pinnipeds use the acoustic properties of sea water to aid in navigation, social communication, and possibly predator avoidance. Increased noise levels in the aquatic environment associated with seismic surveys have the potential to interfere with communications, mask important natural sounds, cause physiological damage, or cause avoidance behavior that keeps animals from biologically important areas.

Seismic surveys produce underwater sounds, typically with air gun arrays. While seismic surveys can contain energy up to 1 kHz, most of the emitted energy is less than 200 Hz. Walruses produce a variety of sounds (grunts, rasps, clicks), which range in frequency from 0.1-10 Hz (Richardson *et al*. 1995). During the winter breeding season, male walruses rely on underwater vocalizations during the breeding period to defend territories and attract mates. However, seismic surveys in the Beaufort and Chukchi Seas are mostly carried out during the summer open water season and are unlikely to have impacts on breeding activity since walruses are not known to breed in those areas. However, low frequency sounds generated from seismic surveys could potentially mask other biologically important sounds. Brief, small-scale masking episodes might, in themselves, have few long-term consequences for individuals or groups of walruses. The consequences might be more serious however, in areas where many acoustic surveys are occurring simultaneously (USFWS 2008: Chukchi Sea ITR EA: http://alaska.fws.gov/fisheries/mmm/itr.htm).

Exposure to pulses of air gun sound could also potentially cause permanent threshold shifts (PTS) to the hearing of any walrus that entered the zone immediately surrounding the sound source. Southall *et al.* (2007) suggest that auditory injury to pinnipeds in the water may occur at a sound level of 218 db re: 1 micropascal. Although it is unlikely that air gun operations during most seismic surveys would cause a PTS in walruses, caution is warranted given the limited knowledge about noise-induced hearing damage in this species. With appropriate protective measures in place (e.g., ramp up procedures to allow marine mammals the opportunity to disperse from the sound source; marine mammal observers on board seismic vessels; and shutdown procedures in the event a marine mammal approaches an air gun array) the probability of seismic-survey-generated injuries to walruses may be mitigated, although detecting walruses in the water from a distance is often difficult, particularly at night.

The responses of walruses to seismic surveys are poorly known. In 2006, marine mammal observers onboard seismic and support vessels operating in the Chukchi Sea recorded a total of 1,186 walrus sightings. Three hundred and eighteen of the walruses sighted (27 %) exhibited some form of behavioral response to the vessels, primarily dispersal or diving. Marine mammal observers reported 19 incidents in which walruses were observed within a predetermined safety zone of ensonification, requiring the shut-down of air gun arrays to prevent potential injuries. Based upon the transitory nature of the survey vessels, and the monitoring reports that noted the behavioral reactions of the animals to the passage of the vessels, our best assessment is that these interactions resulted in no more than temporary changes in animal behavior(USFWS 2008: Chukchi Sea ITR EA: http://alaska.fws.gov/fisheries/mmm/itr.htm).

Most seismic surveys are expected to occur in areas of open water, where walrus densities are expected to be relatively low, and in U.S. waters monitoring requirements and mitigation measures are expected to minimize interactions with large aggregations of walruses. Because seismic operations likely would not be concentrated in any one area for extended periods, any impacts to walruses should be relatively short in duration and should have a negligible overall impact on the Pacific walrus population (USFWS 2008: Chukchi Sea ITR EA: http://alaska.fws.gov/fisheries/mmm/itr.htm).

In June 2008, in response to a petition from members of the oil and gas industry, the Department of Interior issued regulations authorizing the nonlethal, incidental, unintentional take of small numbers of Pacific walruses (and polar bears) during oil and gas exploration activities in the Chukchi Sea (USFWS 2008). Prior to issuing the regulations, the Service (we) analyzed potential impacts of the proposed activities (including geophysical seismic surveys, exploratory drilling, and associated support activities) on the Pacific walrus population. Our analysis considered the scale, timing and location of proposed activities; existing and proposed operating conditions and mitigation measures; information on the biology, ecology, and habitat use patterns of walruses in the Chukchi Sea; available information on potential effects of oil and gas activities on walruses; and the results of previous monitoring efforts in the Beaufort and Chukchi Seas. The analysis concluded that most of the anticipated takes would be limited to temporary, nonlethal disturbances (behavioral changes) impacting a relatively small numbers of animals. Based on our analysis of these factors, no population level effects were anticipated from the proposed activities (USFWS 2008; Chukchi Sea ITR EA available at http://alaska.fws.gov/fisheries/mmm/itr.htm).

The Chukchi Sea Incidental Take Regulations (ITRs) specify operating restrictions and monitoring requirements intended to mitigate potential impacts of noise and physical disturbances to Pacific walruses, and the availability of walruses for subsistence purposes. The ITRs have a life span of 5 years, expiring in June 2013. We expect that through the foreseeable future, all proposed oil and gas activities occurring in the eastern Chukchi Sea will be similarly evaluated under the MMPA, and appropriately regulated to ensure that effects on the Pacific walrus population remain negligible (the standard required for MMPA authorization). It is noted Geological and Geophysical (G&G) permits issued by BOEMRE authorizing oil and gas activities are contingent upon supporting documentation of appropriate MMPA authorization and/or an exemption letter from the appropriate regulating agency (NMFS and/or USFWS) and are not valid without these documents. If an operator begins operations without appropriate MMPA authorization, BOEMRE will shut down operations and the operator can be responsible for criminal or civil penalties (Rance Wall, BOEMRE, 2011. *pers. comm.*)

3.6.2.3.3 Oil Spills

The threat posed to walruses by oil spills increases as offshore oil and gas development and shipping activities increase across their range. Cameron *et al*. (2011) note that large spills at sea are difficult to contain and may spread over hundreds or thousands of kilometers, and that the threats posed by a oil spill in the Arctic are magnified by the limited resources available in the region for effective response. Oil spill clean-up in the broken ice conditions that characterize walrus habitat is likely to be problematic, and response efforts may be delayed by the logistical challenges associated with operating in remote ice-covered waters. The MMS has noted that there are difficulties in effective oil spill response in broken ice conditions (Minerals Management Service 2007)MMS 2007a):

> *"The MMS advocates the use of nonmechanical methods of spill response, such as in situ burning, during periods when broken ice would hamper an effective mechanical response.*

> *In situ burning has the potential to rapidly remove large quantities of oil and can be employed when broken-ice conditions may preclude mechanical response. However, there is a limited window of opportunity (or time period of effectiveness) to conduct successful burn operations. The type of oil, prevailing meteorological and oceanographic conditions, and the time it takes for the oil to emulsify define that window. Once spilled, oil begins to form emulsions. When water content exceeds 25% most slicks are unignitable".*

Walrus behavior will affect their exposure to an oil spill. Although walrus densities are expected to be relatively low near offshore drilling sites, if an oil spill is not rapidly contained near its source, the oil will likely disperse over a broad area and could come into contact with large numbers of animals at coastal haulouts. Low temperatures in the Arctic environment are likely to inhibit the weathering and dispersal of oil prolonging the period of exposure (Engelhardt 1987).

Direct exposure to oil could impact walruses in a number of ways. Freshly spilled oil contains high levels of toxic volatile compounds that, if inhaled, could cause death, as seen in harbor seals following the Exxon Valdez oil spill in Prince William Sound, Alaska (Frost *et al.* 1994a,b; Lowry *et al.* 1994; Spraker *et al.* 1994). Corneal ulcers and abrasions, conjunctivitis, and swollen nictitating membranes have been observed in captive ringed seals placed in oil-covered water (Geraci and Smith 1976), harbor seals following the Exxon Valdez oil spill, and seals in the Antarctic after an oil spill (St. Aubin 1988). After seals were experimentally dosed with crude oil, increased gastrointestinal motility and vocalization and decreased sleep were observed (Geraci and Smith 1976; Engelhardt 1985; Engelhardt 1987). Many pinnipeds including walruses depend on scent to establish a mother-pup bond, and sea lion mothers have been observed to not recognize their oil-coated pups, though oiled grey seal pups appeared to nurse normally (St. Aubin 1990). Oil that disperses from a spill site may still have high levels of toxic volatile compounds. Pinnipeds stressed by parasitism or other metabolic disorders may be susceptible to injury or death from even brief exposure to relatively low concentrations of hydrocarbon vapors (St. Aubin 1990). For example, parasitized lungs, relatively common in pinnipeds, can exacerbate the effects of even mild irritation of respiratory tissues (St. Aubin 1990). Furthermore, oral ingestion of hydrocarbons irritates and destroys epithelial cells in the stomach and intestine, affecting motility, digestion, and absorption, which can result in death or reproductive failure (St. Aubin 1990). Contact with spilled oil is unlikely to affect walrus thermoregulation to the extent that it would for fur seals, sea otters, or polar bears, which depend upon air trapped in the pelage for insulation (St. Aubin 1990), because walruses rely primarily on a layer of blubber under the integument for insulation.

Oil spills could also have long lasting effects on walrus prey species. Spilled oil can cause major disruptions to benthic communities and recovery can take many years, particularly in colder regions (Elmgren *et al.* 1983). For example, as a result of the Exxon Valdez oil spill, oil persisted in toxic forms for more than a decade, resulting in long-term impacts to species closely associated with shallow sediments (Peterson *et al.* 2003). Benthic invertebrates also tend to bioaccumulate oil compounds (Varanasi and Malins 1977, Engelhardt 1987). Because walruses are long-lived animals and somewhat subject to the trophic magnification of contaminants, the effects from contaminants from a large oil spill are likely to persist for decades.

There are no active offshore oil and gas development or production activities occurring in the Bering or Chukchi Seas, therefore, the current risk to Pacific walruses from an oil spill is presently low. The threat posed to walruses by oil spills is expected to increase in the future as offshore oil and gas development increase across their range. Although careful planning, sound regulatory and management actions, and use of best industry practices can help reduce the risks and impacts of future oil spills, the history of oil and gas activities, including the recent oil release in the Gulf of Mexico suggest that potential for accidents to occur cannot be completely eliminated. According to the MMS, if the recent 193 Chukchi Lease Sale does result in an oil and gas development, the chance of one or more large oil spills (greater than or equal to 1,000 barrels) occurring over the production life of the development is between 35-40% (MMS 2007a). However, the estimated probability that oil reserves sufficient for development being discovered is quite low; ranging from 1-10 percent, reducing the chance of a future large oil spill to 0.3-4 percent (MMS 2007a). We are unaware of any information upon which to draw to evaluate the timeframe, scale or location of future oil and gas development and production activities in the western (Russian) Chukchi Sea, or to evaluate potential impacts of these activities on the Pacific walrus population. We assume that the likelihood of oil and gas development or production activities (and associated impacts) occurring in Russian waters are similar to those in the US.

Our analysis of oil and gas development potential and subsequent risks associated with oil spills were based on the analysis of the MMS (MMS 2007a) conducted for the Chukchi Sea lease sales. Due to the *Deepwater Horizon* spill in the Gulf of Mexico, offshore oil and gas activities are under increased scrutiny. Policy and management changes are underway within the Department of Interior that will likely affect the timing and scope of future offshore oil and gas activities. As a result, we anticipate that the potential for a significant oil spill will remain small. Although the probability of an oil spill affecting a significant portion of the Pacific walrus population in the foreseeable future is low, we recognize that the potential impacts from such a spill could be significant, particularly if subsequent clean-up efforts were ineffective.

3.6.3 Commercial Fisheries Interactions

Commercial fisheries may impact Pacific walruses through direct interactions such as incidental take and bycatch, or indirectly through competition for prey resources and/or destruction of benthic prey habitat. A complete list of fisheries is published annually by NOAA-Fisheries, the most recent on November 16, 2009 (NOAA 2009a). Pacific walruses occasionally interact with trawl and longline gear of groundfish fisheries. No data are available on incidental catch of walruses in fisheries operating in Russian waters, although trawl and longline fisheries are known to operate there. In Alaska each year, fishery observers monitor a percentage of commercial fisheries and report injury and mortality of marine mammal's incidental to these operations. There are 13 NOAA managed fisheries that operate in Alaska within the range of the Pacific walrus in the Bering Sea. Incidental mortality during 2002-2006 was recorded only for one fishery, the Bering Sea/Aleutian Island flatfish trawl fishery (Table 2), which is a Category II Commercial Fishery with 34 vessels and/or persons. No incidental injury to walruses was recorded during this time period. During the years 2002-2006 observer coverage for this fishery averaged 64.7%. In September 2007, passage of Amendment 80 to the Bering Sea Aleutian Island Fisheries management Plan mandated 100% observer coverage for the flat fish trawl fishery. The mean number of observed mortalities from 2002-2006 was 1.8 walruses/year, ranging from 0-3 (Table 2). The total estimated annual fishery-related incidental mortality in Alaska was 2.66 walruses per year (USFWS 2010). We do not consider fishery related mortality to be a significant threat to the Pacific walrus population.

Any fishery operating within the range of the Pacific walrus has the potential to cause take. Fisheries occurring near terrestrial haulouts perhaps have the greatest potential for causing disturbance and/or blocking animals from reaching or leaving the haulouts, such as the Yellow fin sole fishery within the Northern Bristol Bay Trawl Area (NBBTA). Although the haulouts occurring within the Round Island State Game Sanctuary are buffered from the trawl activities within the NBBTA, the haulout at Hagemeister Island has no protection zone. Large catcher/processer vessels associated with the yellowfin sole fishery, as well as smaller fishing vessels 32 ft or less in length routinely pass between the haulout and the mainland to a site for offloading product to foreign vessels. Anecdotal reports indicate potential disturbance of walruses using the Hagemeister haulout from seafood product transfer occurring at the NOAA permitted roadstead site (Wilson and Evans 2009a) however, no specific measures have been implemented. To address concerns of disturbance The North Pacific Fisheries Management Council is currently working with the Service to examine alternatives to provide increased protection for the haulout at Hagemeister Island (Wilson and Evans 2009a). State-managed near-shore herring and salmon gillnet fisheries also have the potential to take walruses. The Alaska Department of Fish and Game does not have an observer or self reporting program to record marine mammal interactions. However, it is believed that gear interactions with walruses have not occurred in the recent past (Murphy 2010, *pers. comm.*; Sands 2010, *pers. comm.*). Spotter planes used in the spring herring fishery in Bristol Bay have the potential to cause disturbance at terrestrial haulouts. To mitigate this potential, the Service has developed and distributed guidelines for appropriate use of aircraft within the vicinity of Bristol Bay Walrus haulouts (Wilson and Evans 2009a).

Table 2. **Summary of incidental mortality of Pacific walruses due to commercial fisheries from 2002-2006 and estimated mean annual mortality. Data is from the Bering Sea/Aleutian Islands flatfish trawl fishery. Data provided by the National Marine Fisheries Service. NE = no estimate made because no take was recorded.**

Year	Observer coverage (%)	Observed mortality	Estimated mortality (95% conf. interval)
2002	58.4	2	3.3(1.4-7.5)
2003	64.1	0	NE
2004	64.3	2	3.1(1.4-6.8)
2005	68.3	3	4.1(2.3-7.3)
2006	67.8	2	2.8(1.4-5.9)
Annual mean	64.7	1.8	2.7(1.8-3.9)

Pacific walruses rarely prey on commercial fish species (Fay 1982). Fay (1982) notes that the scarcity of endoparasites of known piscine origin in walruses indicates that fish are rarely ingested. Fay (1982) also notes that various authors have reported occasionally finding several different crab species in walrus stomachs, but apparently at low frequency. In the early 1980's a commercial surf clam fishery was proposed for Bristol Bay. For various reasons including direct competition with walruses, this proposed fishery never received approval from the North Pacific Fishery Management Council. Assuming that commercial harvesting of clams in the Bering Sea remains prohibited, direct competition from commercial fisheries does not appear to be a threat to the Pacific walrus population.

There are several longline and pot fisheries occurring within the range of the Pacific walrus, including crab, sablefish, rockfish and halibut. There has been no documented bycatch of walruses in these fisheries in recent years, and due to the gear types used in these fisheries, the disturbance footprint on the benthos is relatively small.

Pelagic (mid-water trawl) fisheries have the potential to indirectly affect walruses through destruction or modification of benthic prey and their habitat. Pelagic or mid-water trawls can make frequent contact with the bottom, as evidenced by the presence of benthic species (crabs, halibut) which are brought up as bycatch. It is thought that approximately 44% of the area shadowed by the gear receives bottom contact from the footrope (NMFS 2005). Due to the design of the gear most infauna or epifauna which is dislodged or displaced and goes over the footrope does not stay in the net so is not observed and recorded as by catch (Rose 2010, *pers. comm.*). The majority of the pelagic trawl effort in the eastern Bering Sea is directed at walleye pollack in water of 50-300 meters (Olsen 2009). The area north of Unimak Island along the continental shelf edge receives high fishing effort (Olsen 2009). This may put the majority of fishing effort on the periphery of walruses preferred habitat as walruses are usually found over the continental shelf in waters of 100 m or less (Fay and Burns 1988; Jay *et al.* 2001). Fig. 5 shows the locations and frequency of pelagic trawls in the Bearing Sea over an eleven year period.

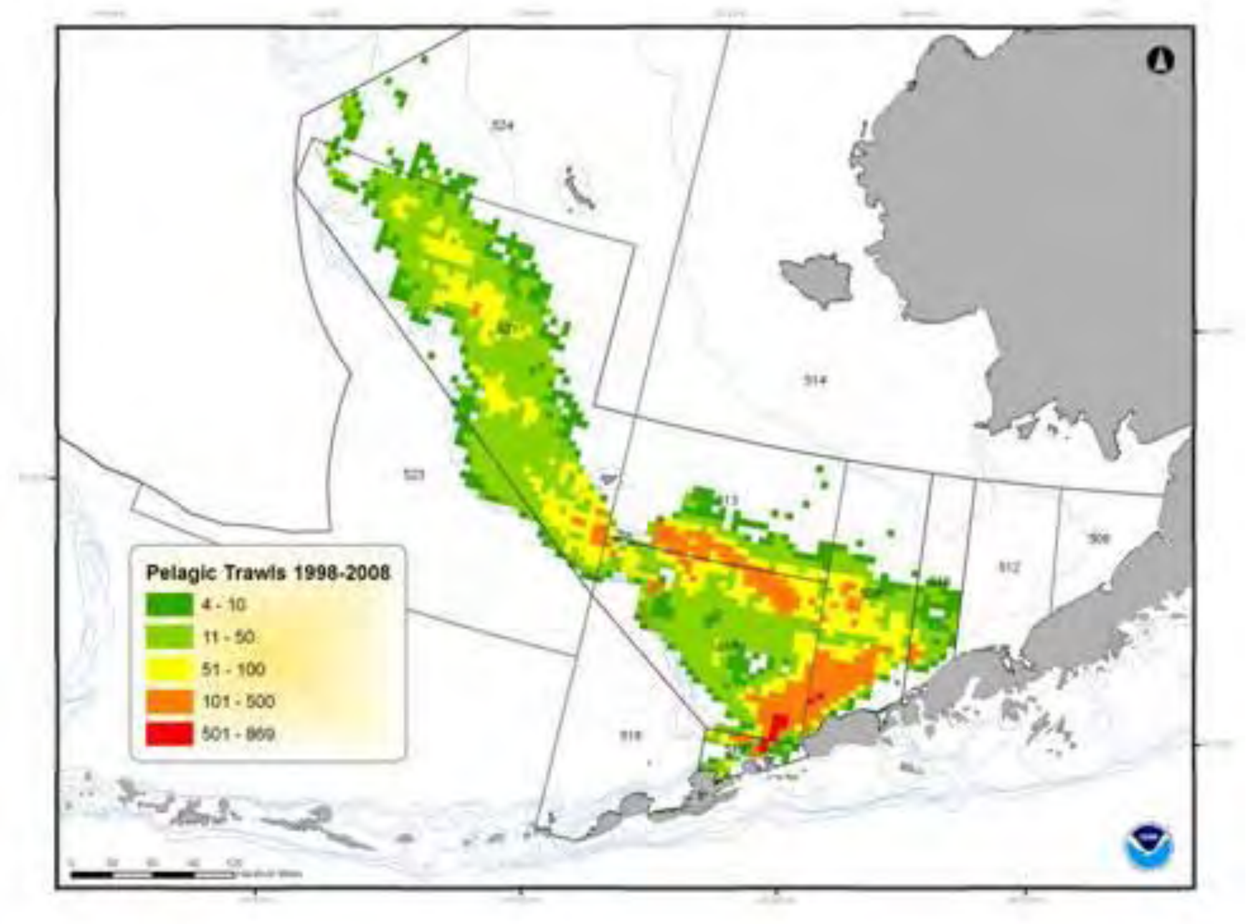


Figure 5. **The location and intensity of pelagic trawl fisheries in southwest Alaska waters from 1998-2008. Colors indicate the number of trawl tows in various areas. Map courtesy of NOAA Alaska Fisheries Science center.**

Non-pelagic (bottom trawl) fisheries also have the potential to indirectly effect walruses through destruction or modification of benthic prey and their habitat. The predominant direct effects of non-pelagic trawl include “smoothing of sediments, moving and turning of rocks and boulders, resuspension and mixing of sediments, removal of sea grasses, damage to corals, and damage or removal of epibenthic organisms” (Mecum 2009). Numerous studies on the effects of trawl gear on infauna have been conducted by various authors (Brylinsky *et al.* 1994; Gilkinson *et al.* 1998; Bergman and Van-Santbrink 2000; Kenchington *et al.* 2001). Two such studies comparing microfaunal population between unfished and heavily fished areas in the eastern Bering Sea, reported that overall, the heavily-trawled and untrawled areas were significantly different. In relation to walrus prey, the abundance of neptunid snails was significantly lower in the heavily trawled area and mean body size was smaller, as was the trend for a number of bivalves (*Macoma*, *Serripes*, *Tellina*) indicating a general decline in these species. The abundance of *Mactromeris* was greater in the heavily trawled area but mean body size was smaller (McConnaughey *et al.* 2000; McConnaughey *et al.* 2005).

In Appendix B of the Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska, conducted by the National Marine Fisheries Service (NMFS), Alaska Regional Office, results of these various bottom trawl studies were analyzed in the context of effects on fish habitat in the southern Bearing Sea (NMFS 2005). This analysis concluded that non-pelagic trawling has long term effects on benthic habitat features, but these effects have little impact on fish stock productivity. The analysis also concluded that the reduction of infaunal and epifanual prey for managed fish species would be 0-3% (Mecum 2009). Since this analysis was done in the context of fish habitat, it is unclear how these long term effects may impact Pacific walruses or their prey.

Non-pelagic trawls are designed to remain on the bottom. The footrope has many variably spaced large diameter (5-10 cm) bobbins or disks which ride on the sea floor. These bobbins compress the bottom sediments somewhat but keep the footrope up off the sea floor and prevent it from gouging the bottom. The bobbins may create a vortex which can carry epifauna up over the footrope into the net (Rose 2010, *pers. comm.*). It appears that these bottom trawls bring up very little in the way of walrus prey items as by catch. Wilson and Evans (2009) report by catch of walrus prey items in the non-pelagic trawl fishery in the NBBTA. Data was collected through the NMFS Fisheries Observer program and is aggregated for the years 2001 to 2009.

Bivalves (mussels, oysters, scallops, and clams) accounted for 334 kg of the 457 kg (73%) of total bycatch reported. It should be noted that snails which are consumed by walruses (see Section 2.4 Foraging and Prey Species) were listed as a bycatch species, but the amount is listed as confidential under NOAA Fisheries confidentiality guidelines. Net mesh size is large enough to allow mollusks and other infauna to escape, but it is believed that bycatch of these species is extremely low because the footrope and bobbins dislodge few of them from the bottom sediments (Rose 2010, *pers. comm.*). Standard non-pelagic trawl gear also makes bottom contact with the sweeps, i.e., cables which connect the net footrope to the doors. The doors are large metal plates which generally contact the bottom and help to keep the footrope bobbins in contact with the sea floor. It has been reported that the flatfish fleet has begun widespread use of off-bottom doors in 2010 (Rose 2010, *pers. comm.*). It has been recommended that starting in 2011, non-pelagic gear be required to be modified in such a way as to install bobbins on the sweeps. These bobbins have been shown to elevate the sweeps 2 - 3” off the ocean floor. It has been shown that these modified sweeps reduce damage and mortality of sessile seafloor animals (crabs, basket stars & sea whips) on unconsolidated (sand & mud) substrates (Mecum 2009). Since the sweeps are elevated off the sea floor, this reduces the amount of gear contact by 90% (Mecum 2009), and therefore should reduce effects on infauna. Fig. 6 shows the location and relative effort of non-pelagic trawls in Alaskan waters in 2008.

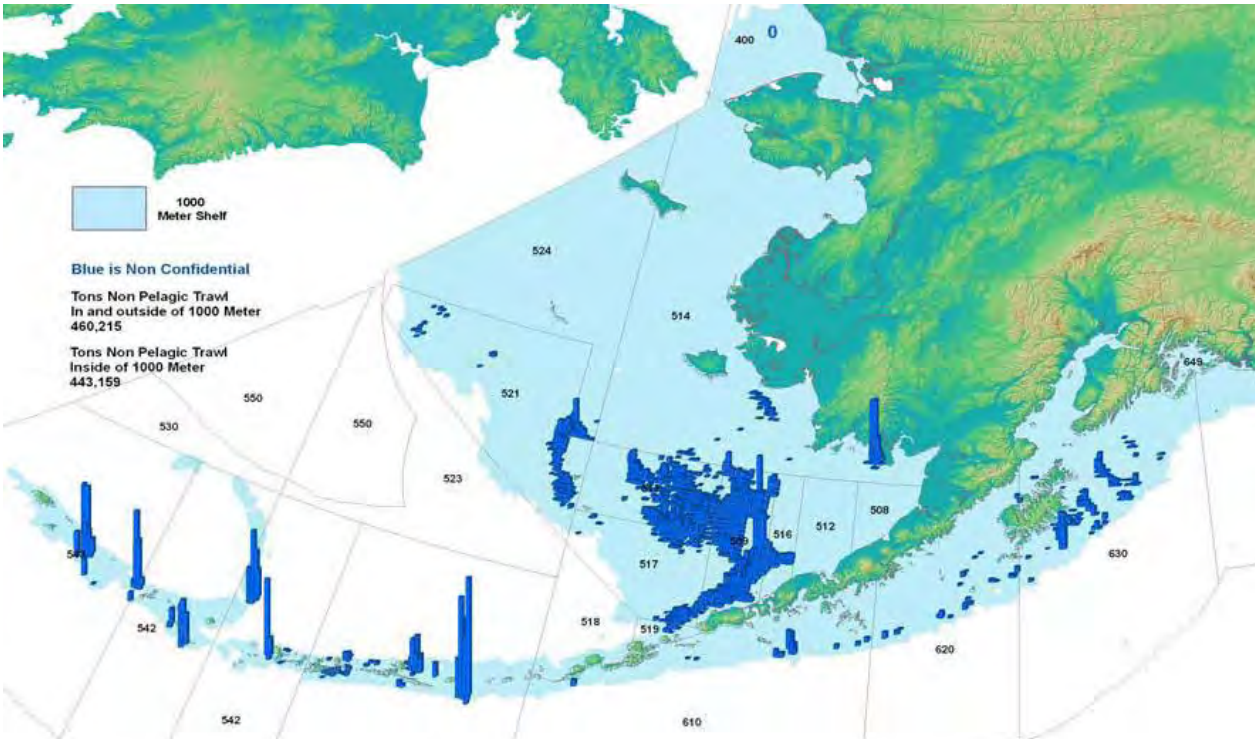


***Figure 6*. Locations and relative effort of non-pelagic trawls in Alaskan waters in 2008. Waters in shaded area are less than 1,000 m. Map courtesy of NOAA Alaska Fisheries Science Center**.

In October, 2009 the North Pacific Fishery Management Council recommended Amendment 94 to the Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands Management Area. NMFS is currently developing the rulemaking package for Secretarial review. Implementation is scheduled after January 1, 2011. Among other changes to the FMP, this amendment would require the use of modified non-pelagic trawl gear in the Bering Sea subarea for the flatfish fishery and for non-pelagic trawl gear fishing in the Modified Trawl Gear Zone, located in the northern Bering Sea subarea (Brown 2010, *pers. comm.*). When implemented, Amendment 94 to the Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands Management Area will open an area within the Northern Bering Sea research Area to modified gear non-pelagic trawl fishing (Mecum 2009). This area (Fig. 7) was previously open to non-pelagic trawling prior to 2008 and establishment of the Northern Bering Sea Research Area (Brown 2010, *pers. comm.*).

There is considerable public opposition to non-pelagic trawl fishing in the Bering Sea especially within the NBBTA. Various individuals and Alaska Native organizations including the Qayassiq Walrus Commission have expressed opposition and requested that the NPFMC close the NBBTA to all commercial fishing. Many of these concerns have centered around potential indirect impacts to walruses (Wilson and Evans 2009a).

Ecosystem shifts in the Bering Sea are expected to extend the distribution of fish populations northward, and along with this shift, non-pelagic bottom trawl fisheries are also expected to move northward (NOAA 2009b). The current lack of information on benthic habitats and community ecology of the northern Bering Sea precludes the possibility of assessing the impacts of nonpelagic bottom trawling within the Northern Bering Sea (NOAA 2009b) or how it may affect the Pacific walrus. In June 2007 the North Pacific Fishery Management Council approved the creation of the Northern Bearing Sea Research Area (NBSRA) and directed NOAA's Alaska Fisheries Science center to develop a research plan to study the effect of bottom trawling on benthic species and their habitat in the northern Bering Sea. The NBSRA area encompasses U.S. waters north of Nunivak and St. Matthew Islands up to the Bering Strait (Fig. 8). The NBSRA is currently closed to bottom trawl fishing (NPFMC 2009).

In summary, commercial fisheries currently do not occur in the Chukchi Sea and are not considered a serious stressor to walrus in the Bering Sea. However, fishermen are interested in following stocks north as fish distribution changes in association with predicted changes in ocean conditions. Even then, it appears that those activities would be adequately researched and well regulated.

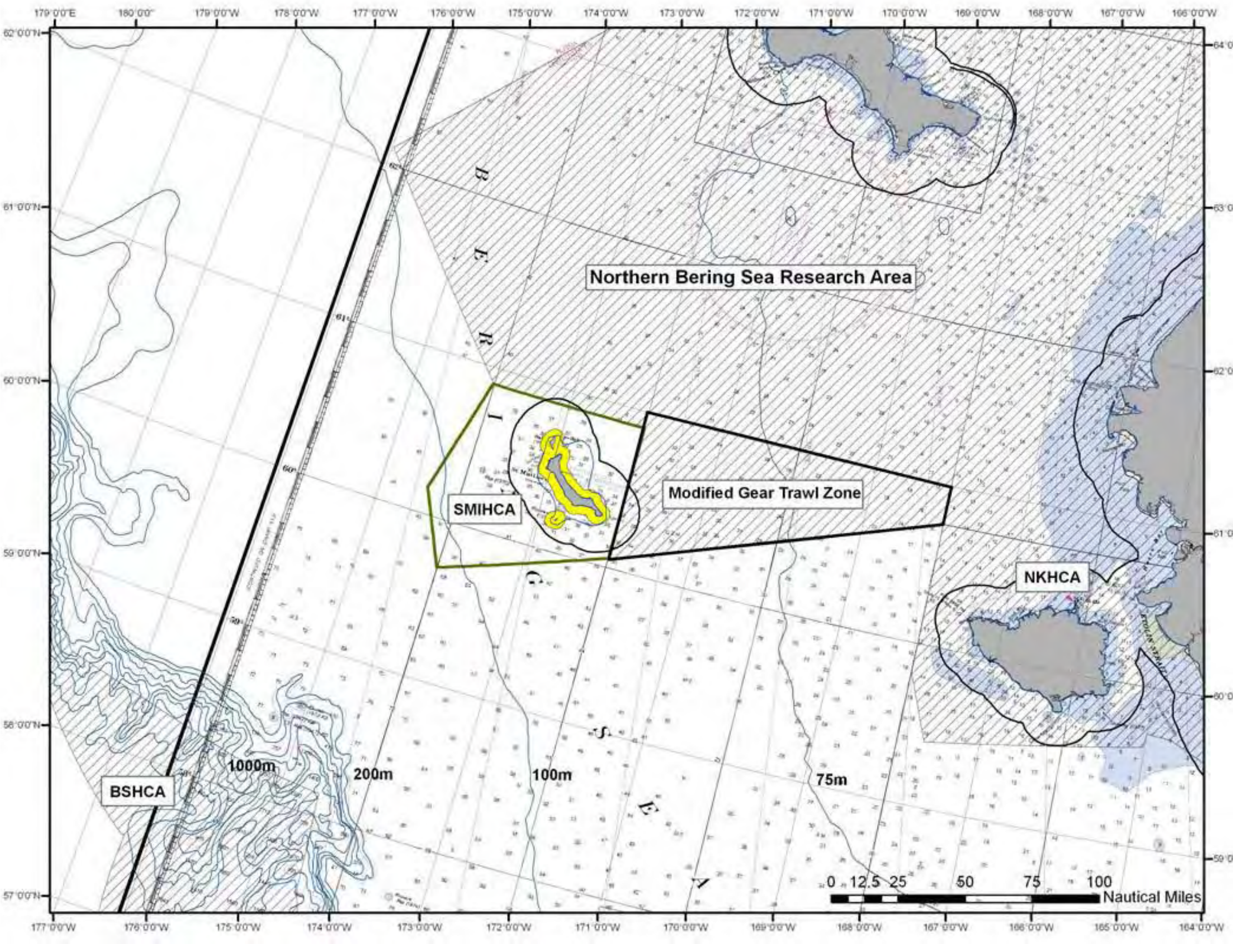


Figure 7. **Maximum geographic extent of the Modified Gear Trawl Zone of the Bearing Sea. Map courtesy of NOAA Alaska Fisheries Science Center.**

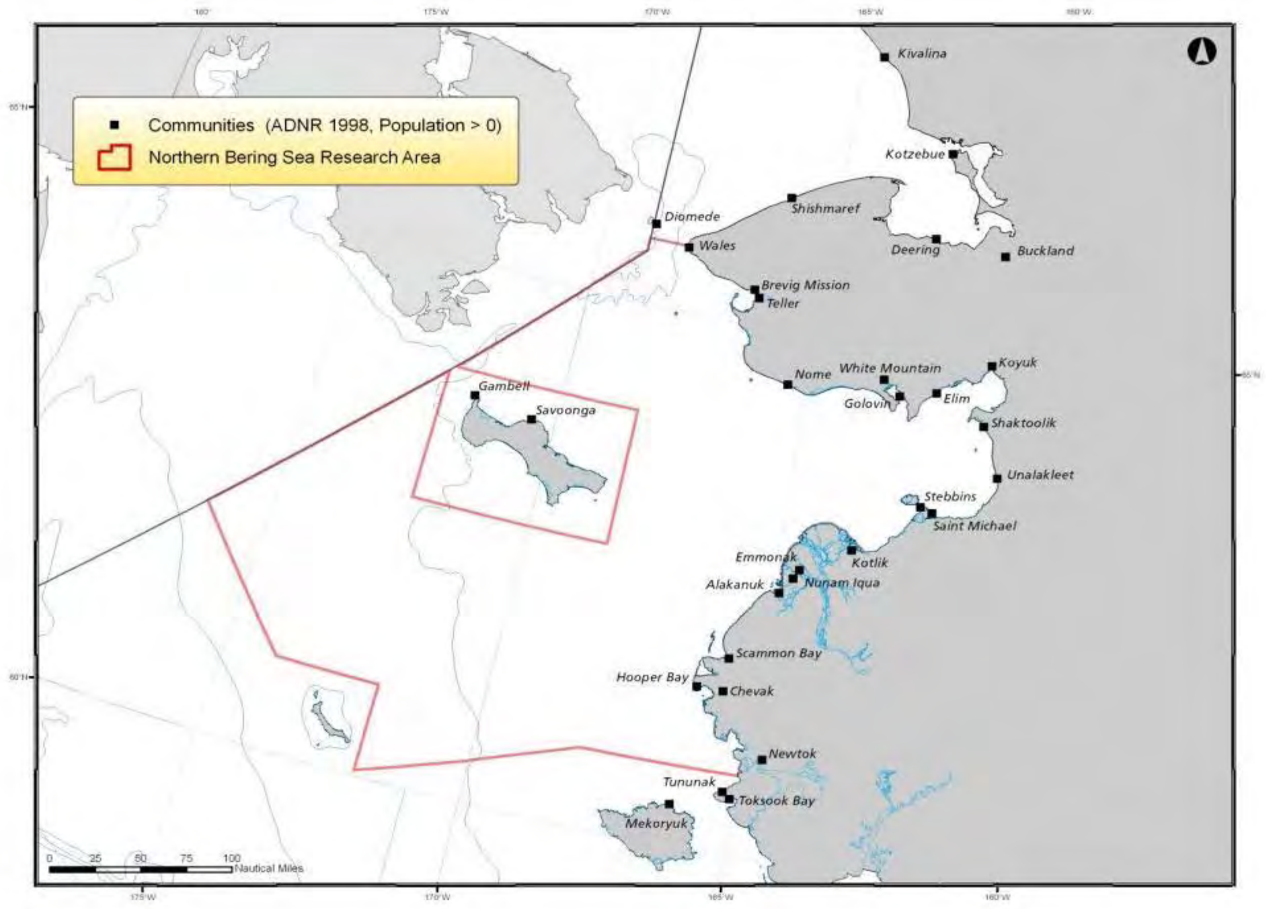


Figure 8. **Location of the Northern Bering Sea Research Area. Map courtesy of NOAA, North Pacific Fisheries Management Council.**

3.6.4 Shipping

Commercial shipping and marine transportation activities include oil and gas tankers, container ships, cargo ships, cruise ships, research vessels, icebreakers, and commercial fishing vessels. These vessels may travel to or from destinations within the Arctic (destination traffic) or may use the Arctic as a passageway between the Atlantic and Pacific Oceans (non-destination traffic). While the level of shipping activity is currently limited, the potential exists for increased activity in the future if changes in sea-ice patterns opens new shipping lanes and results in a longer navigable season. Whether and to what extent marine transportation levels may change in the Arctic depends on a number of factors including: the extent of sea-ice melt, global trade dynamics, infra-structure development, the safety of Arctic shipping lanes, the marine insurance industry, and ship technology. Given these uncertainties, forecasts of future shipping levels in the Arctic are highly speculative (Arctic Council 2009).

Threats to walruses and its habitat from marine transport are the same as for polar bears and include the potential for collisions, spills, noise, and habitat modification associated with icebreaking (USFWS 2009). In general, potential impacts are anticipated to be minimal, given that walrus presence in the region is closely tied to sea-ice, while marine shipping and transportation occurs during the summer months, when sea-ice is absent. Further, oil spill planning and response is subject to a strong regulatory baseline. However, recent trends suggest that most of the Pacific walrus population will be foraging in open water from coastal haulouts along the Chukotka coast during the shipping season. The northeast route (Fig. 9) passes right through this area. It is reasonable to expect walruses will be encountered along this route. Also because of the lack of sea-ice there will be large aggregations of walruses along the coastline at significant risk to any spills or groundings. Technology for cleaning up an oil spill in broken ice conditions remains limited. Currently, only limited icebreaking activities occur in the area. Future activity remains difficult to forecast as there is a lack of reliable information relative to the level of marine transportation and associated icebreaking activity that may occur, and the extent to which changes in marine transport may result in increased oil spills.

3.6.4.1 Scope and Scale of Shipping

Two major shipping lanes in the Arctic intersect the range of the Pacific walrus. The Northwest Passage, which runs parallel to the Alaskan Coast through the Bering Strait up through the Canadian Arctic Archipelago, and the Northern Sea Route, which refers to a segment of the Northeast Passage paralleling the Russian Coast through the Bering Strait and into the Bering Sea (Fig. 9).

3.6.4.2 Current Shipping Levels

Shipping levels in the Northwest Passage and Northern Sea Route are highly dependent on the extent of sea-ice cover. Commercial shipping and marine transportation cease when sea-ice is present. When sea-ice is absent along Arctic coastlines, commercial shipping and marine transportation levels increase. Given the dependence of shipping activities on the absence of sea-ice, shipping levels are seasonally variable. Almost all activity occurs in June through September and to a lesser extent October and November and April and May. There is no commercial shipping or marine transportation in December through March. For example, the Arctic Marine Shipping Assessment (AMSA) reports that no vessel trips occurred in any portion of the Arctic Ocean, except along the coast between northern Norway and eastern Russia, during January of 2004, while one to ten vessel trips occurred along multiple routes along the Alaskan Coast during July of the same year (see Fig. 10) (Arctic Council 2009).

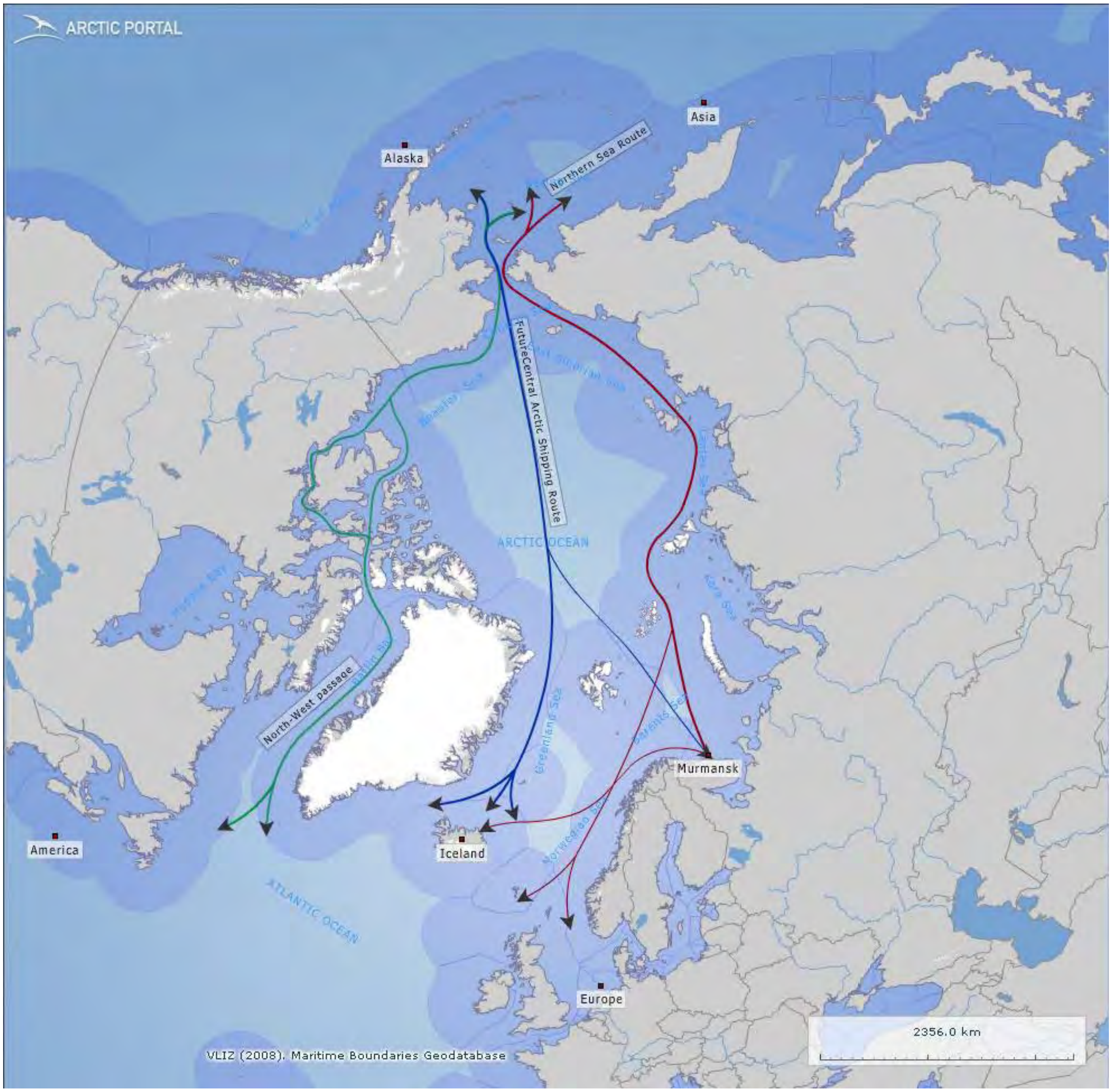
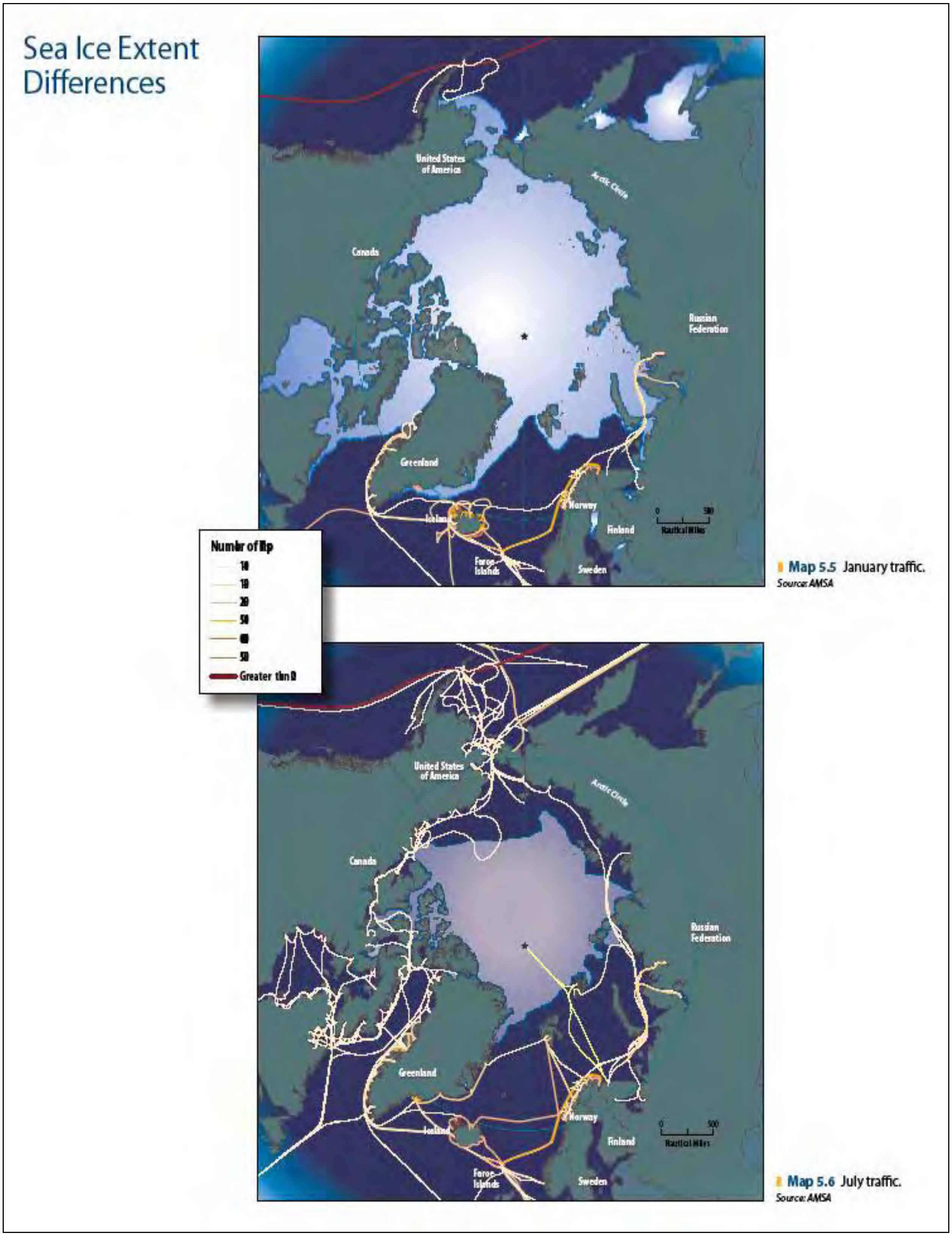


Figure 9. **Major arctic shipping routes as described by Arctic Portal. (http://www.arcticportal.org/portlets/arctic-shipping).**



Map 5.5 January traffic.
Source: AMSA

Map 5.6 July traffic.
Source: AMSA

Figure **10. Differences in vessel traffic in the arctic between winter and summer in 2004.**

Current vessel traffic in the Northwest Passage and the Northern Sea Route includes several vessel types. The most prominent vessel type operating in the Arctic (outside of the Great Circle Route through the Aleutian Islands) is commercial fishing vessels. Specifically, the AMSA reports a total number of vessel days[1] of between 25,001 and 50,000 for fishing vessels along the Alaskan Coast south of the Bering Strait in 2004 (data on vessel days north of the Bering Strait is unavailable). The second most common vessel type in the Arctic is bulk carriers (i.e., oil and gas tankers and barges carrying various types of ore. The majority of bulk carrier traffic is along the Norwegian and Russian Coasts; however, some bulk carrier traffic does traverse the Alaskan coast. Similar to bulk carriers, summer traffic of marine resupply vessels is high, as Arctic communities are unable to receive supplies during the winter. In northern Alaska, resupply trips are carried out by barges pulled by tug boats.

Cruise ships and passenger vessels also make up a significant portion of vessel traffic in the Arctic. According to AMSA, "nearly all passenger vessel activity in the Arctic takes place in ice-free waters, in the summer season and the vast majority of it is for marine tourism purposes." (Arctic Council 2009). Along the North American Continent, almost all passenger vessel traffic occurs south of the Bering Strait or within the Canadian Arctic Archipelago. In 2004, AMSA reports that there were between one and ten passenger vessel trips in both the Bering Sea and the Canadian Arctic.

3.6.4.3 Future Shipping Levels

Sea-ice in the Arctic has been declining over the past 30 years, particularly during the summer. Climate models project longer periods with no sea-ice due to earlier melting in the spring and later freezing in the fall (Section 3.2.1.1). In particular, the navigation period in the Northern Sea Route is forecast to increase from 20-30 days to 90-100 days per year, thereby opening the Northern Sea Route to increased vessel traffic. AMSA and Arctic Marine Transport Workshop also note that sea-ice is likely to decline in the future, which may increase commercial shipping and marine transportation in the Arctic. Other factors which may lead to increased vessel traffic in the Arctic, in addition to reduced sea-ice, include increased oil and gas development, Arctic community population growth and associated development, and increased tourism (Brigham and Ellis 2004; ArcticCouncil 2009).

No quantitative analyses of changes in shipping levels currently exist. Future shipping levels in the Northwest Passage and the Northern Sea Route depend on such uncertainties as the extent of sea-ice melt, global trade dynamics, development of infrastructure along Arctic shipping

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[1] "Vessel days" is the sum of the total number of days each vessel is present in a specific geographic area (e.g., if two vessels are present in an area, one for two days and the other for three days, total vessel days would equal five).

lanes, the safety of Arctic shipping lanes, the marine insurance industry, and ship technology. Both the AMSA and the Arctic Marine Transport Workshop note that the greatest potential for increased shipping and marine transportation is the potential use of the Arctic as an alternative trade route connecting the Atlantic and Pacific Oceans. The Northwest Passage is not considered a viable Arctic throughway given that the oldest and thickest sea-ice in the Arctic is pushed into the western edge of the Canadian Arctic Archipelago, making the passage dangerous to navigate and delaying future reductions in sea-ice (Arctic Council 2009). As a result, future vessel traffic in the Northwest Passage is expected to be focused on destinations within the Arctic, rather than using the Passage as a throughway. Future shipping levels in the Northwest Passage are, therefore, expected to be less than in the Northern Sea Route.

In addition to uncertainty regarding future sea-ice levels, the greatest limiting factor to establishing the Northern Sea Route as a viable alternative trade route is the lack of infrastructure along the route and a set of unified, multilateral marine transport regulations. These factors are reflected in the future shipping scenarios described in both the AMSA and the Arctic Marine Transport Workshop (Table 3). Specifically, the AMSA discusses four different future shipping forecasts through 2020, each defined by different economic and regulatory scenarios (Arctic Council 2009).

Similarly, the Arctic Marine Transport Workshop developed two future shipping scenarios, which depend largely on future levels of infrastructure and the development of unified marine transport regulations. The Workshop described an incremental marine-investment scenario and a large-scale marine-investment scenario. Under the incremental scenario, vessel traffic in the Arctic would remain destinational and increases in shipping levels and infrastructure would be limited to increased utilization of Arctic natural resources and tourism. Under the large-scale investment scenario, the Northern Sea Route would be considered a viable alternative trade route, which would lead to investments in new polar vessel fleets, marine infrastructure, a revamped system of ports, and the development of a unified set of marine transport regulations, as well as a significant increase in vessel traffic. The Workshop concluded, however, that significant economic research is necessary to fully determine likely future shipping levels.

***Table 3*. Future commercial shipping scenarios as put forth by participants of the arctic marine transportation workshop, April 2009.**

Scenario	Description	Future shipping levels
Arctic Saga	High demand for Arctic natural resources and tourism accompanied by high levels of collaboration among Arctic nations leading to unified marine regulations and increased infrastructure.	Large increases in commercial shipping due to both increased destinational vessel traffic and the utilization of the Northern Sea Route as a viable alternative trade route.
Arctic Race	High demand for Arctic natural resources and tourism, but limited unified marine regulation leading to an unstable region with limited Infrastructure.	Increased destinational commercial shipping due to increased demand for Arctic natural resources.
Polar Preserve	Limited demand for Arctic natural resources and tourism, but a large amount of cooperation among Arctic nations leading to unified marine regulation focused largely on the preservation of natural resources.	No increase in commercial shipping levels due to both a lack of demand for Arctic natural resources and and significant regulations making the usage of the Arctic as an alternative trade route cost prohibitive.
Polar Lows	Limited demand for Arctic natural resources and tourism and limited cooperation among Arctic nations preventing the development of a unified set of marine transportation regulations.	No increase in commercial shipping due to under-utilization of Arctic natural resources.

The broad range of future shipping scenarios described in the AMSA and the Arctic Marine Transport Workshop underscore the uncertainties regarding future shipping levels. The AMSA notes that while the reduction in sea-ice will provide the opportunity for increased shipping levels, ultimately, it is economic factors, such as the feasibility of utilizing the Northern Sea Route as an alternative connection between the Atlantic and Pacific Oceans that will determine future shipping levels (Arctic Council 2009). In terms of this analysis, specific future shipping levels are less important than the potential for increased threats to Pacific walruses. Specifically, any increase in shipping will result in increased potential for oil spills and more frequent icebreaking activities. The following sections describe current oil spill prevention and response and icebreaking regulations and actions.

3.6.4.4 Oil Spill Prevention and Response

To date, there have been relatively few oil spills caused by marine vessel travel in the Bering and Chukchi seas. Specifically, the AMSA reports that there were a total of 293 vessel incidents in the Arctic between 1995 and 2004 (Arctic Council 2009). Most of these incidents occurred along the Great Circle shipping route through the Aleutian Islands, along the northern coast of Norway, around Iceland and the Faroe Islands, and in the Canadian Arctic Archipelago. Within the seasonal range of walruses, there were approximately six vessel incidents between 1995 and 2004, two caused by fires, two by machinery damage or failure, one caused by grounding, and one caused by damage to the vessel. In general, the pattern of past vessel incidents corresponds to areas of high vessel traffic. If vessel traffic increases in the Northwest Passage and the Northern Sea Route according to the future shipping scenarios described above, there may be increased risk of oil spills due to the increased number of vessels present in the Arctic. In particular, increased oil and gas development may increase oil and gas tanker traffic in the Arctic, which in turn will increase the potential for a large spill.

Oil spill response in Alaska is regulated by the 1990 Oil Pollution Act (OPA), which requires the U.S. Coast Guard (USCG) and the Environmental Protection Agency (EPA) to develop a statewide oil spill response plan, and by Alaska Statute 46.04, which requires the Alaska Department of Environmental Conservation (ADEC) to develop a statewide response plan and individual response plans for ten geographic subareas spanning the State of Alaska (Oil Pollution Act of 1990 (33 U.S.C. 2701-2761). Finally, Alaska Statute 46.04 requires that the oil industry develop oil discharge prevention and contingency plans.

The MMPA requires the Service to complete contingency planning for response to the stranding and unusual mortality of protected marine mammals. While oil spills are considered a cause of unusual mortality, the MMPA defers to the OPA and Alaska Statutes for oil spill response planning. The level of response and specific response strategy following an oil spill depends on a number of factors including, but not limited to: weather; the type of oil spilled; the amount of oil spilled; the response equipment available; and the location of the spill in relation to environmentally sensitive resources and areas with high human-use value (AAC 75.4, http://www.dec.state.ak.us/SPAR/statutes_regs.htm). In general, the goal of oil spill response is to utilize available response equipment in the most efficient and effective manner possible to limit the effects of spilled oil.

Oil spill response for walruses and for wildlife in general, can be broken into three phases (ARRT 2002). Phase one is focused on eliminating the source of the spill, containing the spilled oil, and protecting environmentally sensitive areas. Oil spill responders rely on delineated sensitive areas to identify where the potential for oil spill effects on wildlife are the greatest. These areas are then prioritized for protection during oil spill response. Most spill response efforts do not advance beyond Phase One. Phase Two involves efforts to herd or haze potentially affected wildlife away from the spill area. Phase Three, the most involved and most infrequently undertaken phase of oil spill response for wildlife, includes the capture and rehabilitation of oiled individuals.

3.6.4.5 Icebreaking Activities

Icebreaking activities can create noise which causes marine mammals to avoid areas where these activities are occurring. Further, icebreaking activities may increase the risk of oil spills by increasing vessel traffic in ice-filled waters. Given that marine mammals have been found to concentrate in and around temporary breaks in the ice created by icebreakers (Arctic Council 2009) there may be greater environmental impact associated with an oil spill involving an icebreaker or a vessel operating in a channel cleared by an icebreaker.

Currently, Russian and Canadian icebreakers are used along the Northern Sea Route and within the Canadian Arctic Archipelago to clear passageways utilized by commercial shipping vessels (Arctic Council 2009). Such icebreaking activities are limited primarily to the summer months. In some cases, commercial shipping vessels contract with private icebreakers to provide an escort through ice-filled waters. The U.S. does not currently engage in icebreaking activities for navigational purposes in the Arctic (NAS 2005). Rather, U.S. icebreaking activities are limited to search and rescue missions and research efforts. There are no federal or state regulations on icebreaking activities, mainly because icebreaking along the Alaskan Coast is minimal and usually carried out by the Coast Guard. However, in the last few years, oil and gas exploration activities in the Beaufort and Chukchi seas have used privately contracted icebreakers in support of their operations.

Icebreaking activities may increase in the future, given increases in commercial shipping and marine transportation. In particular, the establishment of the Northern Sea Route as a viable trade route connecting the Atlantic and Pacific Oceans is contingent on, among other factors, the establishment of a reliable government or private icebreaking fleet, which would be available to clear the entire Route and provide escorts to vessels operating along the Route (Brigham and Ellis 2004; Arctic Council 2009). Although there are no current regulations on icebreaking activities in the Arctic, such regulations may be incorporated into the International Maritime Organization (IMO) voluntary guidelines as part of unified, multilateral regulation on Arctic shipping. IMO is currently considering the development of icebreaking guidelines. Any U.S. specific regulation would likely be similar to potential future IMO guidelines.

Shipping and other boating activities are currently not a serious threat to the Pacific walrus. Shipping activity is predicted to increase in the future, but the magnitude and rate of increase are unknown and dependent on both economic and environmental factors. Shipping regulations would extend to any increased levels in the future. It is unlikely that shipping will become a serious threat to the Pacific walrus in the foreseeable future.

3.6.5 Summary: Effects of Other Natural or Human Factors

Oil and gas exploration and development, commercial fishing, and commercial shipping were the 3 potential stressors identified and analyzed under factor E. Currently, these activities are limited in scope, intensity, and extent. These activities may increase in intensity in the future, particularly oil and gas exploration and development. Available analyses of the risk of an accident and spill from oil and gas activities suggests that the risk to Pacific walruses is small. However, oil and gas activities are currently on hold and will face increased scrutiny in the future, which will likely include a reanalysis of those risks. Nonetheless a large oil spill could have large negative consequences for the Pacific walrus population, depending on location, time of year, weather conditions, and proximity to walruses.

Commercial fishing activities may expand into the northern Bering Sea in the future, and perhaps beyond. Commercial fishing activities are adequately regulated and not expected to significantly impact the Pacific walrus in the future. In addition, research projects are currently being developed to estimate the impact of modified trawl gear on walrus prey.

The melting of sea-ice in the summer in the Arctic allows for the development and increase of circumpolar international commercial shipping. Five shipping scenarios have been developed, ranging from a low demand, largely unregulated situation to a high demand, internationally coordinated and adequately regulated scenario. Which scenario is most likely has not been estimated. Nonetheless, commercial shipping in the Arctic in U.S. waters would have to comply with the take provisions of the MMPA.

3.7 Estimating the Effects of the Threats on the Pacific Walrus Population

Assessments of species status are often required to determine their conservation and legal standing. Unfortunately, many species in this category are not well studied, making it difficult to quantify how perceived threats are currently impacting the species and understanding how those threats and affects will interact and develop in the future. The Pacific walrus is no exception. Data are not available on walrus vital rates to parameterize a population viability model – arguably the best approach to quantify extinction risk. Another challenge is the lack of data linking the magnitude, and temporal and spatial scope of identified threats to walrus population performance.

The Service has used a variety of approaches to conduct threats assessments for poorly studied species. A common theme is to convene a panel of species experts, solicit their opinions on the magnitude and effects of the relevant stressors, and summarize those opinions either qualitatively or quantitatively to render a final assessment. We followed a similar approach. We first compiled the best available scientific and commercial information regarding Pacific walruses and a description of past, present, and likely future stressors to the Pacific walrus population into a draft status review. This information was distributed to a variety of experts for peer-review. We then convened a panel of experts to; (1) confirm that we had identified all the relevant stressors, (2) describe how we expected each stressor to affect the Pacific walrus population, and (3) identify areas of uncertainty and judge the reliability of the information. The panel was tasked with compiling that information and determining how to organize, quantify, and display the cumulative effects of those stresses on the Pacific walrus population. We decided to do this under the framework of a Bayesian belief network (BBN) model.

3.7.1 Bayesian Belief Network Model

Our modeling exercise had the following goals: (1) provide a way to organize, clarify, and graphically display the important stressors and the opinions of the experts on how those stressors operate, (2) maintain and document the logic train and important decisions throughout the assessment, (3) define important interactions among the stressors, (4) account for the cumulative effects of the stressors associated with each listing factor, (5) identify which stressors had the greatest effect on the population to assist in developing targeted management and research programs, (6) determine how uncertainties in future conditions, and how stressors, alone or in combination, affect the population, and (7) to help inform a decision regarding ESA classification for the Pacific Walrus.

Bayesian Belief Network (BBN) models are well suited to formalizing and quantifying the opinions of experts (Marcot *et al.* 2006). They graphically display relevant threats, the interactions among threats, and the cumulative impact of those threats as they are integrated through the network. BBN models are comprised of three elements; (1) nodes representing key explanatory variables and one or more response variables, (2) links among the nodes that represent cause-effect relationships, and (3) probabilities representing the belief that a node will be in a given state, independent of other nodes or given the states of connected (parent) nodes. Nodes are composed of one or more states which are quantified as probabilities, summing to one. Node states can be the amount, intensity, or categories, etc. of a variable. Nodes representing continuous variables have to be divided into discrete states. Equal probabilities of the states of a node represent complete uncertainty about the state of a node. Links among nodes can represent interactions among variables and capture the cumulative effects of several variables. Each node contains a conditional probability table (CPT) that specifies the relationships (in terms of probabilities) among all combinations of the states of the parent node(s) and the states of the focal node (child). A value for each cell of a CPT is derived from data, or otherwise specified by the modeler(s) and it is the process whereby experts express their uncertainty about the relationships. Perhaps the single greatest benefit of a BBN model is the graphical display of system complexity which promotes transparency and understanding among stakeholders (Zorrilla *et al.* 2010). Another important advantage is that BBN models can be easily updated with new data and other types of information.

The information summarized in this status review served as the knowledge base for our model building and threats assessment. The BBN model was developed and finalized by a panel of four marine mammal biologists and three ESA experts during a five-day workshop in April 2010. The team specified all the characteristics of the three elements described above, as well as time periods, and management scenarios examined.

Depending on the number of parent nodes and the number of states of each node, the specification of probabilities in a CPT can be difficult and time-consuming. We used an automated (spreadsheet program) backwards interpolation procedure (Marcot *et al.* 2006) to complete the more complex CPTs in our model, which only required specifying the “best-case”, “worst-case” and “intermediate-case” probabilities. That spreadsheet also had functions for weighting each node as well as states within nodes, and specifying compensatory/non-compensatory interactions among nodes (LLWA 2010). The CPTs for all nodes are presented in Appendix A.

Our BBN model was structured around four of the five listing factors of the ESA (Fig. 11). The four ESA factors modeled included A – the present or threatened destruction, modification, or curtailment of habitat or range, B – overutilization for commercial, recreational, scientific, or educational purposes, C – disease or predation, and E – other natural or manmade factors (Fig. 11). We did not evaluate the adequacy of existing regulations factor (D) in the model because regulations were evaluated separately for each individual threat. The nodes and links associated with each listing factor comprise sub-models that inform the model outcome; the probability of the effects of the listing factors on the walrus population (response variable). The states of the outcome node were negative, neutral, and positive. The information needed to link the intensity of the stressors to a measure of population status was not available, the modeling team did not believe that link could be made based on expert opinion with any reliability, and the goals of the modeling exercise did not require such an outcome.

The BRT also decided that several model "runs" would be useful to; (1) establish a baseline by which to judge BBN model outputs for the future, (2) check model accuracy based on past observations, and (3) assess the future at mid- and late-century periods.

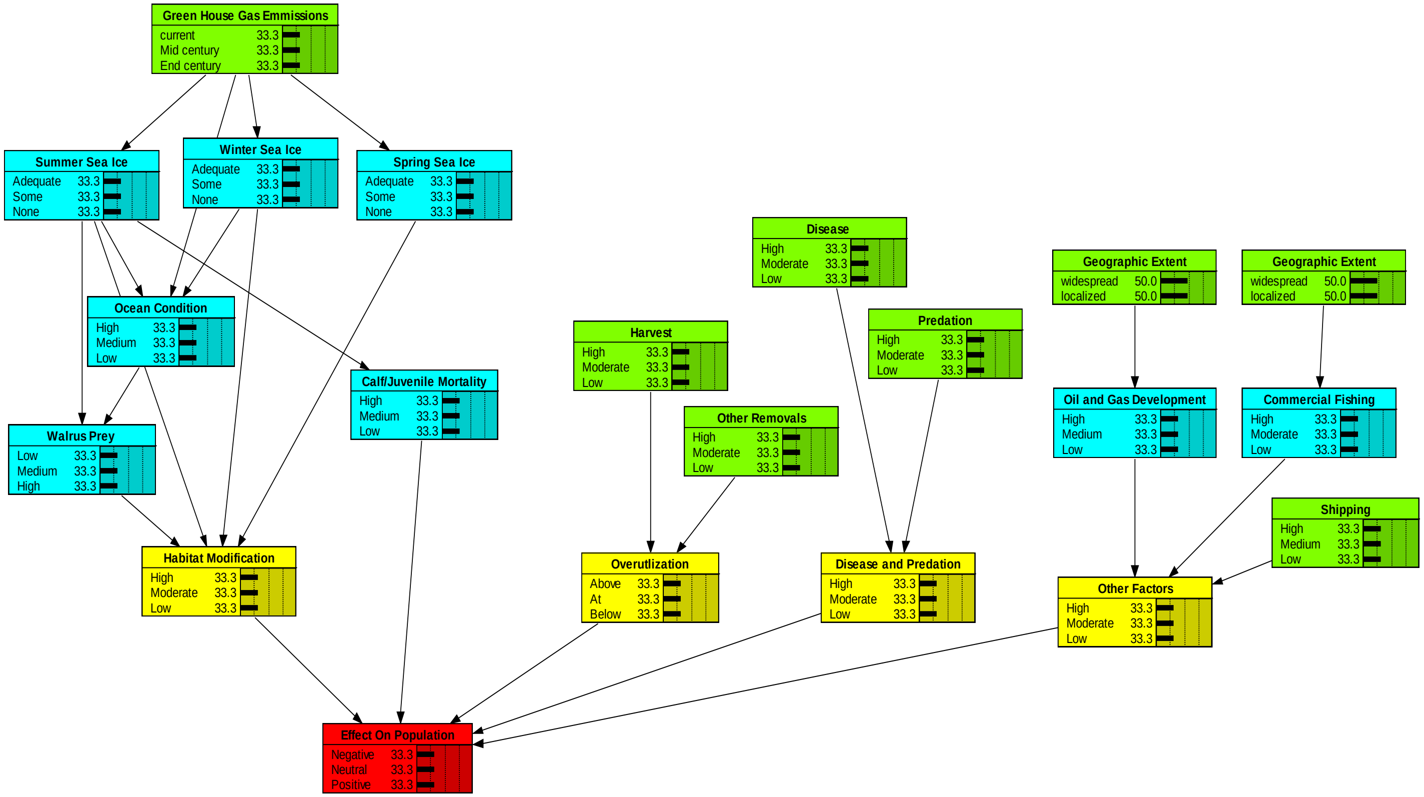

Figure 11. **The full Bayesian belief network model used to assess the cumulative effects of four of the Endangered Species Act listing factors (habitat modification, overutilization, disease and predation, and other man-made factors [yellow nodes]) on the Pacific walrus population (red node). Nodes higher in the network correspond to the individual stressors (singularly [green] or in combination [blue]) that were considered to have the most important effects on the walrus population. Note: probabilities for all nodes presented in this figure were set at unity for illustrative purposes. Conditional probabilities for the nodes used in the threat assessment are presented in Appendix A.**

3.7.1.1 Habitat Modification Sub-model

Green house gas emissions were judged by the workshop participants as the primary variable (parent node) driving habitat modification. This node (GHG emissions, Fig. 12) was given three states reflecting crucial time periods (decades): current (1989-2010), mid-century (2045-2055), and late-century (2090-2099), and further defined by observed or predicted CO_2 concentrations in the atmosphere (Table 4). This node was characterized by time periods to allow us to make model "runs" corresponding to current observations and future projections of sea-ice extent as outlined in Douglas (2010). The GHG node was directly linked to three seasonal sea-ice nodes (summer, winter, and spring) and an ocean condition (ocean acidification/temperature) node. The seasonal ice nodes represented key periods of walrus life history and ice use. Summer (July-November) when females are foraging and rearing dependent calves over continental shelf waters in the Chukchi Sea, Winter (December-March) when the entire population has migrated south into the Bering Sea and breeding occurs, and Spring (March-May) encompassing parturition and the start of the northward migration (See Section 2.2.4.2 *Sea-ice Habitats* for additional details).

The states for each sea-ice node were defined as adequate, some, and none, which were assigned probabilities based on historic observations or sea-ice model projections (Douglas 2010), depending on the time period considered. The summer sea-ice node was linked to the walrus prey node (reflecting access to feeding areas), ocean condition (capturing acidification and temperature effects), calf/juvenile mortality (accounting for mortalities at terrestrial haulouts), and the habitat modification (listing Factor A) nodes. The winter sea-ice node was linked to both the ocean condition and habitat modification nodes, and the spring sea-ice node was linked only to the habitat modification node to capture the effects of changes in birthing and calf rearing ice substrate.

The walrus prey node also had three states that described prey availability as influenced by both prey abundance and access to prey from ice platforms. The link to summer sea-ice was made to reflect the importance of summer sea-ice as a platform for accessing offshore (> 60 km) foraging areas. The link to ocean condition represented potential changes in prey populations due to acidification and warming.

The ocean condition (acidification/temperature) node also had three states representing lower pH/higher temperature (high state) to normal pH/temperature (low state). Explanatory (or input) variables for this node included seasonal ice conditions and GHG emissions. There was great uncertainty in quantifying this node because pH and temperature thresholds for walrus prey species are poorly unknown.

The calf/juvenile mortality node was linked to the summer sea-ice node to capture mortality events on terrestrial haul outs due to stampedes and other factors. When summer sea-ice over the continental shelf completely melts, walrus come to shore in large herds (hundreds to tens of thousands) to rest. When these herds feel threatened, they stampede back into the water, crushing smaller animals. Rates of calf/juvenile mortality at densely packed coastal haulouts have been high in recent years, particularly along the Russian coast of the Chukchi Sea (See Section 3.2.1.2 *Effects of Changing Sea-ice Habitats* for further details*).* This node had three states; high, medium, and low. The importance of this mortality factor was captured through a direct link to the output node (effect on population).

The nodes described above were directly or indirectly linked to the habitat modification node that captured the cumulative effects of all those stressors. In specifying the CPT for the habitat modification node, summer sea-ice and walrus prey were weighted higher than both winter and spring sea-ice.

3.7.1.2 Overutilization Sub-model

Two nodes, harvest (subsistence hunting) and other removals (largely calves for zoos/aquaria) were the explanatory variables for this sub-model (Fig. 13). Harvest and other removals nodes each had three states describing the level of removal as high, moderate, or low. For the harvest node, state definitions were based on the combined United States and Russian harvest levels since 1960 (Fig. 2) and the other removals was based on the annual capture of 25-30 calves (Section 3.3.2). The overutilization node also had three states; above, at, or below replacement levels that were based on potential walrus population growth with a theoretical maximum of 8%/year Chivers (1999). We assumed that harvest had a much greater effect on overutilization than other removals.

3.7.1.3 Disease and Predation Sub-model

The potential effects of changes in disease and parasitism combined, and predation rates due to climate related habitat changes were the primary explanatory variables for the disease and predation node (listing factor C). Each node in this sub model had three states; high moderate and low (Fig. 13). Current levels of these stressors were judged to be low or moderate (Section 3.4) with predation being more of a factor than disease/parasitism.

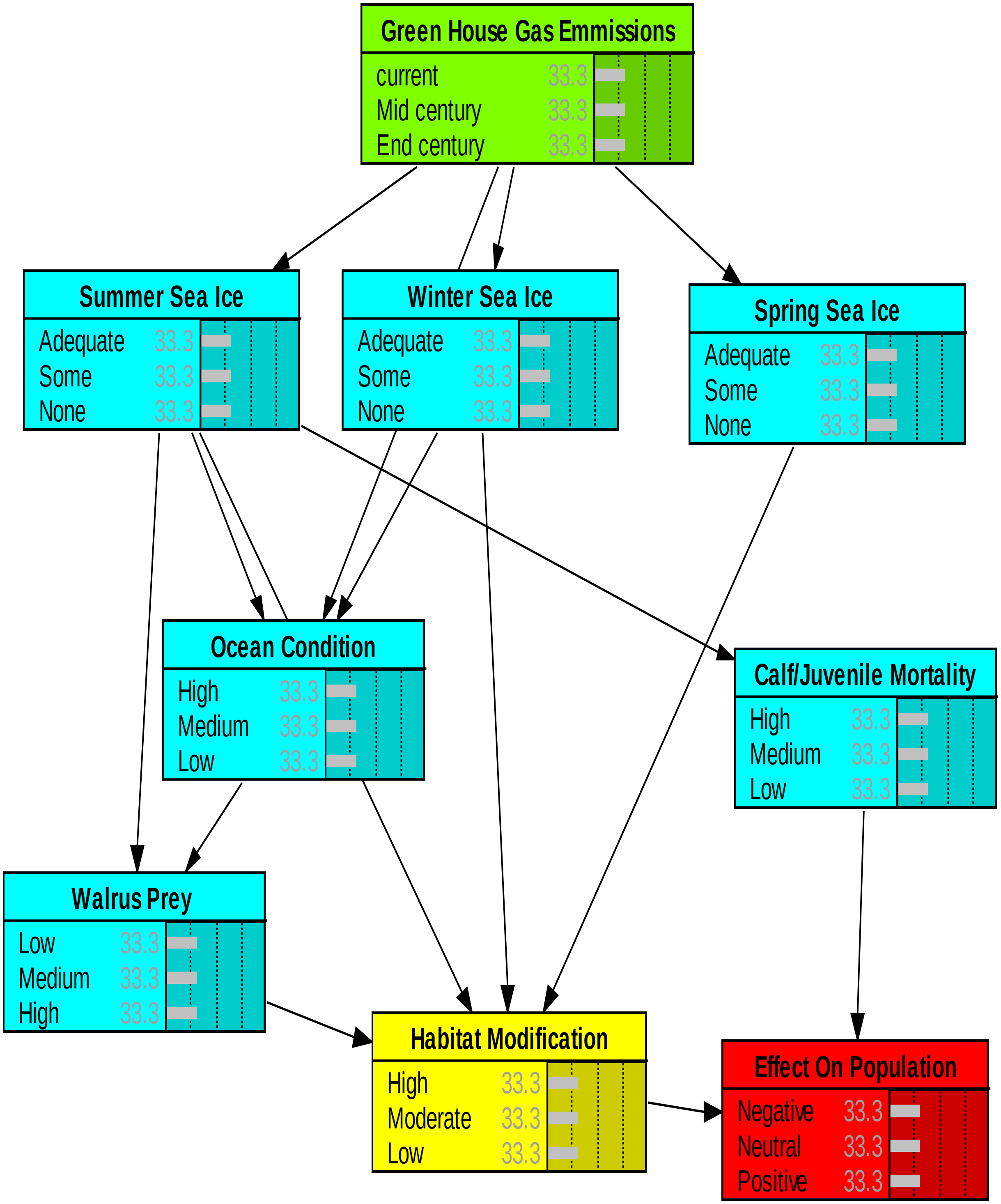

Figure 12. **Details of the Habitat Modification (listing Factor A) Sub-model of the Bayesian belief network model used in the Pacific walrus threats assessment. Note: probabilities for all nodes presented in this figure were set at unity for illustrative purposes. Conditional probabilities for the nodes used in the threat assessment are presented in Appendix A.**

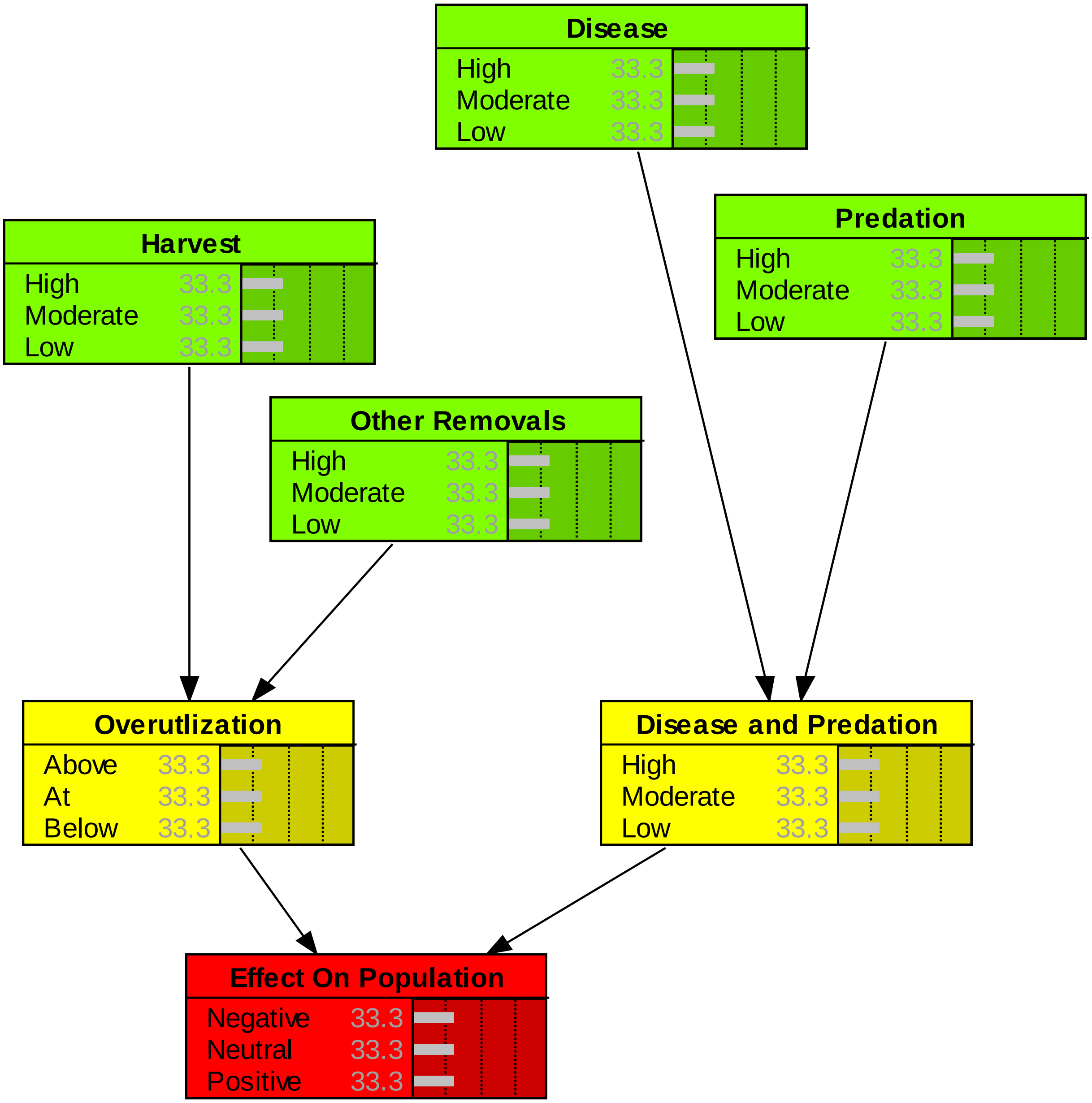

Figure 13. **Overutilization (listing factor B) and Disease and Predation (listing factor C) Sub-models of the Bayesian belief network model used in the Pacific walrus threats assessment. Note: probabilities for all nodes presented in this figure were set at unity for illustrative purposes. Conditional probabilities for the nodes used in the threat assessment are presented in Appendix A.**

3.7.1.4 Other Factors Sub-model

This sub-model focused on oil and gas development, commercial fishing, and shipping (Fig. 14). Each of these nodes had three states; high, moderate, or low and current conditions for each represented low levels of activity. Oil and gas development and commercial fishing were linked to a geographic extent parent node to account for the spatial extent of these activities; today they are concentrated in relatively small areas within the overall range of the Pacific walrus. Oil and gas development impacts were judged to be two-times more important than the other two variables due to the fact that a large oil spill could have greater impacts to walrus and their habitats. Following the *Deepwater Horizon* accident in the Gulf of Mexico, oil and gas activities have been delayed and face greater scrutiny, increasing uncertainty in this area as current analyses of risks and impacts will likely be revisited.

Currently, commercial fishing occurs only along the southern periphery of the Pacific walrus range and has a minor impact on the population. However, as ice dynamics change and the distribution of commercial fish stocks shift northward, commercial fishers are interested in expanding to the north (Section 3.6.3). In addition, as the length of the ice-free period and extent of ice-free waters in the arctic increases each year, international shipping through the arctic will become more feasible. However, future arctic shipping scenarios have only been described in broad qualitative terms and depend on a combination of uncertain environmental, economic, regulatory factors (Section 3.6.4).

3.7.1.5 Effect on Population

All the sub-models described above fed directly into the response variable; effect on population node (Fig. 11). This node expressed the cumulative effects of the four listing factors after each of those nodes accounted for the cumulative effects and interactions of the individual stressors associated with each sub-model. In addition, the calf/juvenile mortality node was directly linked to the outcome node. We considered habitat modification to be the most important listing factor and was given a weight of 20. Overutilization was also considered to be very important and was given half the weight of habitat modification (10), calf/juvenile mortality was considered a little less important (8), disease and predation even less (2), and other factors was given a weight of one.

The output node (effect on the population) quantifies the cumulative effects of habitat modification, overutilization, disease and predation, and other factors as the probability of three states; negative, neutral, or positive. We did not have the information necessary to link the effects of each listing factor to the status of the walrus population and thus could not predict the probability of the four primary ESA listing classes; not warranted, candidate for listing, threatened, or endangered. However, by comparing model output with known conditions and a range of future projections (see below), we were able to judge the relative severity of the stressors at various points in time, estimate trends in the intensity of the stressors, and identify which factors had the greatest effect on model outcomes.

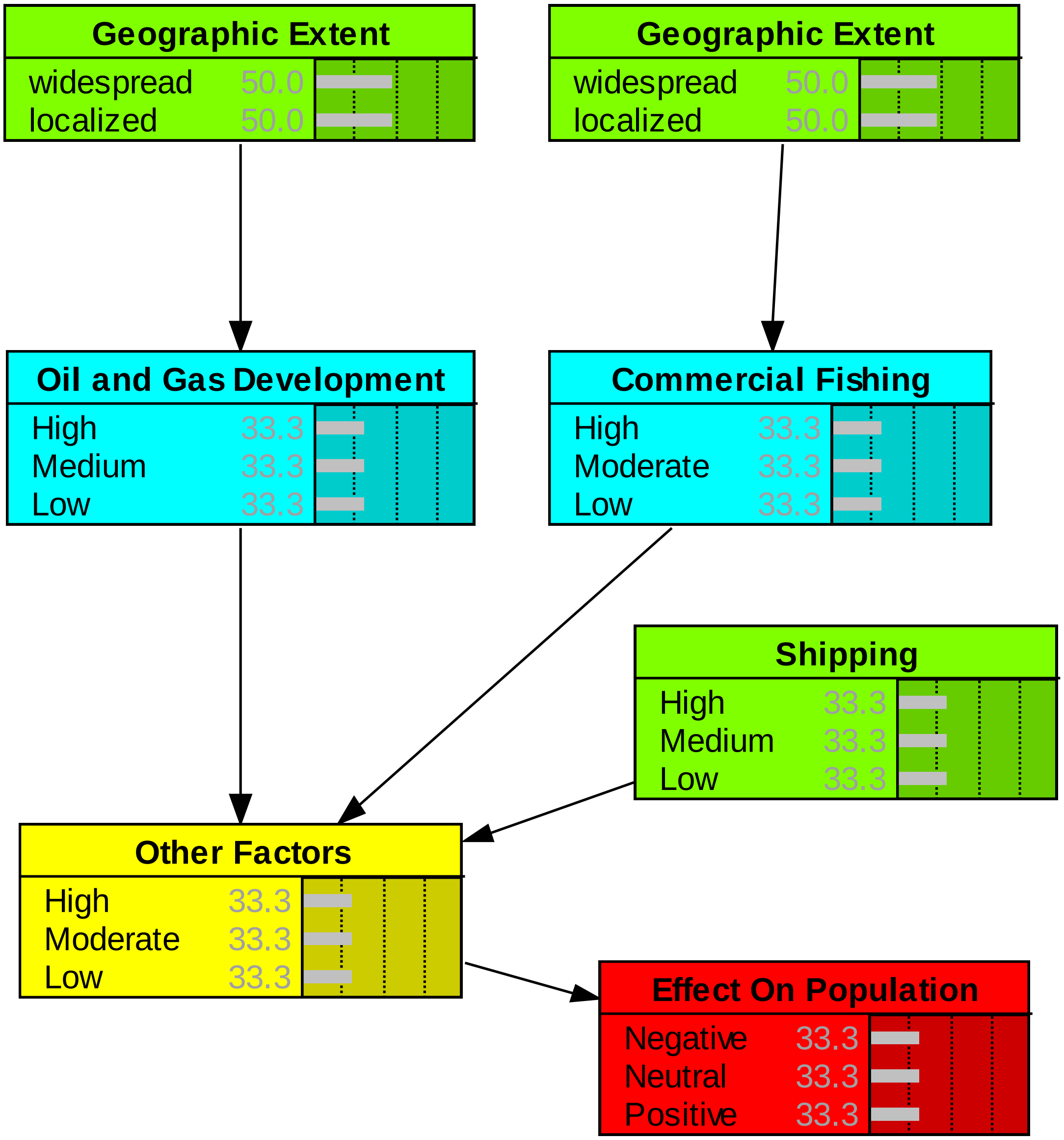

***Figure 14*. The Other Factors (listing factor E) Sub-model of the Bayesian belief network model used in the Pacific walrus threats assessment. Note: probabilities for all nodes presented in this figure were set at unity for illustrative purposes. Conditional probabilities for the nodes used in the threat assessment are presented in Appendix A.**

***Table 4*. Walrus Bayesian belief network model node and state definitions and relative weighting.**

Node	Definitions/quantification
Green house gas (GHG) emissions	Represents current CO_2 atmospheric concentrations (≈400 ppm), and those projected for mid-century (2045-2054, ≈500 ppm) and late- century (2090-2099, ≈800 ppm).
Summer sea-ice	The July-November foraging/calf rearing/migration seasons in the Chukchi sea. Probabilities were set for current conditions based on observations over the last 9 years, where 6 of those summers had no ice. “Adequate” was defined as the extent of the ice edge remaining over the continental shelf. “Some” ice was defined as broken ice over the continental shelf that cannot be detected by satellites, but is still used by walruses as in 2008. “None” is self-explanatory.
Winter sea-ice	The December-March breeding period in the Bering Sea. “Adequate” was defined as useable ice by December in breeding areas noted in Fig. 1, and “some” as useable ice in those areas by January.
Spring sea-ice	The April-June birthing/foraging/migrating season in the Bering Sea, progressing to the Chukchi Sea. “Adequate” was defined as useable ice in April in breeding areas noted in Fig. 1, and “Some” as useable ice by cover in those areas in June.
Ocean condition	Ocean acidification & temperature as effected by ice conditions, currents, & GHG emissions. “Low” was defined as relatively small changes as per current conditions (0.1 pH unit decline, 2^{o} C increase), “Medium” was defined as a greater (but unquantifiable) change, and “High” even greater. In developing the conditional probability table for this node, both factors were weighted equally.

Table 4. **Continued.**

Calf/juvenile mortality	Associated with trampling events at terrestrial haulouts as related to summer ice changes. "Low" was = levels in the past (100-1000 deaths), that occurred infrequently (1 of 5 years), "Medium" = 1000+ deaths more frequently (1 of 3 years), and "High" = current observations of 3,000+ deaths every other year.
Walrus prey	The amount of prey (mass) as effected by ocean condition & access to prey via ice platforms. "Low" = poor ocean conditions (decline in mass) and poor access (no summer ice) where animals are limited to foraging from the coast, "Medium" = medium ocean conditions and some access to offshore ice platforms, and "High" = current ocean conditions (mass) and adequate sea-ice to access offshore feeding areas. In developing the conditional probability table for this node, all inputs were weighted equally.
Habitat modification	ESA listing factor A, integrating the effects of seasonal ice conditions, ocean condition, and walrus prey. "Low" = levels observed in 1990s, "Moderate" = levels observed now, and "High" = levels anticipated in the future. In developing the conditional probability table for this node, all factors were weighted equally.
Harvest	Subsistence harvest. Based on % of assumed population size, theoretical maximum growth rate (8%/yr) & past harvest levels. "Low" <= 2% of population, "Moderate" = 3-4%, & "High" >= 5%.
Other removals	Only known removals are 20-30 calves/year for zoos and aquaria and 2-3/year in fishing by-catch. States are defined the same as for Harvest.

Table 4. **Continued.**

Overutilization	Listing factor B. The cumulative effects of harvest & other removals. States = levels relative to sustainable levels as defined in the Harvest node in terms of % of the population. Current levels are assumed to be at or below the replacement level & as harvest or other removals increase or decrease, the states change as per the conditional probability table. In developing the conditional probability table for this node, harvest was weighed 1000-times more important than other removals.
Disease	The cumulative effects of both disease and parasitism as both are expected to change in similar ways with climate change, etc. Currently levels are considered to be low. It was not possible to quantify these states as there is no/little information on infection or infestation levels.
Predation	The effect of predation by polar bears & killer whales. Current levels of predation were considered to be low. It was not possible to quantify these states as there is no/little information on predation rates.
Disease and predation	Listing factor C. The cumulative effects of both the Disease and Predation nodes. Current conditions = the low state. The other states are relative to current conditions as defined in the conditional probability table. In developing the conditional probability table for this node, predation was weighted twice as important as disease/parasitism.
Geographic extent	These nodes capture the potential for expanded activities in the future, and puts the scope of current activities in context of the range of the Pacific walrus. Currently the geographic extent of oil & gas development is localized (about 10% of the Chukchi Sea OCS area) relative to the summer distribution of Pacific walruses. Activities may be considered widespread if they become > 50% of the area. There are currently no commercial fishing activities in the Chukchi Sea and fishing is restricted to the southern Bering Sea, on the edge of the walrus distribution. Current activities are considered localized. We did not quantify the widespread state.

***Table 4.* Continued.**

Oil and gas development	The cumulative effects of extent and intensity. This node represents the intensity of oil and gas activities: Exploration activities were considered relatively “Low intensity”, development activities “Medium intensity”, and full development and production as ”High intensity”.
Commercial fishing	The cumulative effects of geographic extent and intensity of fishing activities. Current fishing levels were considered low. We did not quantify moderate & high levels other than how those states would be affected based on the conditional probability table.
Shipping	Considered to have a relatively small footprint as shipping lanes are narrow corridors. The states of this node represent the levels of shipping traffic (vessels/unit time) along defined shipping lanes. Current levels of shipping for all purposes are considered low. There is no data available to quantify and define medium and high states, other than incremental increases over current conditions.
Other factors	Listing factor E. The cumulative effects of oil and gas development, commercial fishing, and shipping nodes. The ”Low” state represents current conditions. In developing the conditional probability table for this node, oil & gas was weighted 2-times more important than fishing or shipping.

3.7.1.6 Time Periods and Management Scenarios

To check accuracy, provide context to interpret model results, and assess the future, four time periods were modeled: the past (1979-1988), current conditions (1989-2010), mid-century (2045-2054), and late-century (2090-2099) projections (Table 5). The past represented a period when habitat conditions were favorable for walrus, the population was large, harvests were relatively high, and the other stressors identified had not materialized or were not serious threats. For current, mid-century, and late-century periods, the states of many stressors were unknown or could not be defined (this uncertainty increased with time), and we identified several combinations of plausible states for each node, other than GHG emissions. To narrow the potential combinations of scenarios where uncertainty in the states of stressors was high, we ran only best-case, worst-case, and most likely-case scenarios. In addition, a most likely-case scenario could not be developed for the late-century period due to a high degree of uncertainty in trying to predict states for most variables (eg oil and gas development scenarios; subsistence harvest patterns; shipping traffic etc.) that far into the future. For the past, the habitat modification sub-model was disabled and stressor levels were set consistent with observations from that time period; thus best-case, worst-case, or most likely-case scenarios were irrelevant. Best-case scenarios for the other time periods were based on setting stressor levels to reflect stable or improved conditions that would occur through successful mitigation of threats associated with overutilization, disease or predation, and other man-made factors. Most likely-case scenarios were based on setting stressor levels at states reflecting little change from business as usual. The worst-case scenarios for each time period were modeled by setting stressor levels to high or moderate states, reflecting increasing, unmitigated effects on the population.

3.7.1.7 Sensitivity Analyses/Model Evaluation

As noted, BBNs can be used to identify the most important input factors affecting model outcome, which can provide guidance for research and management activities. This is usually done through a sensitivity analysis that estimates which input variables have the greatest effect on model output. Netica© performs a type of sensitivity analysis known as entropy reduction when the node states are categorical (Marcot *et al.* 2006). In addition, we conducted a sampling based sensitivity analysis (Coupé and Van der Gaag 2002; Kragt 2009, Pollino *et al.* 2007) by varying the states of one input node, while holding all other node states constant. Due to the large number of possible combinations of nodes and states we only analyzed the extreme cases for each node, e.g., high and low.

Data to develop our BBN model and test predictions was not available. However, peer review, scenario analyses, diagnostic analyses, and sensitivity analyses are four methods of model evaluation (Marcot *et al.* 2006; Kragt 2009) that we were able to use. In addition, we also assessed the relative uncertainty of model outcomes for each time period/scenario with a measure of entropy (E), the degree to which the probability of the outcome is spread out over the three different states, as $E = -\sum[p_i * \log_3(p_i)]$, where the p_i is the probability of each state.

3.7.1.8 Model Outcomes

The model output for the past (1979-1988) indicated a probability of 0.74 of the effects of overutilization, disease and predation, and other factors being neutral (Table 6), which was in agreement with expectations based on observations from that time period. Because the model structure and parameters were based on current conditions and uncertain relationships among stressors and walrus response, that run indicated that the model accurately depicted known conditions, should perform well for other time periods, and set a baseline for judging model output for other time periods and scenarios.

Under current conditions (1989-2010), the probability of negative effects increased 16-29% over all scenarios examined (best to worst) while neutral effects declined by 23 -28% respectively (Table 6). There was very little difference in model output between the most likely-case scenario developed by the panel and the worst-case scenario for all possible stressors (Table 6).

For mid-century projections, negative effects increased 21-42% and neutral effects declined 24-35% compared to the historic (1879-1988) baseline level (Table 6). There was no difference between most-likely and worst-case conditions for mid-century, with the probability of negative effects being greatest (0.55), followed by neutral effects (0.39). However, under the best-case scenario (all specified stressors set at low levels), the probability of the effects being neutral was greatest (0.50) and the probability of the effects being positive increased 10%.

As noted for late-century projections, we could not develop a most likely-case scenario. In fact, due to difficulties in forecasting stressor levels and walrus response to those stressors that far into the future any scenario within the bounds of the model input was judged to be equally probable and the worst-case and best-case scenarios represented those bounds (Table 6). Under the worst-case scenario, the probability of the effects being negative increase by 47% compared to the historic (1879-1988) base line level with a 39% decline in neutral effects. The best-case scenario output was similar to that for the other time periods.

Uncertainty in model output as measured by entropy (Table 6) was lowest for the past; consistent with expectations and the available information. Entropy estimates among late-century, mid-century, and current periods differed by only 7%, but uncertainty in model output for those time periods was 29-38% greater than for the past. The lack of a most likely-case scenario for the late century period confounds comparisons of entropy estimates with the other times. The best-case scenario was consistently the most uncertain when compared to the other scenario(s) at each time period (Table 6).

3.7.1.9 Sensitivity Analysis

As noted, BBNs can be used to identify the most important input factors affecting model outcome, which can provide guidance for research and management activities. This is usually done through a sensitivity analysis that estimates which input variables have the greatest effect on model output. We found that the sensitivity analysis employed by the Netica© software (entropy reduction) largely emphasized model structure (i.e., nodes with direct links to the outcome node) and CPT specifications. This procedure identified Factor A (Fig.12) and mortality of calves/juveniles on terrestrial haulouts as being important issues with subsistence harvest ranked fifth. We also employed a sampling based sensitivity analysis (varying the states of one node, while holding all other node states constant). Due to the large number of possible combinations of nodes and states (512) we only considered the extreme cases for each node, e.g., high and low (Table 7). The sampling based sensitivity analysis indicated that model outcomes were most sensitive to changes in harvest levels, followed by GHG emissions, predation, disease, shipping, oil and gas development, other removals, and commercial fishing (Table 8).

3.7.1.10 Interpretation of Results

Our BBN model outcomes suggest a strong probability that a combination of stressors will result in negative effects on the Pacific walrus population in the future. Although we did not have a basis for linking the intensity of stressors to a measure of population status, sensitivity analysis provided useful insights into which stressors were likely to have the greatest influence on future population outcomes. The intensity of most stressors acting on the Pacific walrus population is driven primarily by projected changes in sea-ice over time. Setting future harvest levels at low or moderate levels (i.e. sustainable removals) and reducing calf/juvenile mortalities resulted in positive population outcomes. From a management standpoint, managing subsistence harvests for sustainability and reducing disturbance related mortalities at coastal haulouts are examples where mitigation is practical and likely to be effective. In contrast, mitigating the primary stressor associated with Factor A – greenhouse gas emissions – will require comprehensive international agreements (e.g. Huntington 2009).

Table 5. **Model node specifications for each of 4 scenarios for the walrus Bayesian belief network model threats assessment.**

	Scenario			
Node	Past[a]	Current[b]	Mid-century[c]	Late-century[d]
Input nodes				
Green house gas emissions	not an issue	≈400 ppm	≈500 ppm	≈800 ppm
Harvest	high	low-moderate	low to high	low to high
Other removals	low	low	low	low
Disease	low	low	low or moderate	low or moderate
Predation	low	low or moderate	low or moderate	low or moderate
Geographic extent	not applicable	local	local or widespread	local or widespread
Shipping	low	low	low or moderate	low to high
Intermediate nodes				
Summer sea-ice	adequate	predicted[e]	predicted	predicted
Winter sea-ice	adequate	predicted	predicted	predicted
Spring sea-ice	adequate	predicted	predicted	predicted
Ocean conditions	low	predicted	predicted	predicted
Oil and gas development	low	predicted	predicted	predicted
Commercial fishing	low	predicted	predicted	predicted

[a] 1979-1988, for this time period only, the intermediate nodes were treated as input nodes also.

[b] 1989-2010

[c] 2045-2054

[d] 2090-2099

[e] states of these nodes are a function of the input nodes higher in the network.

***Table 6*. Predictions of the Pacific walrus Bayesian belief network model of the probability of the cumulative effects of habitat modification, overutilization, disease or predation, and other man-made or natural factors being negative, neutral, or positive on the Pacific walrus population for time periods and scenarios.**

	Probability of effect on the population		
Time period and scenario	Negative	Neutral	Positive
Past (1979-1988)	0.13	0.74	0.09
Current (1989-2010)			
Most likely-case scenario	0.36	0.48	0.14
Best-case scenario	0.29	0.51	0.20
Worst-case scenario	0.40	0.47	0.13
Mid-century (2045-2054)			
Most likely-case scenario	0.55	0.39	0.06
Best-case scenario	0.34	0.50	0.16
Worst-case scenario	0.55	0.39	0.06
Late-century (2090-2099)			
Best-case scenario	0.37	0.49	0.13
Worst-case scenario	0.60	0.35	0.05

3.7.2 Comparisons with Other Studies

Following the completion of our threats assessment workshop, the USGS released a walrus BBN model in September, 2010 (Jay *et al.* 2010b). The USGS model was ecologically oriented and organized around various stressors affecting walrus population abundance and suitable sea-ice extent in three different seasons, similar to our seasonal ice definitions. The USGS model included sea-ice changes based on Douglas (2010) forecasts, ocean warming and acidification, haulout mortalities, subsistence harvest, oil and gas development, commercial fishing and shipping, air traffic, human settlements, and incidental takes as major stressors. The USGS model expressed model outcomes in terms of the probabilities of walrus population status, characterized as robust, persistent, vulnerable, rare, and extirpated and examined 6 time periods and a limited number of worst-case and best-case scenarios (Jay *et al.* 2010b). For their normative run (most likely-case scenario) the probability of Pacific walruses becoming vulnerable, rare, or extirpated increases over time, from approximately 22 percent in 2050, to about 35 percent by 2075, and 40 percent in 2095 (Jay *et al*. 2010b). The outcomes of the USGS model were similar to those of our analysis in that the effects of the stressors increase with time and harvest and habitat change were identified as having the greatest influence on model outcomes.

3.8 Conclusions

3.8.1 The Present or Threatened Destruction, Modification, or Curtailment of the Species' Habitat or Range

The Pacific walrus is experiencing habitat modification due to a warming climate and loss of summer sea-ice that has not occurred for several thousand years. Projections of future ice conditions generated from global circulation models suggest that the Bering Sea will likely have sufficient amounts of sea-ice during the winter breeding season and spring calving season to support these activities at least through mid-century. By late-century, the location of favorable ice conditions for breeding and calving will likely shift further to the north. Observed and projected ice loss during the summer feeding season is more pronounced, and walruses are expected to become increasingly dependent on coastal haulouts along the Chukchi Sea coast. This shift in habitat use patterns is expected to result in increased mortality levels, particularly among calves, and increased intra-specific competition for food resources in remaining habitat areas within range of coastal haulouts. These factors are expected to result in a population decline over time; however, the magnitude of the decline is unknown. Sensitivity analyses of our BBN model suggest that Global Greenhouse Gas emissions and associated impacts to walrus sea-ice habitats will significantly influence future outcomes of the Pacific walrus population. As the Pacific walrus population becomes increasingly dependent on coastal haulouts, interactions with humans along the coast are also expected to increase. Human activities along the coast including aircraft over-flights, tourism and hunting have been identified as sources of disturbance related mortalities in recent years. The efficacy of future management efforts to protect walruses at coastal haulouts will likely be an important factor that will influence future population outcomes.

The prey base of the Pacific walrus population will also likely be affected by climate change over time. Because physical processes (changes in currents, temperature, pH, sea-ice extent, wind) drive the biological processes and both processes are very complex, scientists are just beginning to hypothesize about potential changes that may occur to the biota in the Arctic. Therefore, although we can conclude that changes to the prey base are likely to occur, we are unable to predict the regional pattern of change, the magnitude of change, how long it will take for the changes to occur, and how those changes will translate to effects on the Pacific walrus population.

3.8.2 Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Walruses are a subsistence resource of considerable importance in Alaska and Chukotka. The size of the Pacific walrus population has fluctuated markedly over the past two centuries in response to varying levels of commercial and subsistence harvests. Walruses are no longer harvested commercially, and current harvest levels are significantly lower than historic highs. Researchers and managers in both countries remain concerned that a population decline caused by observed and projected habitat loss could result in unsustainable harvests if harvest levels do not adjust in concert with changes in population size. Sensitivity analysis of our BBN model suggests that future harvest levels are one of the most important factors that will influence future outcomes of the Pacific walrus population. Research leading to a better understanding of population responses to changing ice conditions and modeling efforts to examine the impact of various removal levels is needed to evaluate the sustainability of harvest levels. The utilization of Pacific walruses for recreational, scientific, and educational purposes occurs at very low levels and is not projected to increase significantly in the future.

3.8.3 Disease or Predation

Diseases and predation do not appear to represent significant threats to the Pacific walrus population at the present time. Although we recognize that a changing climate will likely increase exposure of walruses to new pathogens, this factor was weighted relatively low in our BBN model because we were unable to predict the likelihood or consequences of future exposures. As walruses and polar bears become increasingly dependent on coastal environments during ice free conditions we expect interactions between the two species to increase. Predation rates and associated disturbance related mortalities (particularly among calves and juveniles) are expected to increase in the future, however the rate and extent of such an increase is unknown. The presence of polar bears stranded along the coast during the ice free season is also likely to influence patterns of haulout use, and may play a significant role in the selection of coastal haulout sites in the future. How these interactions will translate into population level effects in the future is unknown.

3.8.4 Inadequacy of Existing Regulatory Mechanisms

Our analysis of existing laws and regulations indicate that there is a diverse network of international, Federal, State and local laws and regulations that provide protection to Pacific walruses and their habitats. Currently, however, there are no effective mechanisms to regulate the global greenhouse gas emissions that are driving—via climate warming—the loss of sea-ice habitats. Our analysis of future sea-ice conditions is based on models and scenarios that do not include additional climate initiatives but do have built-in emission reductions that are substantial.

3.8.5 Other Natural or Human Factors Affecting the Species' Continued Existence

Contaminants, oil and gas industry activities, fisheries, and shipping are presently occurring at modest levels within the range of the Pacific walrus, and do not represent a significant threat to the population at this time. Moderating ice conditions across the range of the Pacific walrus will likely increase exposure to these stressors. Although all of these factors have potential to impact Pacific walruses in the future, we anticipate that future activities will be well regulated, and that any future impacts will be relatively localized. Compared to the observed and predicted habitat changes and harvest, BBN modeling indicated that these factors had relatively minor influence on future population outcomes. The threat of greatest of greatest concern is the potential for a large oil spill associated with oil and gas activities or shipping. While the probability of a large oil spill occurring is relatively low, the impacts of a large oil spill could be significant and long lasting. The propensity of walruses to aggregate in large numbers along the Arctic coast makes them vulnerable to catastrophic events.

3.8.6 Cumulative Effects

We used BBN modeling to organize and examine the cumulative effects of the various listing factors, and determine which threats had the greatest effect on the population. Modeling indicated that the cumulative effects of the various threats will likely increase over time. The intensity of most stressors acting on the Pacific walrus population were influenced by global greenhouse gas emissions and associated impacts to sea-ice habitats. Over time we expect that the cumulative effects of these stressors will result in a population decline; however, we do not have enough information regarding population size, demographics or habitat relationships to quantify the time frame or magnitude of population responses. It is noteworthy that when stressors such as harvest levels and disturbance related mortalities at coastal haulouts were set at low levels, the probability of negative population effects was significantly reduced, suggesting that the effective mitigation of these potential stressors could influence future population outcomes. Continued monitoring and evaluation of population status and trends, as well as habitat assessment (availability and quality), will be critical to evaluate our assumptions, make adjustments as we gain increased understanding, and make direct links among the threats and population performance.

Table 7. **Results of the walrus Bayesian belief network model sensitivity analysis. Due to the large number of possible state combinations (512) only the extreme cases were calculated. See text for node and state definitions**.

Input nodes and states								Probabilities		
Green house gas	Harvest	Other removals	Predation	Disease	Oil and gas extent	Fishing extent	Shipping	-	=	+
current	low	low	low	low	localized	localized	low	29.2	50.5	20.3
current	low	high	low	low	localized	localized	low	29.3	50.6	20.1
current	low	high	high	low	localized	localized	low	31.3	50.5	18.2
current	low	high	high	high	localized	localized	low	32.2	50.5	17.3
current	low	high	high	high	widespread	localized	low	32.1	50.6	17.3
current	low	high	high	high	widespread	widespread	low	32.1	50.5	17.4
current	low	high	high	high	widespread	widespread	high	32.5	50.7	16.8
current	high	low	low	low	localized	localized	low	46.5	44.0	9.6
current	high	high	low	low	localized	localized	low	46.3	44.1	9.6
current	high	high	high	low	localized	localized	low	49.3	42.2	8.5
current	high	high	high	high	localized	localized	low	50.7	41.5	7.8
current	high	high	high	high	widespread	localized	low	50.9	41.2	7.9
current	high	high	high	high	widespread	widespread	low	50.6	41.5	7.9
current	high	high	high	high	widespread	widespread	high	51.1	41.2	7.7
end	low	low	low	low	localized	localized	low	37.7	48.9	13.4
end	low	high	low	low	localized	localized	low	37.8	48.9	13.3
end	low	high	high	low	localized	localized	low	40.1	48.0	11.9
end	low	high	high	high	localized	localized	low	41.2	47.7	11.1
end	low	high	high	high	widespread	localized	low	41.1	47.8	11.1
end	low	high	high	high	widespread	widespread	low	41.1	47.7	11.2
end	low	high	high	high	widespread	widespread	high	41.5	47.7	10.8
end	high	low	low	low	localized	localized	low	57.2	37.1	5.7
end	high	high	low	low	localized	localized	low	57.1	37.2	5.7
end	high	high	high	low	localized	localized	low	60.3	34.7	5.0
end	high	high	high	high	localized	localized	low	61.8	33.7	4.5
end	high	high	high	high	widespread	localized	low	61.7	33.7	4.6
end	high	high	high	high	widespread	widespread	low	61.6	33.8	4.6
end	high	high	high	high	widespread	widespread	high	62.3	33.3	4.4

Table 8. **Summary statistics for the results of the walrus Bayesian belief network model sensitivity analysis. Values are the change in probability estimates for the cumulative effects on the population being negative, neutral, or positive.**

	Effect on the population		
Input node and statistic	negative	neutral	positive
Green house gas emissions			
maximum	11.2	7.9	6.9
minimum	8.5	1.6	3.3
mean (standard error)	9.2(0.4)	4.6(0.7)	4.6(0.5)
Harvest			
maximum	20.8	14.4	10.7
minimum	17.0	6.5	6.4
mean (standard error)	19.3(0.3)	10.9(0.7)	8.4(0.4)
Other removals			
maximum	0.2	0.1	0.2
minimum	0.1	0.0	0.0
mean (standard error)	0.10(0.02)	0.07(0.03)	0.08(0.05)
Predation			
maximum	3.0	1.9	1.9
minimum	1.5	0.1	0.5
mean (standard error)	2.2(0.1)	1.0(0.4)	0.08(0.05)
Disease			
maximum	1.5	1.0	1.1
minimum	0.9	0.0	0.5
mean (standard error)	1.2(0.1)	0.5(0.2)	0.8(0.1)
Oil and gas extent			
maximum	0.2	0.3	0.1
minimum	0.1	0.0	0.0
mean (standard error)	0.12(0.02)	0.13(0.06)	0.05(0.03)
Commercial fishing extent			
maximum	0.3	0.3	0.1
minimum	0.0	0.1	0.0
mean (standard error)	0.10(0.07)	0.15(0.05)	0.05(0.03)
Shipping			
maximum	0.7	0.5	0.6
minimum	0.3	0.0	0.2
mean (standard error)	0.5(0.1)	0.2(0.1)	0.4(0.1)

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APPENDIX A. CONDITIONAL PROBABILITY TABLES FOR THE NODES OF THE WALRUS ESA THREATS ASSESSMENT BAYESIAN BELIEF NETWORK MODEL.

Node: Summer Sea Ice

Input Nodes and States	Node States		
Green house gas emissions	Adequate	Some	None
Current	10	24	66
Mid-century	0	20	80
Late-century	0	10	90

Node: Winter Sea Ice

Input Nodes and States	Node States		
Green house gas emissions	Adequate	Some	None
Current	90	5	5
Mid-century	65	30	5
Late-century	25	60	15

Node: Spring Sea Ice

Input Nodes and States	Node States		
Green house gas emissions	Adequate	Some	None
Current	90	5	5
Mid-century	80	15	5
Late-century	50	40	10

Node: Ocean Condition

Input Nodes and States			Node States		
Green house gas emissions	Summer sea ice	Winter sea ice	High	Moderate	Low
Current	Adequate	Adequat	0	10	90
Current	Adequate	Some	0	10	90
Current	Adequate	None	15	35	50
Current	Some	Adequate	0	10	90

Ocean condition continued.

Current	Some	Some	7.5	22.5	70
Current	Some	None	22.5	47.5	30
Current	None	Adequate	7.5	22.5	70
Current	None	Some	15	35	50
Current	None	None	30	60	10
Mid-century	Adequate	Adequate	3.8	16.3	79.9
Mid-century	Adequate	Some	11.3	28.8	59.9
Mid-century	Adequate	None	22.2	67.8	10
Mid-century	Some	Adequate	11.3	8.8	59.9
Mid-century	Some	Some	6.7	83.3	10
Mid-century	Some	None	37.8	52.2	10
Mid-century	None	Adequate	6.7	83.3	10
Mid-century	None	Some	22.2	67.8	10
Mid-century	None	None	53.3	36.7	10
Late-century	Adequate	Adequate	9.4	25.6	65
Late-century	Adequate	Some	2.8	87.2	10
Late-century	Adequate	None	33.9	56.1	10
Late-century	Adequate	Adequate	2.8	87.2	10
Late-century	Adequate	Some	18.3	71.7	10
Late-century	Adequate	None	49.4	40.6	10
Late-century	Some	Adequate	18.3	71.7	10
Late-century	Some	Some	33.9	56.1	10
Late-century	Some	None	65	25	10

Node: Calf/juvenile mortality

Input Nodes and States	Node States		
Summer sea ice	High	Medium	Low
Adequate	5	5	90
Some	50	30	20
None	80	10	10

Node: Walrus prey

Input Nodes and States		Node States		
Summer sea ice	Ocean condition	High	Medium	Low
Adequate	High	10	60	30
Adequate	Medium	45	35	20
Adequate	Low	80	10	10
Some	High	10	35	55
Some	Medium	10	60	30
Some	Low	45	35	20

Walrus prey node continued.

None	High	10	10	80
None	Medium	10	35	55
None	Low	10	60	30

Node: Habitat Modification

Input Nodes and States				Node States		
Summer sea ice	Winter sea ice	Walrus prey	Spring sea ice	High	Moderate	Low
Adequate	Adequate	Low	Adequate	15	35	50
Adequate	Adequate	Low	Some	16.7	40	43.3
Adequate	Adequate	Low	None	18.3	45	36.7
Adequate	Adequate	Medium	Adequate	10	20	70
Adequate	Adequate	Medium	Some	11.7	25	63.3
Adequate	Adequate	Medium	None	13.3	30	56.7
Adequate	Adequate	High	Adequate	5	5	90
Adequate	Adequate	High	Some	32	32	36
Adequate	Adequate	High	None	32	32	36
Adequate	Some	Low	Adequate	18.3	45	36.7
Adequate	Some	Low	Some	20	50	30
Adequate	Some	Low	None	21.7	55	23.3
Adequate	Some	Medium	Adequate	13.3	30	56.7
Adequate	Some	Medium	Some	15	35	50
Adequate	Some	Medium	None	16.7	40	43.3
Adequate	Some	High	Adequate	8.3	15	76.7
Adequate	Some	High	Some	10	20	70
Adequate	Some	High	None	11.7	25	63.3
Adequate	None	Low	Adequate	21.7	55	23.3
Adequate	None	Low	Some	33.3	41.1	25.6
Adequate	None	Low	None	40	36.7	23.3
Adequate	None	Medium	Adequate	16.7	40	43.3
Adequate	None	Medium	Some	18.3	45	36.7
Adequate	None	Medium	None	20	50	30
Adequate	None	High	Adequate	11.7	25	63.3
Adequate	None	High	Some	13.3	30	56.7
Adequate	None	High	None	15	35	50
Some	Adequate	Low	Adequate	20	50	30
Some	Adequate	Low	Some	21.7	55	23.3
Some	Adequate	Low	None	33.3	41.1	25.6
Some	Adequate	Medium	Adequate	15	35	50
Some	Adequate	Medium	Some	16.7	40	43.3
Some	Adequate	Medium	None	18.3	45	36.7

Habitat modification node continued.

Some	Adequate	High	Adequate	10	20	70
Some	Adequate	High	Some	11.7	25	63.3
Some	Adequate	High	None	13.3	30	56.7
Some	Some	Low	Adequate	33.3	41.1	25.6
Some	Some	Low	Some	40	36.7	23.3
Some	Some	Low	None	46.7	32.2	21.1
Some	Some	Medium	Adequate	18.3	45	36.7
Some	Some	Medium	Some	20	50	30
Some	Some	Medium	None	26.7	45.6	27.7
Some	Some	High	Adequate	13.3	30	56.7
Some	Some	High	Some	15	35	50
Some	Some	High	None	16.7	40	43.3
Some	None	Low	Adequate	46.7	32.2	21.1
Some	None	Low	Some	53.3	27.8	18.9
Some	None	Low	None	60	23.3	16.7
Some	None	Medium	Adequate	26.7	45.6	27.7
Some	None	Medium	Some	33.3	41.1	25.6
Some	None	Medium	None	40	36.7	23.3
Some	None	High	Adequate	16.7	40	43.3
Some	None	High	Some	13.3	54.4	32.3
Some	None	High	None	20	50	30
None	Adequate	Low	Adequate	40	36.7	23.3
None	Adequate	Low	Some	46.7	32.2	21.1
None	Adequate	Low	None	53.3	27.8	18.9
None	Adequate	Medium	Adequate	20	50	30
None	Adequate	Medium	Some	26.7	45.6	27.7
None	Adequate	Medium	None	33.3	41.1	25.6
None	Adequate	High	Adequate	15	35	50
None	Adequate	High	Some	16.7	40	43.3
None	Adequate	High	None	13.3	54.4	32.3
None	Some	Low	Adequate	53.3	27.8	18.9
None	Some	Low	Some	60	23.3	16.7
None	Some	Low	None	66.7	18.9	14.4
None	Some	Medium	Adequate	33.3	41.1	25.6
None	Some	Medium	Some	40	36.7	23.3
None	Some	Medium	None	46.7	32.2	21.1
None	Some	High	Adequate	13.3	54.4	32.3
None	Some	High	Some	20	50	30
None	Some	High	None	26.7	45.6	27.7
None	None	Low	Adequate	66.7	18.9	14.4
None	None	Low	Some	73.3	14.4	12.3
None	None	Low	None	80	10	10

Habitat modification continued.

None	None	Medium	Adequate	46.7	32.2	21.1
None	None	Medium	Some	53.3	27.8	18.9
None	None	Medium	None	60	23.3	16.7
None	None	High	Adequate	26.7	45.6	27.7
None	None	High	Some	33.3	41.1	25.6
None	None	High	None	40	36.7	23.3

Node: Overutilization

Input Nodes and States		Node States		
Harvest	Other removals	Above	At	Below
High	High	80	10	10
High	Moderate	80	10	10
High	Low	79.9	10.1	10
Moderate	High	30	40	30
Moderate	Moderate	30	40	30
Moderate	Low	30	40	30
Low	High	1.1	4.1	94.8
Low	Moderate	1	4	95
Low	High	1	4	95

Node: Disease and Predation

Input Nodes and States		Node States		
Disease	Predation	High	Moderate	Low
High	High	90	5	5
High	Moderate	50	28.3	21.7
High	Low	10	51.7	38.3
Moderate	High	70	16.7	13.3
Moderate	Moderate	30	40	30
Moderate	Low	13.3	16.7	70
Low	High	38.3	51.7	10
Low	Moderate	21.7	28.3	50
Low	High	5	5	90

Node: Oil and Gas Development

Input Nodes and States	Node States		
Geographic extent	High	Medium	Low
Widespread	0	5	95
Localized	10	5	85

Node: Commercial Fishing

Input Nodes and States	Node States		
Geographic extent	High	Medium	Low
Widespread	0	0	100
Localized	0	10	90

Node: Other factors

Input Nodes and States			Node States		
Shipping	Oil and gas development	Commercial fishing	High	Moderate	Low
High	High	High	98	1	1
High	High	Moderate	78.5	14.1	7.4
High	High	Low	59.1	27.1	13.8
High	Medium	High	59.1	27.1	13.8
High	Medium	Moderate	39.6	40.2	20.2
High	Medium	Low	20.1	53.3	26.6
High	Low	High	20.1	53.3	26.6
High	Low	Moderate	0.7	66.3	33
High	High	Low	13	25.5	61.5
Medium	High	High	83.4	10.8	5.8
Medium	High	Moderate	63.9	23.9	12.2
Medium	High	Low	44.5	36.9	18.6
Medium	Medium	High	44.5	36.9	18.6
Medium	Medium	Moderate	25	50	25
Medium	Medium	Low	19.7	39.1	41.2
Medium	Low	High	5.5	63.1	31.4
Medium	Low	Moderate	14.3	28.2	57.5
Medium	Low	Low	9	17.3	73.7
Low	High	High	33	66.3	0.7
Low	High	Moderate	27.7	55.4	16.9
Low	High	Low	22.3	44.6	33.1

Other factors continued.

Low	Medium	High	22.3	44.6	33.1
Low	Medium	Moderate	17	33.7	49.3
Low	Medium	Low	11.7	22.8	65.5
Low	Low	High	11.7	22.8	65.5
Low	Low	Moderate	6.3	11.9	81.8
Low	Low	Low	1	1	98

Node: Effect on the Population

Input Nodes and States					Node States		
Habitat modification	Overutilization	Disease and predation	Other factors	Calf/juvenile mortality	Negative	Neutral	Positive
High	Above	High	High	High	95	5	0
High	Above	High	High	Medium	83.3	15.7	1
High	Above	High	High	Low	71.6	26.5	1.9
High	Above	High	Moderate	High	93.5	6.3	0.2
High	Above	High	Moderate	Medium	81.8	17.1	1.1
High	Above	High	Moderate	Low	70.1	27.8	2.1
High	Above	High	Low	High	92.1	7.7	0.2
High	Above	High	Low	Medium	80.4	18.4	1.2
High	Above	High	Low	Low	68.7	29.1	2.2
High	Above	Moderate	High	High	92.1	7.7	0.2
High	Above	Moderate	High	Medium	80.4	18.4	1.2
High	Above	Moderate	High	Low	68.7	29.1	2.2
High	Above	Moderate	Moderate	High	90.6	9	0.4
High	Above	Moderate	Moderate	Medium	78.9	19.8	1.3
High	Above	Moderate	Moderate	Low	67.2	30.5	2.3
High	Above	Moderate	Low	High	89.1	10.4	0.5
High	Above	Moderate	Low	Medium	77.4	21.1	1.5
High	Above	Moderate	Low	Low	65.7	31.8	2.5
High	Above	Low	High	High	89.1	10.4	0.5
High	Above	Low	High	Medium	77.4	21.1	1.5
High	Above	Low	High	Low	65.7	31.8	2.5
High	Above	Low	Moderate	High	87.7	11.7	0.6
High	Above	Low	Moderate	Medium	76	22.4	1.6
High	Above	Low	Moderate	Low	64.3	33.2	2.5
High	Above	Low	Low	High	86.2	13	0.8

Effect on the population continued.

High	Above	Low	Low	Medium	74.5	23.8	1.7
High	Above	Low	Low	Low	62.8	34.5	2.7
High	At	High	High	High	80.4	18.4	1.2
High	At	High	High	Medium	68.7	29.1	2.2
High	At	High	High	Low	57	39.9	3.1
High	At	High	Moderate	High	78.9	19.8	1.3
High	At	High	Moderate	Medium	67.2	30.5	2.3
High	At	High	Moderate	Low	55.5	41.2	3.3
High	At	High	Low	High	77.4	21.1	1.5
High	At	High	Low	Medium	65.7	31.8	2.5
High	At	High	Low	Low	54	42.6	3.4
High	At	Moderate	High	High	77.4	21.1	1.5
High	At	Moderate	High	Medium	65.7	31.8	2.5
High	At	Moderate	High	Low	54	42.6	3.4
High	At	Moderate	Moderate	High	76	22.4	1.6
High	At	Moderate	Moderate	Medium	64.3	33.2	2.5
High	At	Moderate	Moderate	Low	52.6	43.9	3.5
High	At	Moderate	Low	High	74.5	23.8	1.7
High	At	Moderate	Low	Medium	62.8	34.5	2.7
High	At	Moderate	Low	Low	51.1	45.2	3.7
High	At	Low	High	High	74.5	23.8	1.7
High	At	Low	High	Medium	62.8	34.5	2.7
High	At	Low	High	Low	51.1	45.2	3.7
High	At	Low	Moderate	High	73	25.1	1.9
High	At	Low	Moderate	Medium	61.3	35.9	2.8
High	At	Low	Moderate	Low	49.6	46.6	3.8
High	At	Low	Low	High	71.6	26.5	1.9
High	At	Low	Low	Medium	59.9	37.2	2.9
High	At	Low	Low	Low	48.2	47.9	3.9
High	Below	High	High	High	65.7	31.8	2.5

Effect on the population continued.

High	Below	High	High	Medium	54	42.6	3.4
High	Below	High	High	Low	42.3	53.3	4.4
High	Below	High	Moderate	High	64.3	33.2	2.5
High	Below	High	Moderate	Medium	52.6	43.9	3.5
High	Below	High	Moderate	Low	40.9	54.6	4.5
High	Below	High	Low	High	62.8	34.5	2.7
High	Below	High	Low	Medium	51.1	45.2	3.7
High	Below	High	Low	Low	39.4	56	4.6
High	Below	Moderate	High	High	62.8	34.5	2.7
High	Below	Moderate	High	Medium	51.1	45.2	3.7
High	Below	Moderate	High	Low	39.4	56	4.6
High	Below	Moderate	Moderate	High	61.3	35.9	2.8
High	Below	Moderate	Moderate	Medium	49.6	46.6	3.8
High	Below	Moderate	Moderate	Low	37.9	57.3	4.8
High	Below	Moderate	Low	High	59.9	37.2	2.9
High	Below	Moderate	Low	Medium	48.2	47.9	3.9
High	Below	Moderate	Low	Low	36.5	58.7	4.8
High	Below	Low	High	High	59.9	37.2	2.9
High	Below	Low	High	Medium	48.2	47.9	3.9
High	Below	Low	High	Low	36.5	58.7	4.8
High	Below	Low	Moderate	High	58.4	38.5	3.1
High	Below	Low	Moderate	Medium	46.7	49.3	4
High	Below	Low	Moderate	Low	35	60	5
High	Below	Low	Low	High	57	39.9	3.1
High	Below	Low	Low	Medium	45.2	50.6	4.2
High	Below	Low	Low	Low	33.5	61.3	5.2
Moderate	Above	High	High	High	65.7	31.8	2.5
Moderate	Above	High	High	Medium	54	42.6	3.4
Moderate	Above	High	High	Low	42.3	53.3	4.4
Moderate	Above	High	Moderate	High	64.3	33.2	2.5

Effect on the population continued.

Moderate	Above	High	Moderate	Medium	52.6	43.9	3.5
Moderate	Above	High	Moderate	High	40.9	54.6	4.5
Moderate	Above	High	Low	high	62.8	34.5	2.7
Moderate	Above	High	Low	Medium	51.1	45.2	3.7
Moderate	Above	High	Low	Low	39.4	56	4.6
Moderate	Above	Moderate	High	High	62.8	34.5	2.7
Moderate	Above	Moderate	High	Medium	51.1	45.2	3.7
Moderate	Above	Moderate	High	Low	39.4	56	4.6
Moderate	Above	Moderate	Moderate	High	61.3	35.9	2.8
Moderate	Above	Moderate	Moderate	Medium	49.6	46.6	3.8
Moderate	Above	Moderate	Moderate	Low	37.9	57.3	4.8
Moderate	Above	Moderate	Low	High	59.9	37.2	2.9
Moderate	Above	Moderate	Low	Medium	48.2	47.9	3.9
Moderate	Above	Moderate	Low	Low	35.7	60.4	3.9
Moderate	Above	Low	High	High	59.9	37.2	2.9
Moderate	Above	Low	High	Medium	48.2	47.9	3.9
Moderate	Above	Low	High	Low	36.5	58.7	4.8
Moderate	Above	Low	Moderate	High	58.4	38.5	3.1
Moderate	Above	Low	Moderate	Medium	46.7	49.3	4
Moderate	Above	Low	Moderate	Low	35	60	5
Moderate	Above	Low	Low	High	57	39.9	3.1
Moderate	Above	Low	Low	Medium	37	63	0
Moderate	Above	Low	Low	Low	34.3	59.6	6.1
Moderate	At	High	High	High	51.1	45.2	3.7
Moderate	At	High	High	Medium	39.4	56	4.6
Moderate	At	High	High	Low	27.7	66.7	5.6
Moderate	At	High	Moderate	High	49.6	46.6	3.8
Moderate	At	High	Moderate	Medium	37.9	57.3	4.8
Moderate	At	High	Moderate	Low	26.2	68	5.8
Moderate	At	High	Low	High	48.2	47.9	3.9

Effect on the population continued.

Moderate	At	High	Low	Medium	36.5	58.7	4.8
Moderate	At	High	Low	Low	29.9	57.4	12.7
Moderate	At	Moderate	High	High	48.2	47.9	3.9
Moderate	At	Moderate	High	Medium	36.5	58.7	4.8
Moderate	At	Moderate	High	Low	24.8	69.4	5.8
Moderate	At	Moderate	Moderate	High	46.7	49.3	4
Moderate	At	Moderate	Moderate	Medium	35	60	5
Moderate	At	Moderate	Moderate	Low	29.1	57.1	13.8
Moderate	At	Moderate	Low	High	45.2	50.6	4.2
Moderate	At	Moderate	Low	Medium	34.3	59.6	6.1
Moderate	At	Moderate	Low	Low	28.4	56.7	14.9
Moderate	At	Low	High	High	45.2	50.6	4.2
Moderate	At	Low	High	Medium	33.5	61.3	5.2
Moderate	At	Low	High	Low	28.4	56.7	14.9
Moderate	At	Low	Moderate	High	43.8	52	4.2
Moderate	At	Low	Moderate	Medium	33.5	59.3	7.2
Moderate	At	Low	Moderate	Low	27.7	56.3	16
Moderate	At	Low	Low	High	38	62	0
Moderate	At	Low	Low	Medium	32.8	58.9	8.3
Moderate	At	Low	Low	Low	27	56	17
Moderate	Below	High	High	High	36.5	58.7	4.8
Moderate	Below	High	High	Medium	24.8	69.4	5.8
Moderate	Below	High	High	Low	13	80.1	6.9
Moderate	Below	High	Moderate	High	35	60	5
Moderate	Below	High	Moderate	Medium	23.3	70.7	6
Moderate	Below	High	Moderate	Low	23.3	54.1	22.6
Moderate	Below	High	Low	High	33.5	61.3	5.2
Moderate	Below	High	Low	Medium	28.4	56.7	14.9
Moderate	Below	High	Low	Low	22.6	53.8	23.6
Moderate	Below	Moderate	High	High	33.5	61.3	5.2

Effect on the population continued.

Moderate	Below	Moderate	High	Medium	21.8	72.1	6.1
Moderate	Below	Moderate	High	Low	22.6	53.8	23.6
Moderate	Below	Moderate	Moderate	High	32.1	62.7	5.2
Moderate	Below	Moderate	Moderate	Medium	27.7	56.3	16
Moderate	Below	Moderate	Moderate	Low	21.8	53.4	24.8
Moderate	Below	Moderate	Low	High	32.8	58.9	8.3
Moderate	Below	Moderate	Low	Medium	27	56	17
Moderate	Below	Moderate	Low	Low	21.1	53	25.9
Moderate	Below	Low	High	High	30.6	64	5.4
Moderate	Below	Low	High	Medium	27	56	17
Moderate	Below	Low	High	Low	21.1	53	25.9
Moderate	Below	Low	Moderate	High	32.1	58.5	9.4
Moderate	Below	Low	Moderate	Medium	26.2	55.6	18.2
Moderate	Below	Low	Moderate	Low	20.4	52.7	26.9
Moderate	Below	Low	Low	High	31.3	58.2	10.5
Moderate	Below	Low	Low	Medium	25.5	55.2	19.3
Moderate	Below	Low	Low	Low	19.6	52.3	28.1
Low	Above	High	High	High	35.7	60.4	3.9
Low	Above	High	High	Medium	29.9	57.4	12.7
Low	Above	High	High	Low	24	54.5	21.5
Low	Above	High	Moderate	High	35	60	5
Low	Above	High	Moderate	Medium	29.1	57.1	13.8
Low	Above	High	Moderate	Low	23.3	54.1	22.6
Low	Above	High	Low	High	34.3	59.6	6.1
Low	Above	High	Low	Medium	28.4	56.7	14.9
Low	Above	High	Low	Low	22.6	53.8	23.6
Low	Above	Moderate	Low	High	34.3	59.6	6.1
Low	Above	Moderate	Low	Medium	28.4	56.7	14.9
Low	Above	Moderate	Low	Low	22.6	53.8	23.6
Low	Above	Moderate	Moderate	High	33.5	59.3	7.2

Effect on the population continued.

Low	Above	Moderate	Moderate	Medium	27.7	56.3	16
Low	Above	Moderate	Moderate	Low	21.8	53.4	24.8
Low	Above	Moderate	Low	High	32.8	58.9	8.3
Low	Above	Moderate	Low	Medium	27	56	17
Low	Above	Moderate	Low	Low	21.1	53	25.9
Low	Above	Low	High	High	32.8	58.9	8.3
Low	Above	Low	High	Medium	27	56	17
Low	Above	Low	High	Low	21.1	53	25.9
Low	Above	Low	Moderate	High	32.1	58.5	9.4
Low	Above	Low	Moderate	Medium	26.2	55.6	18.2
Low	Above	Low	Moderate	Low	20.4	52.7	26.9
Low	Above	Low	Low	High	31.3	58.2	10.5
Low	Above	Low	Low	Medium	25.5	55.2	19.3
Low	Above	Low	Low	Low	19.6	52.3	28.1
Low	At	High	High	High	28.4	56.7	14.9
Low	At	High	High	Medium	22.6	53.8	23.6
Low	At	High	High	Low	16.7	50.9	32.4
Low	At	High	Moderate	High	27.7	56.3	16
Low	At	High	Moderate	Medium	21.8	53.4	24.8
Low	At	High	Moderate	Low	16	50.5	33.5
Low	At	High	Low	High	27	56	17
Low	At	High	Low	Medium	21.1	53	25.9
Low	At	High	Low	Low	15.2	50.1	34.7
Low	At	Moderate	High	High	27	56	17
Low	At	Moderate	High	Medium	21.1	53	25.9
Low	At	Moderate	High	Low	15.2	50.1	34.7
Low	At	Moderate	Moderate	High	26.2	55.6	18.2
Low	At	Moderate	Moderate	Medium	20.4	52.7	26.9
Low	At	Moderate	Moderate	Low	14.5	49.8	35.7
Low	At	Moderate	Low	High	25.5	55.2	19.3

Effect on the population continued.

Low	At	Moderate	Low	Medium	19.6	52.3	28.1
Low	At	Moderate	Low	Low	13.8	49.4	36.8
Low	At	Low	High	High	25.5	55.2	19.3
Low	At	Low	High	Medium	19.6	52.3	28.1
Low	At	Low	High	Low	13.8	49.4	36.8
Low	At	Low	Moderate	High	24.8	54.9	20.3
Low	At	Low	Moderate	Medium	18.9	52	29.1
Low	At	Low	Moderate	Low	13	49	38
Low	At	Low	Low	High	24	54.5	21.5
Low	At	Low	Low	Medium	18.2	51.6	30.2
Low	At	Low	Low	Low	12.3	48.7	39
Low	Below	High	High	High	21.1	53	25.9
Low	Below	High	High	Medium	15.2	50.1	34.7
Low	Below	High	High	Low	9.4	47.2	43.4
Low	Below	High	Moderate	High	20.4	52.7	26.9
Low	Below	High	Moderate	Medium	14.5	49.8	35.7
Low	Below	High	Moderate	Low	8.7	46.8	44.5
Low	Below	High	Low	High	19.6	52.3	28.1
Low	Below	High	Low	Medium	13.8	49.4	36.8
Low	Below	High	Low	Low	7.9	46.5	45.6
Low	Below	Moderate	High	High	19.6	52.3	28.1
Low	Below	Moderate	High	Medium	13.8	49.4	36.8
Low	Below	Moderate	High	Low	7.9	46.5	45.6
Low	Below	Moderate	Moderate	High	18.9	52	29.1
Low	Below	Moderate	Moderate	Medium	13	49	38
Low	Below	Moderate	Moderate	Low	7.2	46.1	46.7
Low	Below	Moderate	Low	High	18.2	51.6	30.2
Low	Below	Moderate	Low	Medium	12.3	48.7	39
Low	Below	Moderate	Low	Low	6.5	45.7	47.8
Low	Below	Low	High	High	18.2	51.6	30.2

Effect on the population continued.

Low	Below	Low	High	Medium	12.3	48.7	39
Low	Below	Low	High	Low	6.5	45.7	47.8
Low	Below	Low	Moderate	High	17.4	51.2	31.4
Low	Below	Low	Moderate	Medium	11.6	48.3	40.1
Low	Below	Low	Moderate	Low	5.7	45.4	48.9
Low	Below	Low	Low	High	16.7	50.9	32.4
Low	Below	Low	Low	Medium	10.9	47.9	41.2
Low	Below	Low	Low	Low	5	45	50