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Status Review of the Spotted Seal (*Phoca largha*)

by
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STATUS REVIEW OF THE SPOTTED SEAL (*Phoca largha*)

NOAA photo by Michael Cameron

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EXECUTIVE SUMMARY

This status review is intended to be a compilation of the best available information concerning the status of spotted seals (*Phoca largha*), including the past, present, and future threats to this species. It was compiled by a National Oceanic and Atmospheric Administration (NOAA) Biological Review Team (BRT) in response to a petition filed by the Center for Biological Diversity to list the spotted seal as threatened or endangered under the U.S. Endangered Species Act (ESA) (16 U.S.C. 1531 et seq.), primarily due to concern about threats to this species' habitat from climate warming and loss of sea ice.

There are two key tasks associated with conducting an ESA status review: The first is to delineate the taxonomic group under consideration; the second is to conduct an extinction risk assessment for support of a determination of whether the species is threatened or endangered. The ESA defines the term *endangered species* as "any species which is in danger of extinction throughout all or a significant portion of its range". The term *threatened species* is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range". The BRT considered the time frames over which threats to spotted seals – and their response to those threats – are foreseeable, and concluded that there is no scientific basis for a single time frame that defines the foreseeable future. The threats of primary concern, stemming from rising greenhouse gas (GHG) concentrations and the associated warming climate, have been projected from climate models for the 21st century and were thus evaluated over that time frame. The scientific literature as well as recent, yet-to-be published research results were reviewed and summarized to support the extinction risk assessment of this rather poorly understood species.

Species Background: The spotted seal is a member of the pinniped family Phocidae that is similar in appearance to its close relative, the widely-distributed harbor seal (*Phoca vitulina*). Spotted seals breed in the Yellow Sea, Sea of Japan, Sea of Okhotsk, and Bering Sea. This species is primarily associated with sea ice during its whelping, nursing, mating, and pelage molt periods, though in some places these functions take place on shore. These functions occur earliest (January-April) in the Yellow Sea, and latest (April-June) in the Bering Sea. Most spotted seals spend the rest of the year making periodic foraging trips from haul-out sites ashore or on sea ice. The vital rates of survival and reproduction are not well known. Both sexes usually reach maturity at about 4-5 years of age, and most mature females give birth to a single pup annually. Spotted seals may live to 30-35 years of age. They consume a broad variety of mostly fishes and some crustaceans and cephalopods, taken from waters over the continental shelves and shelf breaks.

Species Delineation: Eight main areas of spotted seal breeding have been reported. On the basis of small samples and preliminary analyses of genetic composition, potential geographic barriers, and significance of breeding groups, the species was divided into three Distinct Population Segments (DPSs): The Bering DPS; the Okhotsk DPS; and the Southern DPS, which is composed of the spotted seals breeding in the Yellow Sea and Peter the Great Bay in the Sea of Japan. These were considered separately whenever there was sufficient information to assess the risks specific to each DPS.

Extinction Risk Assessment: To assess the extinction risk, the BRT evaluated the specific threats faced by the species, as outlined in Section 4(a)(1) of the ESA:

- the present or threatened destruction, modification, or curtailment of its habitat or range,
- overutilization for commercial, recreational, scientific, or educational purposes,
- disease or predation,
- the inadequacy of existing regulatory mechanisms, or
- other natural or manmade factors affecting its continued existence

The risks posed by these threats were then assessed in terms of their implications for demographic factors, such as abundance, productivity, spatial structure, and diversity.

Present or threatened destruction, modification, or curtailment of the species' habitat or range: The main concern about the conservation status of spotted seals stems from the likelihood that their sea-ice habitat has been modified by the warming climate and, more so, that the scientific consensus projections are for continued and perhaps accelerated warming in the foreseeable future. A second major concern, related by the common driver of carbon dioxide (CO_2) emissions, is the modification of habitat by ocean acidification, which may alter prey populations and other important aspects of the marine ecosystem. A reliable assessment of the future conservation status of each spotted seal DPS requires a focus on projections of specific regional conditions, especially sea ice.

In contrast to the Arctic Ocean, where sea ice is present year-round, the ice in the sub-Arctic seas of the spotted seal breeding range is seasonal in nature. Despite the recent dramatic reductions in Arctic Ocean ice extent during summer, the sea ice in the Bering Sea is expected to continue forming annually in winter for the foreseeable future, based on consensus (but still highly uncertain) projections through the 21st century. The sea-ice regime will continue to be subject to large interannual variations in extent and seasonal duration, as it has throughout recorded history. There will likely be more frequent years in which ice coverage is reduced, resulting in a decline in the long-term average ice extent, but Bering Sea spotted seals will likely continue to encounter sufficient ice to support adequate vital rates. Even if sea ice were to vanish completely from the Bering Sea, there may be prospects for spotted seals to adjust their breeding grounds to follow the northward shift of the annual ice front into the Chukchi Sea.

For the Sea of Okhotsk, Sea of Japan, and Yellow Sea, current global climate models for sea ice do not perform satisfactorily. Inference about future ice conditions in these areas was drawn indirectly from projections of air or sea surface temperatures, and thus has even greater uncertainty than the projections for the Bering Sea. All three regions are likely to experience sufficient warming by the latter half of the 21st century that ice conditions will be significantly compromised in extent or duration during the important months for spotted seal pup suckling and pup maturation. In the Southern DPS, this may already occur on a regular basis, as much of the breeding now takes place ashore on rocks and small islands. There is no prospect in the Okhotsk or Southern DPS for long-term shifts of the breeding range into the Arctic Ocean because these areas have no northern marine connectivity to the Arctic.

Ocean acidification, a result of increased carbon dioxide in the atmosphere, may impact spotted seal survival and recruitment through disruption of trophic regimes that are dependent on calcifying organisms. The nature and timing of such impacts are extremely uncertain. Because of spotted seals' apparent dietary flexibility, this threat should be of less immediate concern than the direct effects of sea-ice degradation.

Changes in spotted seal prey, anticipated in response to ocean warming and loss of sea ice, have the potential for negative impacts, but the possibilities are complex. Some changes already documented in the Bering Sea and the North Atlantic Ocean are of a nature that could be ameliorative or beneficial to spotted seals. For example, several fish species, including walleye pollock (*Theragra chalcogramma*), a common spotted seal prey, have shown northward distribution shifts and increased recruitment in response to warming, at least initially. These ecosystem responses may have very long lags as they propagate through trophic webs. Apparent flexibility in spotted seal foraging locations and habits may make these threats of lower concern than more direct impacts from changes in sea ice.

Overutilization for commercial, subsistence, recreational, scientific, or educational purposes: Recreational, scientific, and educational utilization of spotted seals is currently at low levels and is not projected to increase to significant threat levels in the foreseeable future for any of the DPSs. Commercial harvests by Soviet sealers were at moderate levels from the mid-1950s to the early 1990s. Russia has established harvest quotas in recent years but no significant numbers have been taken because of poor economic viability of the hunt. Subsistence harvest levels have been moderate historically in both the Bering and Okhotsk DPS but are not anticipated to increase significantly.

Diseases, parasites, and predation: A variety of pathogens (or antibodies), diseases, helminthes, cestodes, and nematodes, have been found in spotted seals. The prevalence of these agents is not unusual among seals, but the population impact is unknown. There may be an increased risk of outbreaks of novel pathogens or parasites as climate-related shifts in species distributions lead to new modes of transmission. There is little or no direct evidence of significant predation on spotted seals and they are not thought to be a primary prey of any predators. Polar bears (*Ursus maritimus*) and killer whales (*Orcinus orca*) may be the most likely opportunistic predators in the current sea-ice regime, but walruses (*Odobenus rosmarus*) could pose a potentially greater risk if reduced sea-ice conditions force these pagophilic species into closer proximity in the future. Also predation risk could increase if loss of sea ice requires spotted seals to spend more time in the water or more time ashore.

Inadequacy of existing regulatory mechanisms: There are currently no effective mechanisms to regulate GHG emissions domestically or internationally. The BRT did not attempt to separate the risk posed by the lack of a regulatory mechanism for GHG emissions from the risks posed by the effects of the emissions. The risks posed by future GHG emissions, via potential destruction or modification of spotted seal habitat, were assessed as described above by evaluating the best available projections of future conditions under scenarios of no regulation of GHGs (the projections were based on "non-mitigated" scenarios for future emissions). Therefore, the implications of the current lack of regulations are already included in the evaluation of risks to spotted seal habitat in the three DPSs. The inadequacy of existing regulatory mechanisms poses no additional threat to any of the spotted seal DPSs. In other words, while there are no regulatory mechanisms that effectively address reductions in sea ice habitat or ocean acidification, we do not expect this shortcoming to result in population-level impacts beyond those already identified in the section on present or threatened destruction of habitat.

Inadequacy or lack of stringency of mechanisms to regulate oil and gas activities in the Yellow Sea and Sea of Okhotsk could contribute to the cumulative risk faced by the Southern and Okhotsk DPSs.

Other natural or human factors affecting the species' continued existence: Risks could be significant to the Southern and Okhotsk DPSs from petroleum exploration, development, and production activities because these activities are already underway in those areas. Potentially significant interactions with commercial fisheries may pose significant risks, as well.

Conclusions:

Bering DPS: The primary threats faced by spotted seals in the Bering Sea are likely to be climate-related changes to the sea-ice habitat and to the prey community. Sea ice is expected to decline such that the average extent in May, during the latter half of the period for nursing and initial independent development of pups, is limited to areas north of St. Lawrence Island by about the middle of the 21st century. There will, however, likely continue to be large interannual variations of nearly the same magnitude as in the past, so that some years will have very extensive ice and others will have very low ice extent. The low ice years, which will come more frequently than in the past, may have impacts on recruitment, primarily through pup survival. On the other hand, some aspects of reduced ice may be beneficial to spotted seals, mitigating the impacts of low ice years. This is possible because of the prospect that thinner and more broken ice is likely to occur over large areas of the northern Bering Sea and Chukchi Sea that are currently too densely covered to be suitable for spotted seal breeding. The impacts of ocean acidification, the other significant climate-related threat to spotted seals, are even less predictable than the impacts of sea-ice reduction. Spotted seals, like other ice-associated species, are adapted for coping with large ranges of variability in conditions. There is currently no quantitative basis for determining whether the climate-related habitat impacts will outweigh the mitigating factors.

No other threats were thought to pose significant demographic risks to the Bering DPS. A large population (at least 100,000) has persisted over the past several decades with no conspicuous extreme fluctuations. The suite of risks from overutilization, disease and predation, inadequacy of regulatory mechanisms, and other natural or human factors is not anticipated to change sufficiently to place the Bering DPS at risk of extinction within the foreseeable future.

Okhotsk DPS: The threats faced by spotted seals in the Sea of Okhotsk are the same as to those in the Bering Sea, but the projections of future climate-related habitat conditions are less certain. In consideration of observed climatology and projected air temperatures, much of the region may have ice-deteriorating conditions in April by the mid-21st century. This region is characterized by some differences from the Bering Sea that may be significant to the status of spotted seals. The ice-covered area is smaller in the Sea of Okhotsk and there is no marine connection to the Arctic Ocean, unlike in the Bering Sea. Over the very long term, spotted seals in the Sea of Okhotsk do not have the prospect of following a retreating ice front northward into the Arctic, as Bering Sea spotted seals would. There is currently no basis to judge whether ocean acidification will be any more severe or rapid in the Sea of Okhotsk than in other parts of the North Pacific, so the impact from that threat is no more predictable than for the other spotted seal DPSs.

Although most of the other risks are expected to be similarly low between the Bering and Okhotsk DPSs, the risks associated with petroleum exploration, development, and production are likely to be significantly greater in the Okhotsk DPS. Oil production and further development in the Sea of Okhotsk are well underway and likely to be less stringently regulated than similar activities that are as yet only proposed for the Bering and Chukchi Seas (at least in U.S. waters). Commercial fishery interactions, either direct or indirect, also may pose a significant risk in the Okhotsk DPS. Together, these risks and the climate-related risks summarized above could have substantial cumulative effects.

The demographic status of the Okhotsk DPS is less certain than the Bering DPS, but large numbers (as high as 268,000) of spotted seals were reported in the late-1960s to 1990. No conspicuous extreme changes are known to have occurred more recently. Even if the population was typically overestimated by a factor of 2, there would likely be approximately 100,000 spotted seals currently in the Okhotsk DPS, so that demographic and genetic risks from low abundance should not be a significant concern.

Southern DPS: Although there is great uncertainty in projecting sea-ice conditions for the Yellow Sea and Sea of Japan, sea-ice formation in the recent past has already been greatly reduced, and indirect evidence from air and sea surface temperature modeling suggests that seasonal ice will rarely form in these areas by about the middle of the 21st century. The species appears to have some capability to accomplish breeding and molting on shore when ice is not available. However, pinnipeds are generally not well protected from predation when they are constrained by the necessity of maintaining a mother-pup bond; that is, when escape to the water may disrupt the bond or poses thermoregulation problems for the pup. Therefore, suitable space for spotted seals to breed on land is likely limited to offshore rocks and small islands without human habitation, which are relatively scarce in the Southern DPS.

The dire status of spotted seals in the Southern DPS is likely to be maintained or worsened by the cumulative effects of: poaching for genitalia and culling by fisherman; loss of sea-ice habitat; breeding and molting in a non-preferred and possibly scarce habitat (ashore vs. on ice); reduced prey populations (e.g., pollock in the Sea of Japan and herring in the Yellow Sea); possible prey community disruption from ocean warming and acidification; and oil and gas development activities. The population sizes are already significantly reduced from historical levels, and if reduced further they may begin to be at significant risk from small-population threats such as demographic stochasticity and genetic problems. The small sizes of these populations, as well ecologically unique characteristics associated with life at the southern extremity of the species' range, have been recognized by China, South Korea, and Russia through designation of special conservation status on the seals and portions of their habitat, though the effectiveness of these measures for preventing extinction is uncertain.

1 INTRODUCTION

On May 28, 2008, the Center for Biological Diversity (CBD) filed a petition with the Secretary of Commerce (Secretary) and the National Marine Fisheries Service (NMFS) to list the ringed seal (*Phoca hispida*), bearded seal (*Erignathus barbatus*), and spotted seal (*Phoca largha*) as threatened or endangered species and to designate critical habitat for these species pursuant to the U.S. Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 et seq.) (Center for Biological Diversity 2008).

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. This finding is to be promptly published in the *Federal Register*. On September 4, 2008, NMFS published a positive 90-day finding stating that the CBD's petition presented substantial scientific or commercial information indicating that the petitioned action *may be* warranted (National Marine Fisheries Service 2008b). To assist in determining whether listing the spotted seal under the ESA *is* warranted, NMFS convened an expert panel (the 2009 Spotted Seal Biological Review Team, or BRT) to conduct an ESA status review for this species. The BRT was composed of five marine mammal biologists, three fishery biologists, and one climate scientist. Status reviews for the ringed seal and bearded seal will be conducted subsequent to this one.

There are two key tasks associated with conducting an ESA status review. The first task is to delineate the taxonomic group under consideration. To be considered for listing under the ESA, a group of organisms must constitute a "species", which according to the ESA includes "any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature". The BRT applied the joint U.S. Fish and Wildlife Service (USFWS)-NMFS *Policy Regarding the Recognition of Distinct Population Segments Under the Endangered Species Act* (U.S. Fish and Wildlife Service and National Marine Fisheries Service 1996) to determine whether the spotted seal species merits delineation into distinct population segments (DPSs). This analysis can be found in Section 3 of the review.

The second key task of a status review is to conduct an extinction risk assessment as the scientific basis for determining whether the petitioned species is threatened or endangered. The ESA defines the term *endangered species* as "any species which is in danger of extinction throughout all or a significant portion of its range". The term *threatened species* is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range". 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 based on specific demographic factors of the species, such as abundance, productivity, spatial structure, and diversity, as well as specific threats faced by the species, as outlined in Section 4(a)(1) of the ESA:

- the present or threatened destruction, modification, or curtailment of its habitat or range,

- overutilization for commercial, recreational, scientific, or educational purposes,
- disease or predation,
- the inadequacy of existing regulatory mechanisms, or
- other natural or manmade factors affecting its continued existence

This analysis can be found in Section 4 of the review.

This document is a compilation of the best available scientific and commercial data and a description of past, present, and likely future threats to the spotted seal. It does not represent a decision by NMFS on whether this taxon should be proposed for listing as threatened or endangered under the ESA. That decision will be made by NMFS after reviewing this document, 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 of whether or not to list spotted seals under the ESA will be posted on the NMFS website (refer to: http://www.nmfs.noaa.gov/pr/species/) and announced in the *Federal Register*.

2 SPECIES BACKGROUND

2.1 Taxonomy and Phylogeny

The spotted seal, *Phoca largha* Pallas 1811 (Rice 1998), is also often referred to as the larga seal. Larga is the most common Russian name for this species which stems from the Tungus language of eastern Siberia. Other Native Russian names for spotted seals include *pygi* by the Sakhalin Giliaks, *teoska* by the Amur Giliaks, *nerpa* in the Amur estuary and Tatar Strait, *pestrukha* in the Sea of Okhotsk, *memel* by the Chukchi, and *piatnistaia nerpa* on the Chukchi Peninsula (Krylov et al. 1964). Alaska Eskimo names for spotted seals include *issuriq* in Central Yupik, *gazigyaq* in St. Lawrence Island Yupik, and *qasigiaq* or *kasegaluk* in northern Inupiaq (Lowry 1985, Burns 1994).

The taxonomic placement of spotted seals relative to harbor seals (*Phoca vitulina*) has been a topic of much debate. The complete taxonomic history of spotted seals is too complex to describe in this status review. Shaughnessy and Fay (1977) reviewed the taxonomic literature and took the position that *largha* should be considered a separate species. Genetic isolation between spotted and harbor seals was confirmed by mitochondrial DNA (mtDNA) studies reported in O'Corry-Crowe and Westlake (1997) and Mizuno et al. (2003). Compared with harbor seal sequences, all spotted seals shared two deletions (3 and 11 base pairs long) in the mtDNA control region adjacent to the tRNA gene.

In outward appearance, spotted seals are almost identical to light-phase (see Section 2.2) harbor seals; however, there are a few diagnostic characteristics that can be used to separate the two species. Spotted seals are pagophilic (“ice-loving”) and typically haul out on sea ice during their breeding season in winter to early spring, whereas harbor seals typically haul out and breed ashore, mainly on rocky islets, sand bars, and mud flats (Fisher 1952, Bishop 1967). Some harbor seals in southern Alaska also use icebergs from tidewater glaciers (Bishop 1967). In areas where they are sympatric, harbor seals whelp and mate about a month later than spotted seals, in late spring to early summer (Bigg 1969, Shaughnessy and Fay 1977). Spotted seal pups are born with a wooly white coat called lanugo and retain it for 2-4 weeks after birth, while harbor seal pups typically shed their lanugo *in utero* (Stutz 1966).

The ancestors of spotted seals and all other northern true seals (sub-family Phocinae) except for bearded seals became adapted to breeding on ice ~13-17 million years ago (mya) as indicated by their common trait of having pups with a white lanugo coat (Árnason et al. 2006, Higdon et al. 2007). Molecular studies showed limited resolution within the sub-tribe Phocina – which includes spotted, harbor, ringed, grey (*Halichoerus grypus*), Caspian (*Phoca caspica*), and Baikal (*Phoca sibirica*) seals – suggesting that their diversification was both rapid and relatively recent (Árnason et al. 2006, Higdon et al. 2007). This agrees with biogeographic evidence that suggests that Phocina arose in the Greenland/Barents Sea portion of the Arctic and radiated following a geological change that altered the ecological conditions of that area, such as the opening of the Bering Strait ~5.4 mya or perhaps the gradual rise of the Isthmus of Panama ~3 mya which changed the circulation of the North Atlantic and resulted in the freezing of the Arctic Ocean (Árnason et al. 2006, Higdon et al. 2007). Although the relationships within Phocina are generally unclear, the sister group relationship between spotted and harbor seals is strongly supported (Árnason et al. 2006, Dasmahapatra et al. 2009) and the two species are believed to have diverged ~1.1 mya (Higdon et al. 2007).

2.2 Species Description

Unlike harbor seals which are dimorphic in their pelage pattern, exhibiting both light and dark phases, spotted seals are monomorphic and closely resemble the light phase of the harbor seal (Rice 1998). The spotted seal's pelage coloration is usually a light-colored background with dark grey and black spots scattered quite densely on the body (Figure 1). The ventral side is usually silvery-white with fewer spots than the dorsal side, although some young seals have numerous spots on the belly (Heptner et al. 1976a, Bigg 1981, Lowry 1985, Quakenbush 1988, Burns 2002). Older seals have a more vivid and contrasting spottiness, where the dark and light components are fairly evenly represented and uniformly alternated. Young spotted seals often have a broad, dark-brownish band that extends along the middle of the back from the head to the tail (Heptner et al. 1976a). As juveniles age, the dark-colored dorsal band gradually becomes more mottled, often with fairly distinct oval rings, and becomes less apparent in older animals. However, there are also juvenile spotted seals that are indistinguishable from adults in coloration and do not exhibit the dark dorsal band (Heptner et al. 1976a). Males and females are generally similar in size and appearance (Lowry 1985), although Chapskii (1967, cited in Heptner et al. 1976) observed the spot color is brighter and the pattern more strongly contrasted in males than females.

Figure 1. -- Adult female spotted seal.

Spotted seal pups are born with a pelage called lanugo (Figure 2), which consists of long (20-30 mm), dense, wooly hairs that are white and cream-colored. The lanugo is important for thermoregulation and provides better insulation in the air than the short adult hair (Burns 2002). Pups retain the lanugo throughout the nursing period while they develop an insulating layer of blubber (Naito and Nishiwaki 1972, Burns 2002). The lanugo is usually shed around the time of weaning and is replaced with a short, smooth, very firm coat (Naito and Nishiwaki 1972, Heptner et al. 1976a, Lowry 1985, Quakenbush 1988).

Figure 2. -- Spotted seal pup in lanugo pelage.

Compared with other phocids in the North Pacific Ocean, spotted seals are medium-sized being larger than ringed seals, smaller than bearded seals, and similar in size to ribbon seals (*Histriophoca fasciata*) and harbor seals (Lowry 1985, Burns 2002). Their body proportion has been described as being typical of the genus; they have a medium build overall and are not as lean as ribbon seals or as plump as ringed seals (Lowry 1985). Spotted seals also grow more rapidly than ringed seals but slower than ribbon seals (Tikhomirov 1968). At birth, pups weigh between 7 and 12 kg (Tikhomirov 1968, Lowry 1985, Burns 2002) and are generally between 75 and 92 cm long, nose to tail (Tikhomirov 1968, Naito and Nishiwaki 1972, Heptner et al. 1976a, Burns 2002). By the end of the nursing period, pups may more than triple their birth weight to 30 kg or more (Tikhomirov 1968, Heptner et al. 1976a, Burns 2002). Naito and Nishiwaki (1972) measured blubber thickness of pups captured on ice floes at the end of April and beginning of May. Mean blubber thickness was 4.5 cm in 1969 and 5.1 cm in 1971, and pups seemed to be in maximum condition and had molted most of their lanugo. By the end of May through the end of June, blubber thickness had decreased to 2.6 cm (Naito and Nishiwaki 1972).

In the Bering Sea and Sea of Okhotsk, adult female spotted seals typically weigh between 65 and 115 kg and lengths range from 151 to 169 cm, while adult males typically weigh between 85 and 110 kg and lengths range from 161 to 176 cm (Wilke 1954, Heptner et al. 1976a, Burns 2002). The mean weight of sexually mature females and males was 68.3 kg and 78.4 kg, respectively (Tikhomirov 1968). Growth curves indicated that females stopped growing at an average length of 162 cm, and males stopped growing at an average length of 168 cm (Tikhomirov 1968). The maximum lengths of females and males was reported to be 182 cm and 185 cm, respectively (Tikhomirov 1968). Naito and Nishiwaki (1972) found that growth rates of spotted seals near Hokkaido were similar between the sexes for the first 5 years, and that males continued to grow until about age 15 while females discontinued growing at about age 10. However, Tikhomirov (1968) determined that female growth rates began to lag behind the males within the first year, and that the growth rates of both sexes leveled off at about age 8 or 9.

2.3 Behavior

The behavior of spotted seals has not been studied extensively, but a few of their behavioral characteristics are noteworthy. Spotted seals are unusual among phocids in that they are considered to be annually monogamous, with adult females and males forming pair-bonds on the sea ice prior to whelping that last throughout the nursing and breeding season (Tikhomirov 1964, Burns 2002). Female spotted seals are strongly attached to their pups and will occasionally defend them from human intruders (Burns et al. 1972, Wang 1986, Quakenbush 1988). Females will stay on the sea ice with their pups even when boats approach within 10-20 m (Quakenbush 1988). When approached very closely, the female usually escapes into the water but remains nearby to maintain visual contact with her pup (Wang 1986). Occasionally, the female will haul back onto the ice floe with her pup, even with people standing a few paces away (Krylov et al. 1964, Tikhomirov 1964, Wang 1986), and attempt to move her pup to a different ice floe by pushing it into the water and diving with the pup in her teeth (Tikhomirov 1964, Wang 1986) or by swimming with the pup on her back (Wang 1986). In other instances, the female takes a more passive approach by repeatedly hauling out on nearby ice floes and waiting for the pup to follow her away from the intruders (Burns et al. 1972). Apparently, female spotted seals are not able to discern their own pups from others (Burns et al. 1972) and may rely more on site fidelity and location of the natal floe to reunite after disturbance events (Quakenbush 1988). Male spotted seals show a similar attachment during disturbance events; however, their attention is directed primarily towards the female and not the pup (Tikhomirov 1964, Burns et al. 1972). During hunting expeditions, males have even been observed approaching their dead female companion on the ice while disregarding the hunters' presence (Tikhomirov 1964). Females do not show a similar attachment to the males (Tikhomirov 1964).

Outside of the whelping and breeding season, spotted seals are one of the most cautious phocid species and are easily disturbed from their haul-out sites on land or sea ice (Krylov et al. 1964, Tikhomirov 1964, Heptner et al. 1976a, Wang 1986, Frost et al. 1993). When hauled out on land, spotted seals sleep very lightly and will frequently raise their heads to survey their surroundings (Tikhomirov 1966a, cited in Heptner et al. 1976). If they do not sense danger, the seals will go back to sleep, but if they are frightened, the seals will all flee into the water. Spotted seals will often haul out again in the same place from which they were disturbed when they feel safe again (Heptner et al. 1976a, Bigg 1981, Wang 1986); however, constant or repetitive disturbances may cause pups or haul-out sites to be abandoned (Lowry 1985). Although spotted seals are extremely wary, there is some debate about which of its senses are best developed. According to Tikhomirov (1966a, cited in Heptner et al. 1976), their sight and smell are the most developed, while Marakov (1966, cited in Heptner et al. 1976) suggested it was their sight and hearing. Elsner et al. (1989) conducted a study to examine which senses were most important to seals when attempting to locate breathing holes from under the ice. Vision appeared to be the most important, followed by hearing, and vibrissal sense was least important to spotted seals (Elsner et al. 1989). Spotted seal pups are able to dive to 80 m depth, and stomach contents indicated that adults forage at depths up to about 300 m (Gol'tsev 1971). Chugunkov (1970, cited in Bigg 1981) reported that spotted seals can travel up to 400 m underwater and can swim at speeds up to 3.8 m/s.

Studies of the mating behavior of spotted seals in the wild are limited because they are difficult to observe for prolonged periods in the pack ice and much of the mating behavior occurs underwater. Beier and Wartzok (1979) examined the mating behavior of two captive spotted seals from the Bering Sea over a period of 5 years. The authors found that although the male was sexually persistent for about 2 weeks during each breeding season, mating attempts only occurred during 1-2 days and it was the receptivity of the female that determined when copulations took place. The authors suggested that the concentrated breeding effort of this species was an adaptation to maximize the probabilities of pup survival and successful fertilization of females before the breakup of their seasonal sea-ice habitat. Beier and Wartzok (1979) also identified five distinct types of vocalizations used by both sexes (growl , drum, snort, chirp, and bark), plus one additional vocalization used only by the male (creaky door). The creaky door vocalizations by the male and chirps by the female were only heard during the breeding season. Both seals were most vocal during the first day of mating attempts than at any other time of the year, and the male was more vocal than the female. The authors determined that the frequency of behavioral interactions and vocalizations – especially nosing, biting, growling, and drumming – increased during the breeding season, and suggested that these probably facilitate successful pair-bonding and may act as social stimuli to induce ovulation (Beier and Wartzok 1979).

2.4 Seasonal Distribution, Habitat-use, and Movements

Spotted seals are widely distributed on the continental shelf of the Beaufort, Chukchi, southeastern East Siberian, Bering, and Okhotsk Seas, south throughout the Sea of Japan, and into the northern Yellow Sea (Burns and Fay 1972, Naito and Nishiwaki 1972, Shaughnessy and Fay 1977, Naito and Konno 1979, Lowry 1985) (Figure 3). Their range extends over about 40 degrees of latitude from Point Barrow, Alaska, in the north (~71°N) to the Yangtze River, China in the south (~31°N). The distribution of spotted seals is seasonally related to specific life history events that can be broadly divided into two periods: late-fall through spring when whelping, nursing, breeding, and molting all take place in association with the presence of sea ice on which the seals haul out, and summer through fall when the sea ice has melted and spotted seals remain closer to shore to use land for hauling out. The timing of the formation and persistence of sea ice, and thus the spotted seals use of sea-ice habitat, roughly varies with latitude throughout the species' range.

From late fall through spring, spotted seal habitat-use is closely associated with the distribution and characteristics of seasonal sea ice. The ice provides a dry platform away from land predators during the whelping, nursing, breeding, and molting periods. When sea ice begins to form in the fall, spotted seals start to occupy it immediately, concentrating in large numbers on the early ice that forms near river mouths and estuaries. In winter, as the ice thickens and becomes shorefast along the coasts, spotted seals move seaward to areas near the ice front with broken ice floes (Burns 2002). Spotted seals can only make and maintain holes in fairly thin ice (Fay 1974) and have been known to travel 10 km or more over solid ice in search of cracks or open patches of water (Fedoseev 1971). Spotted seals usually avoid very dense, compacted ice and stay near the ice front (Fay 1974, Heptner et al. 1976a, Burns 2002). In the northern Yellow Sea, spotted seals begin to occupy sea-ice habitat in Liaodong Bay from October to December (Won and Yoo 2004), and in the western Sea of Japan, they begin arriving in the Peter the Great Bay in December (Trukhin and Mizuno 2002). In the Sea of Okhotsk and the Bering Sea, spotted seals begin hauling out on sea ice from November and December to March (Shaughnessy and Fay 1977, Lowry et al. 1998, Lowry et al. 2000). Before the whelping and breeding seasons, spotted seals are scattered among the drifting ice floes (Fay 1974, Heptner et al. 1976a). As spring approaches in the Bering Sea, spotted seals mainly inhabit the southern margin of the sea ice, mostly within 25-100 km of the irregular and shifting pack ice edge in areas of extensive ice coverage (e.g., 7/10 -9/10) where water depth does not exceed 200 m (Braham et al. 1984, Rugh et al. 1995, Lowry et al. 2000). In general, spotted seals select floes that are less than 20 m in diameter, often with a thick layer of snow and some remnant of a pressure ridge, on which to rest, whelp, nurse, and wean their pups, and breed (Fay 1974, Simpkins et al. 2003). Lowry (1985) suggested that for whelping, spotted seals may preferentially select floes that are less than 10 m in diameter in areas where wind or currents separate them from surrounding floes, offering reliable access to the water. From early to mid-spring, isolated pairs of adults can be found on these floes along with a pup. In late spring, after weaning and breeding, the ice begins to disintegrate and spotted seals congregate on the remnant ice floes, forming small herds and spending much of the day hauled out on ice floes while weaned pups develop self-sufficiency and adults complete their molt and bask (Burns and Fay 1972, Burns et al. 1981). The sizes, form, shape, and condition of these floes are not as restricted as those used for whelping and breeding. Indeed, spotted seals are not entirely dependent on sea ice for molting and may also haul out on land (Tikhomirov 1961, Tikhomirov 1964, Burns et al. 1981). Recent research has also shown that, unlike spotted seals in more northerly latitudes, a proportion of spotted seals in the Peter the Great Bay (Katin and Nesterenko 2008) and the northern Yellow Sea (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, February 24, 2009, pers. comm.) use shore haul-out sites for whelping, nursing, and breeding as well as molting. This behavior appears to be more common in years when less sea ice is present (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, February 24, 2009, pers. comm.)

In summer, after molting and when the usable sea ice disappears, the herds break up and spotted seals move toward the ice-free waters of the coasts where they are concentrated in areas that provide the most favorable food conditions, such as dense schools of spawning herring and smelt (Heptner et al. 1976a, Burns 2002). As with whelping and breeding, the timing of these shoreward movements varies with the region. In the northern Yellow Sea, spotted seals migrate to the south and east beginning in March or April. The spring migration in the Sea of Okhotsk is less directed, with spotted seals appearing along the western Kamchatka Peninsula in April, in the Yamsk and Tauisk inlets in May and June, and in the Shantar region in July and August (Tikhomirov 1961, Fedoseev 1971, Quakenbush 1988). In the eastern Bering Sea, spotted seals begin using coastal haul-out sites from Kuskokwim Bay to the Bering Strait – including Nunivak, St. Matthew, and St. Lawrence Islands – from May to July (Frost et al. 1982), and in the eastern Chukchi Sea, spotted seals primarily haul out on the coast of Kotzebue Sound and in Kasegaluk Lagoon during the summer and fall (Frost et al. 1983). Satellite tagging studies have provided considerable insight into the seasonal movements of spotted seals (Lowry et al. 1998, Lowry et al. 2000). These studies showed that spotted seals in the Chukchi Sea migrated south in October and passed through the Bering Strait in November en route to their whelping and breeding grounds in the Bering Sea (Lowry et al. 1998). Seals remained in the Bering Sea along the ice edge making east-west movements, presumably to remain in their preferred habitat (Lowry et al. 1998). In summer, these seals moved into nearshore areas of the Bering Sea or north into the Chukchi and Beaufort Seas, reaching their limits in August (Burns 1970, Burns 1973, Fay 1974, Lowry et al. 1998). Spotted seals tagged by Lowry et al. (1998) seemed to use coastal haul-out sites in Kasegaluk Lagoon in the eastern Chukchi Sea as short-term resting places (average of 2 days) between longer foraging trips (average of 9 days), many of which ranged over 1,000 km towards the Bering Strait, Beaufort Sea, or the Russian coast.

Spotted seal terrestrial haul-out sites are usually remote and located on isolated mud, sand, or gravel beaches, or on rocks close to shore (Heptner et al. 1976a, Lowry 1985, Quakenbush 1988, Burns 2002). Important factors for selecting a haul-out site appear to include proximity to food, lack of disturbance, and favorable tidal conditions; other characteristics are not well known (Heptner et al. 1976a, Lowry 1985). In Alaska, major spotted seal haul-out sites are located near herring and capelin spawning areas (Quakenbush 1988). Tides clearly affected spotted seal behavior in the Sea of Okhotsk where seals haul-out islets and reefs that are exposed at low tides (Heptner et al. 1976a). As the tide receded, seals gathered around a site and began to haul out and occupy the newly exposed sections of shoal or reef, forming a large group in a relatively short time. Often, the seals remained hauled out even under apparently unfavorable conditions such as frost, rain, or snow, and they only left if they were disturbed or when the high tide forced them back into the water (Heptner et al. 1976a).

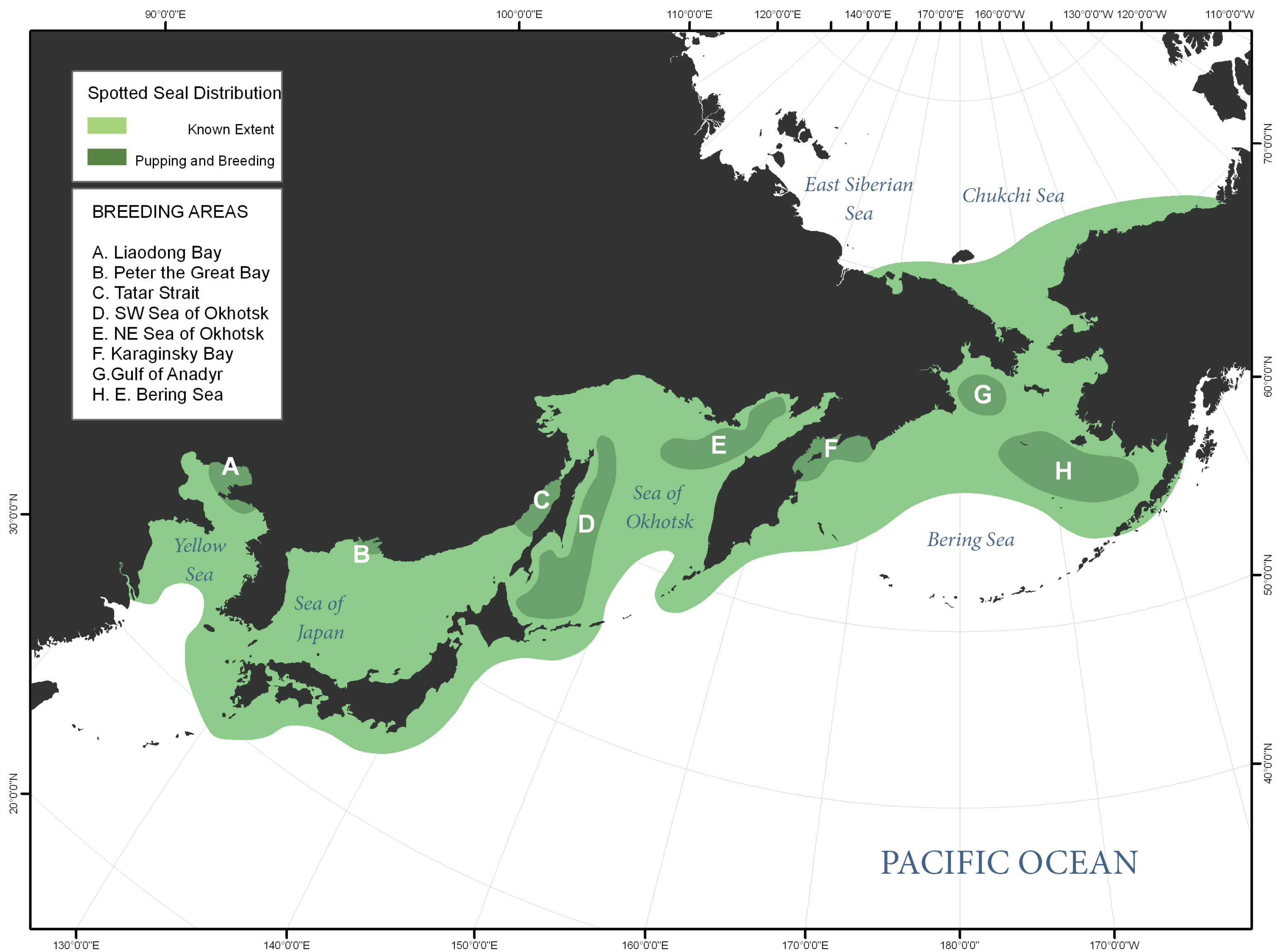

Figure 3. -- The global distribution of spotted seals, adapted from maps in Shaughnessy and Fay (1977), Mizuno et al. (2001), Burns (2002), and Trukhin (2003), as well as information provided by V. Burkanov (Kamchatka Branch of the Pacific Institute of Geography, February 24, 2009, pers. comm.).

2.5 Reproduction and Molting

Spotted seals typically haul out on seasonal sea ice each winter and spring to perform their annual cycles of reproduction and molting. Shaughnessy and Fay (1977) identified eight approximate breeding areas of spotted seals spread across their range, including three in the Bering Sea (eastern Bering Sea, Gulf of Anadyr, and Karaginsky Gulf), two in the Sea of Okhotsk (northeastern Sea of Okhotsk and southwestern Sea of Okhotsk), two in the Sea of Japan (Tatar Strait and Peter the Great Bay), and one in the northern Yellow Sea (Liaodong Bay) (Figure 3). The annual timing of spotted seals' reproduction has evolved to coincide with the average period of maximum extent and stability of the seasonal sea ice (Tikhomirov 1964, Burns et al. 1981), which varies latitudinally across their range (Figure 4). In the Bering Sea and northern Sea of Okhotsk, whelping typically occurs from late March to the end of April with most pups being born during early to mid-April (Krylov et al. 1964, Tikhomirov 1966b, Burns et al. 1972, Burns 2002). In the southern Sea of Okhotsk and Tatar Strait, whelping mainly occurs from late February to the end of March with a peak in mid- to late March (Wilke 1954, Tikhomirov 1961, Tikhomirov 1966b, Kosygin and Gol'tsev 1971, Naito and Nishiwaki 1972, Mizuno et al. 2002), but may extend into April in some years (Belkin 1964). In Peter the Great Bay, spotted seals give birth between early February and mid-March with a peak during late February to the beginning of March (Krylov et al. 1964, Tikhomirov 1966b, Kosygin and Tikhomirov 1970 cited in Heptner et al. 1976, Burns 2002), and at their southernmost extreme, spotted seals in Liaodong Bay whelp from early January to mid-February with a peak in late January (Wang 1986, Burns 2002).

Although spotted seals almost always give birth on sea ice, there are several areas in which they breed on shore, including the Bohai Sea (in the Yellow Sea), Peter the Great Bay, the South Kurile Islands, the Second Kurile Strait, Utashud Island, and the east coast of Kamchatka (Trukhin 2005). Wang (1986) reported a few cases of young pups still in their natal pelage being found on beaches in the Yellow Sea, and attributed this to pregnant females not being able to reach the whelping area in Liaodong Bay in time and being compelled to give birth on land. Most breeding in Peter the Great Bay apparently takes place on shore, with only a small portion of the population breeding on ice north of the Rimsky-Korsakov Archipelago (Trukhin 2005, Nesterenko and Katin 2008, Nesterenko and Katin 2009). Pups born ashore there have been observed to enter the water prior to weaning (Katin and Nesterenko 2008), a behavior that is not typical among seals on the ice (Burns 2002). Also, Trukhin (2005) indicated that the whelping season of spotted seals on shore in Peter the Great Bay now extends from mid-January to April and speculated that this lengthened season (see Figure 4) reflects a relaxation of constraints imposed by the timing of ice persistence.

Sexually mature female spotted seals typically give birth to a single pup each year (Sleptsov 1943, Tikhomirov 1966b). Pups are reportedly nursed for 2-3 weeks in the southern Sea of Okhotsk (Naito and Nishiwaki 1972) and 3-4 weeks in other parts of their range (Tikhomirov 1964, Burns 1973, Wang 1986). During this time, pups are dependent upon the sea ice and rarely enter the water until they are weaned and molted (Tikhomirov 1961, Heptner et al. 1976a, Burns 2002). Earlier than normal disintegration of the sea ice is thought to result in high morality of nursing pups (Burns 2002). In an apparently annual occurrence, large numbers of spotted seal pups still in their lanugo coats washed up dead on the eastern coast of the Kamchatka Peninsula in late April to early May (Heptner et al. 1976a); it is unclear whether the authors believed these pups died from premature entry into the icy water or from being crushed by the hummocking of ice floes, but both scenarios are possible. Pups are weaned abruptly, being abandoned by their mothers in peak numbers during early to mid-May in the Bering Sea and northern Sea of Okhotsk (Tikhomirov 1964, Tikhomirov 1966b) and during mid-April in the southern Sea of Okhotsk (Naito and Nishiwaki 1972). Newly weaned pups remain at least partially dependent on the sea ice while they develop proficiency at diving and foraging for themselves (Lowry 1985, Burns 2002). Independent feeding begins about 10-15 days after weaning (Gol'tsev 1971).

Breeding takes place shortly after pups have been weaned. Unlike most pinnipeds which are polygynous, spotted seals are thought to be annually monogamous and territorial (Fay 1974, Burns 2002). Sexually mature males and females form pair-bonds about 7-10 days before whelping (Tikhomirov 1964) and guard small (~0.25-0.5 km) territories around the birth floe throughout the reproductive period (Burns et al. 1972, Heptner et al. 1976a). Breeding is reported to occur from April 20 to mid-May with a peak in the first 10 days of May in the Bering Sea and northern Sea of Okhotsk (Tikhomirov 1964) and from early to mid-April in the southern Sea of Okhotsk and Tatar Strait (Kosygin and Gol'tsev 1971, Naito and Nishiwaki 1972). The mating act has apparently not been witnessed in the wild, but is thought to occur mostly underwater as was observed with captive seals (Beier and Wartzok 1979; see Section 2.3 for more information). Similar to other pinnipeds, spotted seals delay implantation of the blastocyst for about 2-4 months after fertilization with gestation lasting another 7-9 months, so the total pregnancy from mating to birth lasts about 10.5-11 months on average (Heptner et al. 1976a).

Spotted seals shed and regrow their epidermis and pelage annually in a process termed molting. The timing of an individual's molt depends upon its age, reproductive status, and location (Heptner et al. 1976a, Burns 2002). Subadult seals (ages 1 to about 3 or 4) begin and complete molting first, followed by newborn pups, adult females, and finally adult males, with overlap occurring among these groups (Burns 2002). Subadults are not reproductively active, and therefore are able to molt during the whelping, nursing, and breeding period – about 1 month before the adults (Ashwell-Erickson et al. 1986). During this time, subadults mainly remain separate from the adults (Heptner et al. 1976a), perhaps hauling out deeper in the ice pack while adults remain closer to the ice edge (Bigg 1981). Newborn pups typically shed their lanugo coats about 2-4 weeks after birth, or at about the same time that they are weaned (Naito and Nishiwaki 1972, Wang 1986, Burns 2002), while adults begin molting immediately after breeding (Tikhomirov 1964, Burns 2002). There is some indication that non-reproducing adults may begin molting 10-15 days earlier than females that whelped, and some adult males may begin molting before or during the mating period (Tikhomirov 1964). Spotted seals congregate in large mixed groups of 200 or more individuals on the sea ice during the adult molt (Lowry 1985), which is likely an adaptation to protect against predators (Krylov et al. 1964). In the Bering Sea and northern Sea of Okhotsk, adult spotted seals molt over a 2-2.5 month period beginning in late April or early May and finishing by early to mid-July (Tikhomirov 1961, Krylov et al. 1964, Tikhomirov 1964) with the molt being most intensive during May and June (Burns 2002). There are fewer reports in the literature about the timing of molting in the southern parts of the spotted seal's range, but it is likely that the timing there follows the same pattern relative to the other ice-associated life history events as it does in the northern parts of this species' range.

Based on examinations of seven captive spotted seals from the Bering Sea, Ashwell-Erickson et al. (1986) determined that immature seals molted mainly from April to May while the adults molted mainly from May to June. The entire duration of the molt varied widely between individuals, ranging between about 1 and 22 weeks with an average of 7.7 weeks (Ashwell-Erickson et al. 1986). The resting metabolic rate declined by an average of 18.6% below pre-molt levels, suggesting that maintenance costs are lower during the molt and daily energy requirements may be met without excessive depletion of fat reserves (Ashwell-Erickson et al. 1986). The lowered metabolic rate probably facilitates the molt by reducing the need for feeding at a time when the seals benefit from staying out of the cold water and maintaining elevated skin temperatures and circulation which are conducive to hair growth (Feltz and Fay 1966). This modifies Tikhomirov's (1964) view that spotted seals required an abundant food supply and continued to feed throughout molting. Spotted seals typically molt or at least begin molting while hauled out on sea ice; however, some seals – especially adults – may finish their molt on land if the sea ice disintegrates before their molt is completed (Tikhomirov 1964, Heptner et al. 1976a, Burns 2002, Trukhin and Mizuno 2002). This likely occurs more frequently in the southern parts of their range where sea ice typically persists for a shorter duration. As the seasonal sea ice melts away in the spring to early summer, spotted seals move to coastal haul-out sites to feed and replenish their fat reserves during the remainder of the summer and early fall (Lowry 1985, Burns 2002).

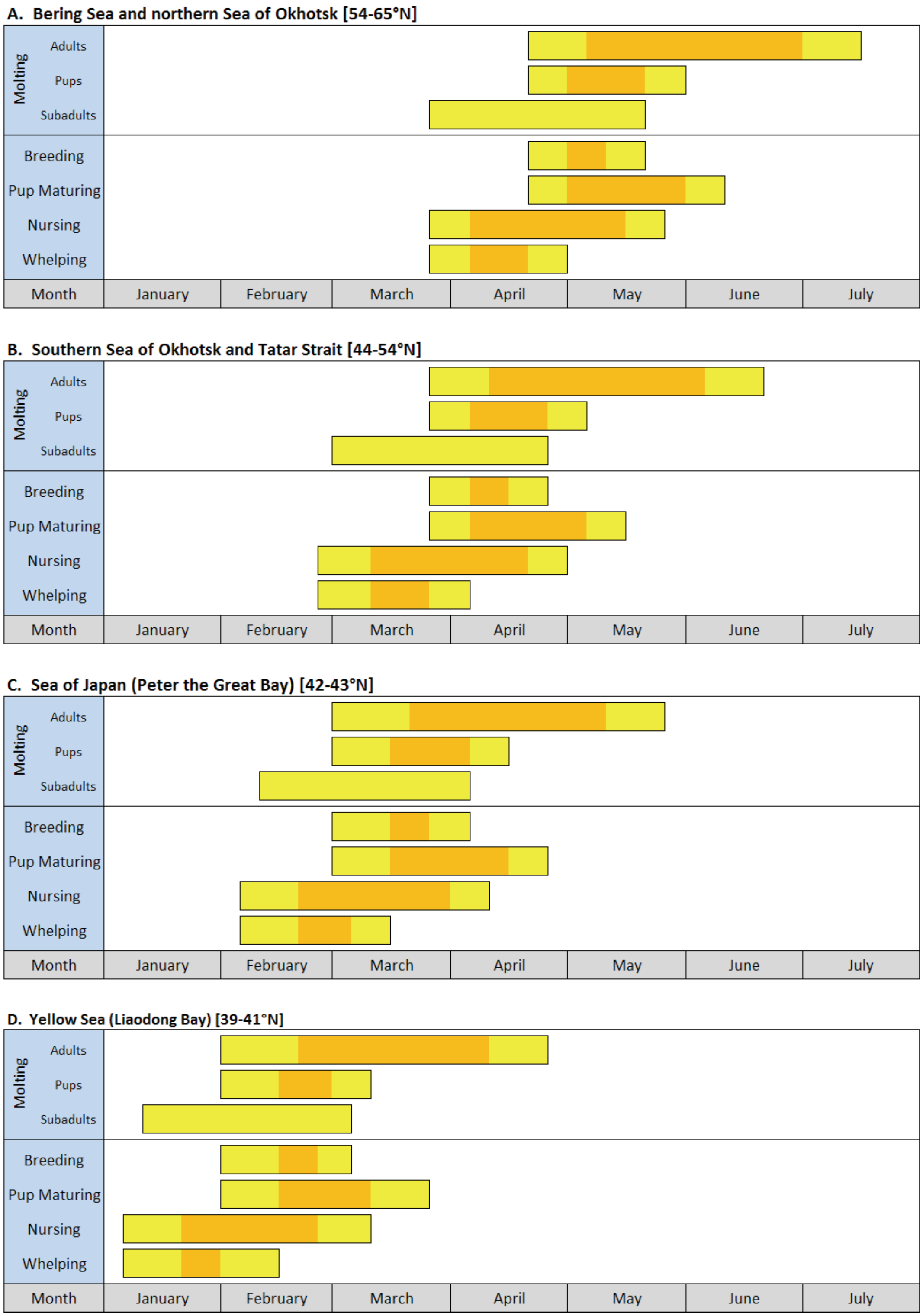

Figure 4. -- Approximate annual timing of the spotted seal's reproduction and molting in four regions of its breeding range. Yellow bars indicate the range over which each event is reported to occur and orange bars indicate the peak timing of each event. "Pup Maturing" refers to the period when weaned pups may remain at least partially dependent on sea ice while they develop proficiency at diving and foraging for themselves.

2.6 Vital Parameters

Little information has been published on the biological characteristics of spotted seal populations, and the data that have been published (e.g., Fedoseev 2000) are often difficult to interpret due to possible age- and sex-biased sampling or the effects of heavy exploitation on density-dependent parameters, such as productivity and mortality, which may vary during the depletion and subsequent recovery of the sampled populations.

The age that spotted seals become sexually mature has been variously reported for females and males, respectively, as age 3 and 4 (Sleptsov 1943), ages 3-6 and 3-4 (Tikhomirov 1966b), ages 3-4 and 3-5 (Naito and Nishiwaki 1972), ages 3-4 and 4-5 (Burns 1973), ages 4-5 and 5-6 (Popov 1976), and ages 3-6 and 5-6 (Fedoseev 2000). The reproductive status of females collected from five different regions in the Bering Sea, Sea of Okhotsk, and Tatar Strait between 1967 and 1987 were presented by Fedoseev (2000, Tables 38 and 39). The results showed that the age of sexual maturity varied within and between regions over time, which was likely a response to changes in intensity or selectivity of hunting pressure (Fedoseev 2000). An analysis of the combined data from these tables indicated that 1% of females were sexually mature by age 2, 18% by age 3, 66% by age 4, 91% by age 5, 97% by age 6, and 100% by age 7. A separate analysis of combined data from much smaller samples presented by Tikhomirov (1966b) and Naito and Nishiwaki (1972) indicated that 29% of males were sexually mature by age 3, 67% by age 4, and 100% by age 5. Taken together, these results indicate that less than a third of females and males become sexually mature by age 3, about two-thirds of both sexes become mature by age 4, and nearly all spotted seals (i.e., >90%) are sexually mature by age 5. Quakenbush et al. (2009) examined age at maturity and pregnancy rates of spotted seals collected during the 1960s, 1970s, and 2000s, and suggested that environmental conditions may have been less favorable for seals in the 1970s than in the 1960s or 2000s because average age at maturity was significantly older in the 1970s. The lowest pregnancy rate was observed in the 2000s, which possibly indicates that environmental conditions are currently less favorable than in the 1970s. However, sample size was smallest in the 2000s, and more sampling is necessary to determine whether pregnancy rates have truly declined (Quakenbush et al. 2009). It should be noted that sexual maturity in females has been defined by different researchers as either the age of first ovulation (e.g., Tikhomirov and Fedoseev) or the age of first pregnancy (e.g., Burns), which likely has an impact on the reported estimates of age of sexual maturity and age-specific fecundity.

The age composition (excluding pups) of spotted seal catches from the Sea of Okhotsk and Bering Sea were presented by Fedoseev (2000, Tables 40 and 41). Sexually mature seals (age 5 and older) composed 62.2% of the catch from the northern Sea of Okhotsk in the fall of 1967, and 55.7% of the catches from the northwestern Bering Sea in the springs of 1967 and 1968, which were considered the least age-biased samples of those presented (Fedoseev 2000). Combined, these figures produce a weighted average of 57.1%, which is similar to figures published by Gol'tsev and Fedoseev (1970, cited in Heptner et al. 1976) of 55.7% and by Lowry (1985) of about 60%. The sex ratio of spotted seals is typically reported to be 1:1 (Sleptsov 1943, Lowry 1985). Analyzing the sex composition by age group, Fedoseev (2000) indicated that the sex ratio remained approximately equal up to age 9 or 10, but for older age groups, females comprised a greater proportion in some catches and males in others. The sex ratio also differed from 1:1 in the catches reported by several authors (reviewed by Fedoseev 2000), but this was attributed to changes in the seasonal sex and age composition of localized herds and not to a real disproportion in the spotted seal population as a whole. Quakenbush et al. (2009) found that sex ratios of spotted seals were generally male-biased, but the ratios were not consistent over time or by age class.

The proportion of sexually mature females that were barren (i.e., non-reproductive) or aborted their fetus was reported to range between 0-11% in the Bering Sea and 0-14% in the Sea of Okhotsk (Fedoseev 2000, Tables 38 and 39). Gol'tsev and Fedoseev (1970, cited in Heptner et al. 1976) assumed these figures to be 8% in the Bering Sea and 15% in the Sea of Okhotsk. Sleptsov (1943) and Tikhomirov (1966b) reported rates of barrenness among adult females of 4% and about 5%, respectively. Apparently based on these figures, the proportion of sexually mature females that became pregnant each year was reported to be 85-95% (Burns 1978, Lowry 1985, Quakenbush 1988). Lowry (1985) and Quakenbush (1988) reported an additional abortion rate of 10% in their estimates of productivity; however, it is uncertain where this figure came from. Both authors produced an estimate of gross annual production of 22-25% (Lowry 1985, Quakenbush 1988), while Popov (1976) reported an annual production rate of 20%. Fedoseev (2000) estimated gross annual pup production at 24.1% in the northern Sea of Okhotsk and 25.1% in the northwestern Bering Sea. The mortality rate of pups during their first year of life was reported to be 43% in the Sea of Okhotsk and 42% in the Bering Sea (Fedoseev 2000), which results in a net annual production rate of about 14%. In both seas, mortality rates dropped to 18% by age 2, 7% by age 3, 2-4% for ages 4-6, and 1-2% for spotted seals age 7 and older (Fedoseev 2000, Table 42). These figures evidently produced an average weighted mortality rate of 13.7% in the Sea of Okhotsk and 14.8% in the Bering Sea for seals age 1 and older (Fedoseev 2000). Because the net annual production of pups just offset the annual mortality of older age groups, Fedoseev (2000) concluded that the spotted seal populations were in equilibrium. Females between the ages of 6 and 12 had the highest fecundity which diminished slowly with age (Fedoseev 2000, Table 42), indicating a slight reproductive senescence or a higher average mortality rate for females that reproduce more frequently. Spotted seals have a maximum lifespan of about 30-35 years, and females may live longer than males (Tikhomirov 1968, Naito and Nishiwaki 1972).

2.7 Feeding Habits

Spotted seals are generalist feeders with a varied diet (Gol'tsev 1971, Fedoseev and Bukhtiyarov 1972, Nikolaev and Skalkin 1975, Frost et al. 1977, Lowry et al. 1979a, Lowry et al. 1979b, Lowry et al. 1981, Kato 1982, Bukhtiyarov et al. 1984, Lowry 1985, Frost and Lowry 1987a, Bukhtiyarov 1990, Sobolevsky 1996, Pauly et al. 1998, Burns 2002, Dehn et al. 2007) (Table 1). Most studies have found that fishes are spotted seals' primary prey (Wilke 1954, Gol'tsev 1971, Fedoseev and Bukhtiyarov 1972, Nikolaev and Skalkin 1975, Frost et al. 1977, Lowry et al. 1978, Lowry et al. 1979a, Kato 1982, Bukhtiyarov et al. 1984, Bukhtiyarov 1990, Dehn et al. 2007, Quakenbush et al. 2009). Bukhtiyarov (1990) collected spotted seals from the Sea of Okhotsk, and found that although the diet was dominated by fish species, there were also large numbers of crustaceans and cephalopods. Bukhtiyarov et al. (1984) suggested that the diverse diet and regional and seasonal differences in foods of spotted seals are related to the seasonal distribution and abundance of their principal prey species. Spotted seals appear to have a fairly flexible diet and can feed on whatever prey items are available and abundant (Kato 1982, Bukhtiyarov 1990, Sobolevsky 1996).

Table 1. -- Prey species eaten by spotted seals.

Species	Common Name	Sources*
FISHES		
Clupeidae		
Clupea pallasii	Pacific herring	2, 3, 6, 7, 9, 11, 12, 15, 17
Osmeridae		
Hypomesus japonicas	Japanese smelt	11
Mallotus villosus	capelin	6, 7, 8, 9, 12, 15, 17
Osmerus mordax	rainbow smelt	11, 15
Salmonidae		
Oncorhynchus kisutch	coho	13, 14
Oncorhynchus keta	chum	13, 14
Oncorhynchus gorbuscha	pink	13, 14
Salvelinus alpinus	Arctic char	13, 14
various spp.	salmon	13, 14, 16
Gadidae		
Boreogadus saida	Arctic cod	3, 9, 10, 12, 17
Eleginus gracilis	saffron cod	3, 4, 9, 11, 12, 15, 17
Gadus macrocephalus	Pacific cod	9
Theragra chalcogramma	walleye pollock	2, 3, 4, 6, 7, 8, 10, 11, 12, 14, 15
Scorpaenidae		
Sebastes schlegelii	rockfish	11
Sebastolobus macrochir	broadfin thornyhead	11
Hexagrammidae		
Hexagrammos sp.	greenling	12
Pleurogrammus sp.	Okhotsk mackerel	11
unidentified spp.	greenling	1, 8
Cottidae		
Gymnocanthus sp.	sculpin	11, 12
Icelus sp.	sculpin	12
Myoxocephalus sp.	sculpin	12
Triglops sp.	sculpin	12
unidentified spp.	sculpin	1, 3, 8, 9, 10, 11, 12, 15, 17
Agonidae		
unidentified spp.	poacher	3
Cyclopteridae		
Aptocyclus ventricosus	smooth lumpsucker	11
Liparidae		
unidentified spp.	snailfish	15, 17
Zoarcidae		
Bothrocara sp.	eelpout	11
Lycodes sp.	eelpout	8, 12

Table 1. -- Continued.

Species	Common Name	Sources*
Stichaeidae		
Lumpenus sp.	prickleback	3, 12
unidentified spp.	prickleback	17
Ammodytidae		
Ammodytes hexapterus	Pacific sand lance	3, 4, 12, 15, 17
Ammodytes sp.	sand lance	9, 10, 11
Pleuronectidae		
Lyopsetta sp.	flatfish	3
Pleuronectes sp.	flounder	3
Reinhardtius hippoglossoides	Greenland halibut	3
unidentified spp.	flatfish	9, 11, 12, 15,17
Unknown family		
unidentified spp.	unknown fish	2, 3, 4, 5, 11, 17
CRUSTACEANS		
Mysidacea		
Neomysis rayii	mysid	3, 12
unidentified spp.	mysid	9
Euphausiacea		
Thysanoessa inermis	euphausiid	11
Thysanoessa raschii	Arctic euphausiid	11, 15
Thysanoessa sp.	unknown euphausiid	12, 15
unidentified spp.	unknown euphausiid	4, 9
Amphipoda		
Anonyx nugax	gammarid amphipod	3
Gammarus sp.	gammarid amphipod	1
Nototropis sp.	gammarid amphipod	3
Themisto libellula	hyperiid amphipod	12
Themisto sp.	hyperiid amphipod	3, 10
unidentified spp.	unknown amphipod	9, 17
Decapoda		
Pandalidae		
Pandalopsis sp.	pandalid shrimp	3
Pandalus borealis	northern shrimp	11
Pandalus goniurus	humpy shrimp	3, 5, 10, 15
Pandalus hypsinotus	coonstriped shrimp	12
Pandalus sp.	pandalid shrimp	3, 5, 15
Hippolytidae		
Eualus fabricii	Arctic eualid	3
Eualus gaimardii	circumpolar eualid	3, 10, 12
Lebbeus groenlandicus	spiny lebbeid	12
Spirontocaris sp.	hippolytid shrimp	3
unidentified spp.	hippolytid shrimp	15
Crangonidae		
Argis crassa	rough argid	12
Argis lar	kuro shrimp	12
Crangon alaskensis	northern crangon	12
Crangon dalli	ridged crangon	5, 15
Crangon sp.	crangonid shrimp	12
Sclerocrangon boreas	sculptured shrimp	12

Table 1. -- Continued.

Species	Common Name	Sources*
Sclerocrangon salebrosa	Bering shrimp	12
Sclerocrangon sp.	crangonid shrimp	3
unidentified spp.	crangonid shrimp	8
Paguridae		
Pagurus sp.	hermit crab	3, 12, 15
Majidae		
Chionoecetes opilio	snow crab	3, 5, 11, 12, 15
Chionoecetes sp.	tanner crab	3, 17
Hyas coarctatus	Arctic lyre crab	12, 15
Hyas sp.	lyre crab	3
Unknown family		
unidentified spp.	unknown decapod	4, 15
unidentified spp.	unknown crustacean	9, 17
MOLLUSCS		
Gonatidae		
Gonatus sp.	gonatid squid	15
Octopodidae		
Enteroctopus dofleini	Pacific giant octopus	11
Octopus sp.	unknown octopus	7, 12, 15
unidentified spp.	unknown octopus	3, 5, 9
Unknown family		
unidentified spp.	unknown cephalopod	2, 11, 17
unidentified spp.	unknown bivalve	17

* Sources: (1) Barabash-Nikiforov 1938, (2) Wilke 1954, (3) Gol'tsev 1971, (4) Fedoseev and Bukhtiyarov 1972, (5) Nikolaev and Skalkin 1975, (6) Frost et al. 1977, (7) Lowry et al. 1978, (8) Lowry et al. 1979a, (9) Lowry et al. 1979b, (10) Lowry et al. 1981, (11) Kato 1982, (12) Bukhtiyarov et al. 1984, (13) Kosygin et al. 1986, (14) Burkanov 1989, (15) Bukhtiyarov 1990, (16) Sobolevsky 1996, (17) Dehn et al. 2007

Spotted seals are not deep divers and feed almost solely over the continental shelf; they have generally been collected in water less than 200 m deep (Bukhtiyarov et al. 1984, Lowry 1985). Gol'tsev (1971) suggested that the feeding ecology of spotted seals is in a position between ringed and bearded seals. Using stable isotopes, Dehn et al. (2007) found the nitrogen isotope ratios of spotted seals indicated feeding at higher trophic levels than other ice-associated seals (ringed, ribbon, and bearded seals). This finding was supported by stomach content analyses that found fish occurred at high frequencies in their diet (Bukhtiyarov et al. 1984, Sobolevsky 1996, Dehn et al. 2007). Carbon isotope ratios of spotted seal muscle were lower than those found for bearded seal and walrus (*Odobenus rosmarus*), indicating that spotted seals mainly forage pelagically and do not depend on the benthic ecosystem as much as bearded seals and walrus do (Dehn et al. 2007). Cooper et al. (2009) used blubber fatty acid analysis to examine resource partitioning among bearded, ringed, ribbon, and spotted seals. Analyses indicated that fatty acid compositions of bearded and ringed seals were significantly different than each of the three other species, but ribbon and spotted seal fatty acid compositions could not be distinguished from each other (Cooper et al. 2009). Both species had higher concentrations of two types of fatty acids (20:1n-11, 20:1n-9) than either bearded or ringed seals. These two fatty acids are often found in high levels in planktivorous fish that are common in ribbon and spotted diets. Although the compositions were similar between spotted and ribbon seals, differences in the concentrations of these two fatty acids suggested that spotted seals may have consumed more Arctic cod (*Boreogadus saida*) and octopus than ribbon seals (Cooper et al. 2009). High concentrations of n-7 fatty acids strongly differentiated bearded seal fatty acid composition from the other species. The high levels of this fatty acid also indicated that bearded seal diet was rich in benthic mollusks (Cooper et al. 2009), which corresponds with previous studies that used stomach contents analysis and stable isotope ratios to examine diet.

Although the distribution of spotted seals changes seasonally, it is difficult to discern any seasonal pattern in prey consumption because spotted seals have a varied diet and most food habits data are from seals collected during spring, so less is known about food habits during the rest of the year (Barabash-Nikiforov 1938, Gol'tsev 1971, Fedoseev and Bukhtiyarov 1972, Nikolaev and Skalkin 1975, Frost et al. 1977, Lowry et al. 1979a, Kato 1982, Bukhtiyarov et al. 1984, Bukhtiyarov 1990, Burns 2002). Spotted seals consume a wide variety of prey items from the Bering Sea and Sea of Okhotsk during spring when they are associated with sea ice; primary prey items include many schooling fishes such as walleye pollock (*Theragra chalcogramma*), Pacific herring (*Clupea pallasii*), Arctic cod, Pacific sand lance (*Ammodytes hexapterus*), capelin (*Mallotus villosus*), saffron cod (*Eleginus gracilis*), and Japanese smelt (*Hypomesus japonicas*), as well as greenlings, Okhotsk mackerel, eelpouts, sculpins, flatfishes, cephalopods, and crustaceans (Wilke 1954, Gol'tsev 1971, Fedoseev and Bukhtiyarov 1972, Nikolaev and Skalkin 1975, Frost et al. 1977, Lowry et al. 1978, Lowry et al. 1979a, Lowry et al. 1981, Kato 1982, Bukhtiyarov et al. 1984, Lowry 1985, Bukhtiyarov 1990, Huntington 2000). In the summer, spotted seals primarily consume fishes and crustaceans similar to those they prey on in spring; however, at this time, seals will often redistribute and gather near rivers where they frequently prey on runs of spawning salmon (Kosygin et al. 1986, Burkanov 1989, Sobolevsky 1996). During summer in Norton Bay, commercial fishermen have observed spotted seals eating only the heads of coho salmon (*Oncorhynchus kisutch*); they leave the bodies and do not appear to eat chum salmon (*Oncorhynchus keta*; Huntington 2000). There are only limited food habits data for spotted seals in fall and winter (Lowry et al. 1978, Burns 2002), but Lowry (1985) suggested that herring, capelin, smelt, saffron cod, and Arctic cod all may be important in the diet during these times of year. However, non-fish prey items, such as octopuses, small crabs, and shrimps, are abundant and comprise 40-50% of the diet near the coast in the fall (Sobolevsky 1996). One fall in Norton Bay, when freeze-up was very late, spotted seals were observed near the beach, where Alaska Natives believed they were feeding on herring (Huntington 2000). In winter, fishes are more important than non-fish prey, and the dominant species are walleye pollock, capelin, Pacific sand lance, Arctic cod, and shrimp (Sobolevsky 1996). In contrast, Barabash-Nikiforov (1938) found that stomachs from seals collected in winter mostly contained mollusks, crabs, worms, and small crustaceans. Ashwell-Erickson et al. (1979) measured metabolic rate, food consumption, and body fat content in three captive spotted seals and compared seasonal differences. They found that food consumption in a subadult spotted seal was highest in winter and lowest in summer. Body fat content also varied seasonally as food intake changed, but total body weight and lean body mass increased steadily over the year (Ashwell-Erickson et al. 1979). Seasonal basal metabolic rates were constant over the year, which contrasts with the changing food consumption, but may be explained partly by seals consuming more food in winter to increase their blubber layer and maintain thermoneutrality (Ashwell-Erickson et al. 1979) and utilizing stored blubber reserves during spring and summer.

There is little information on prey size preference of spotted seals. Walleye pollock is a major component in the spotted seal diet, as well as an important species in the Bering Sea commercial fishery (Frost and Lowry 1986). Frost and Lowry (1986) used otolith length to estimate sizes of pollock eaten by spotted seals. They collected spotted seals north of St. Matthew Island and found that they primarily ate small pollock <20 cm long (Frost and Lowry 1986), in contrast to the commercial fishery, which typically harvests pollock 30-60 cm long (Ianelli et al. 2008).

Some regional differences in the diet of spotted seals are noted among studies. Spotted seals have been collected from the Sea of Okhotsk and Chukchi Sea and from all over the Bering Sea, which has been separated into several regions (western, southeastern, central, and northern), to examine food habits. Studies have found that fish, shrimp, small crabs, and octopus are important prey items in all regions (Sobolevsky 1996); however, some geographical differences in diet have been observed (Gol'tsev 1971, Fedoseev and Bukhtiyarov 1972, Nikolaev and Skalkin 1975, Lowry et al. 1977, Lowry et al. 1978, Lowry et al. 1979b, Kato 1982, Bukhtiyarov et al. 1984, Sobolevsky 1996, Burns 2002). Some prey items are important across almost the entire spotted seal range. Pacific herring and crustaceans are major prey in all locations except the central Bering Sea, and walleye pollock is important in all regions except the Chukchi Sea (Wilke 1954, Fedoseev and Bukhtiyarov 1972, Nikolaev and Skalkin 1975, Kato 1982). Arctic cod, saffron cod, and Pacific sand lance are major prey items in the western and northern Bering Sea and the Chukchi Sea (Gol'tsev 1971, Lowry et al. 1977, Lowry et al. 1978, Lowry et al. 1979b, Lowry et al. 1981, Bukhtiyarov et al. 1984, Sobolevsky 1996). Other species were found to be major prey items in only two of the examined regions: cephalopods in the Sea of Okhotsk and western Bering Sea, capelin in the southeast and northern Bering Sea, sculpins in the western Bering Sea and Chukchi Sea, and saffron cod and smelt in the northern Bering Sea and Chukchi Sea (Gol'tsev 1971, Frost et al. 1977, Lowry et al. 1977, Lowry et al. 1978, Lowry et al. 1979a, Lowry et al. 1979b, Kato 1982, Bukhtiyarov et al. 1984, Sobolevsky 1996, Dehn et al. 2007). Two prey species were only major prey items in a single region: eelpout in central Bering Sea and flatfish in the Chukchi Sea (Lowry et al. 1977, Lowry et al. 1979b, Bukhtiyarov et al. 1984, Dehn et al. 2007). One study identified greenling as a major prey item in the southeast Bering Sea; however, all the greenling came from a single seal that had many fresh specimens in its stomach (Lowry et al. 1977).

Several studies have indicated that spotted seal food habits vary among age classes. Younger animals predominantly consume crustaceans, and older seals mainly eat fish (Gol'tsev 1971, Kato 1982, Bukhtiyarov et al. 1984, Bukhtiyarov 1990, Sobolevsky 1996). Amphipods, euphausiids, and other crustaceans were the dominant and often only prey type in spotted seal pups, especially newly weaned pups (Gol'tsev 1971, Kato 1982, Bukhtiyarov et al. 1984, Bukhtiyarov 1990). The few fish found in older pup stomachs were all Pacific sand lance, a small schooling fish (Gol'tsev 1971, Bukhtiyarov et al. 1984). The primary prey items of juvenile seals (1-2 years old) were fishes; Gol'tsev (1971) determined that almost 90% of juvenile stomachs contained fish. Kato (1982) observed that juvenile spotted seals also consumed euphausiids, but they were much less important than in the pups' diet. In maturing and adult seals, fishes were the dominant prey type (Kato 1982, Bukhtiyarov et al. 1984, Sobolevsky 1996). Kato (1982) found very few euphausiids in adult stomachs and suggested that they were an accidental prey item. Fish and larger shrimp were found in greater quantities than small crustaceans in maturing seals

(1-4 years old); in adult seals, fish made up the greatest proportion of stomach contents and bone sizes indicated that most prey were large (Bukhtiyarov et al. 1984). Cephalopods have also been consumed frequently by all age classes (Kato 1982). Dehn et al. (2007) did not find any indications of age-related differences in consumption of invertebrate prey when they used nitrogen isotope ratios to examine the diet. This may have been due to the fact that they collected samples in early summer for stable isotope analysis, and there was an abundance of spawning herring at this time that would have been easy prey for pups. Also, stable isotope analysis may not have shown differences in the diet between age classes because stable isotope signatures reflect feeding habits over about a month, and it is possible that younger seals fed on lower trophic levels earlier in the year and then switched to a mainly fish diet to take advantage of the spawning herring (Dehn et al. 2007). Quakenbush et al. (2009) found differing results for prey consumption by age class during two time periods. They determined that in the 1960s and 1970s, older seals consumed fish more frequently than younger seals (similar to results from most studies), but in the 2000s, consumption of fish did not differ between age classes.

The effects of spotted seal predation on several salmon species were examined on the west coast of the Kamchatka peninsula (Burkanov 1989). Spotted seals were observed during three summers in 1986-1988, and Burkanov (1989) was able to compare prey consumption between years with high and low abundance salmon runs. He examined stomach contents and determined frequency of occurrence and biomass of prey items. During the year with low salmon runs, pollock were found most frequently in juvenile spotted seals. In adult spotted seals, Arctic char (*Salvelinus alpinus*) were the most abundant prey item, and pollock were the second most abundant based on frequency of occurrence and biomass (Burkanov 1989). In August of the year with low salmon returns, no Pacific salmon were found in spotted seal stomachs. Pink salmon (*Oncorhynchus gorbuscha*) and chum were both observed in streams in the area, but none were found in stomach contents.

Two of the years had high abundance salmon runs in the summer and early fall. In these years, juvenile spotted seals primarily consumed pink salmon and other salmonids, which together composed about 80% of the biomass in juvenile stomachs. For adults, the feeding season in high salmon run years was separated into two periods, summer (13 July-20 August) and fall (20 August-9 October). During the summer period, the major run was composed of pink salmon; and during the fall period, the major returning run was coho salmon. In the summer period, pink salmon were found most frequently in the stomachs of adult spotted seals, followed by Arctic char; other species were found in insignificant amounts (Burkanov 1989). In the fall period, when the major salmon runs were composed of coho salmon, spotted seal diet changed considerably. The most abundant prey species was coho salmon, followed by saffron cod. Runs of both pink salmon and Arctic char usually finish in early September, and accordingly, the proportion of pink salmon and Arctic char in diets decreased significantly in the fall period (Burkanov 1989).

Spotted seals can affect salmon resources both directly and indirectly (Burkanov 1989). The effects of spotted seal predation and harvesting by fishing on salmonids were measured at the Bolshaya River and on the west coast of Kamchatka. Spotted seals consumed a larger proportion of returning coho salmon than pink salmon in both areas (Burkanov 1989). Coho salmon were also injured most often, followed by pink and chum salmon, in unsuccessful predation attempts by spotted seals; and most injuries were light and not serious or life-threatening (Burkanov 1989).

Concern has been focused primarily on effects of predation on commercial salmon species, which include pink, coho, sockeye (*Oncorhynchus nerka*), and chinook (*Oncorhynchus tshawytscha*) salmon. Pink and coho salmon are the most important prey species for spotted seals on the western Kamchatka coast; sockeye and chinook salmon are less important because they are generally too large for spotted seals to consume easily and successfully. Burkanov (1989) also found that spotted seals selected smaller fish; length and body mass of fish found in stomachs were statistically smaller than fish collected by seining in the area. Although Arctic char is a major component of spotted seal diet, there is less interest in how it is affected by seal predation because it is not a commercial species (Burkanov 1989).

Quakenbush et al. (2009) compared spotted seal food habits across years and noted several differences in diet. They summarized data from seals harvested by Alaska Natives and during scientific cruises and found that spotted seals consumed more fish in the 2000s than in the 1960s and 1970s. Spotted seals consumed Pacific herring, smelt, and pleuronectid flatfishes more frequently in the 2000s than in the 1960s and 1970s. Consumption of several species from the Gadidae family, which are important prey for spotted seals, also increased in the 2000s. Although the occurrence of most fishes increased in spotted seal diets in the 2000s, the occurrences of sculpins and greenling were lower. Species composition of prey also changed over time; in the 2000s, Pacific herring, smelt, Arctic cod, and saffron cod all had frequencies of occurrence greater than 30%, but in the 1960s and 1970s, saffron cod was found most frequently in the diet. Quakenbush et al. (2009) also examined relative occurrence of prey and determined that spotted seals consumed a greater diversity of fish species in the 2000s than they did in the 1960s and 1970s. While spotted seals consumed more fish in the 2000s, invertebrate prey were found less frequently in their diet in the 2000s compared to the 1960s and 1970s. This change in invertebrate prey consumption is almost entirely explained by the decrease in crustaceans in the diet. Seals from the Chukchi Sea consumed fewer crustaceans in the 2000s, while frequency of occurrence of crustaceans from seals in the Bering Sea was similar in the 1960s and 1970s compared to the 2000s; so the primary region where crustaceans were found in spotted seal diets changed from the Chukchi to the Bering Sea in the 2000s. Comparing the 1960s and 1970s to the 2000s, Quakenbush et al. (2009) did not find any positive or negative correlations between occurrences of prey items that would suggest the availability or abundance of prey items of different taxa might be related.

2.8 Historic and Current Abundance and Trends

No accurate range-wide abundance estimates exist for spotted seals. Aerial and shipboard surveys of abundance have been conducted sporadically in the Bering Sea, Sea of Okhotsk, and Sea of Japan since the late 1960s (Fedoseev 1970, Kosygin and Tikhomirov 1970, Fedoseev 1971, Shustov 1972, Burns and Harbo 1977, Braham et al. 1984, Frost and Lowry 1987b, Fedoseev et al. 1988, Trukhin and Kosygin 1988, Rugh et al. 1995, Rugh et al. 1997, Mizuno et al. 2002, Trukhin and Mizuno 2002) and estimates of abundance and trends in the northern Yellow Sea (Liaodong Bay) have been based on a statistical analysis of Chinese harvest data collected since the 1930s and survey data from 1978-1990 (Dong and Shen 1991) as well as unpublished survey data from 2007 (Han et al. *In press*) (Table 2).

Several factors make it difficult to accurately assess spotted seals' abundance and trends. The remoteness and dynamic nature of their sea-ice habitat along with their broad distribution and seasonal movements makes surveying spotted seals expensive and logistically challenging. Additionally, the species' range crosses political boundaries and there has been limited international cooperation to conduct range-wide surveys. Details of survey methods and data are often limited or have not been published, making it difficult to judge the reliability of the reported numbers, especially some produced by Soviet-era government institutions. Logistical challenges also make it difficult to collect the necessary behavioral data to make proper adjustments to seal counts. Survey data were often inappropriately extrapolated to the entire survey area based on seal densities and ice concentration estimates without behavioral research to determine factors affecting habitat selection. No suitable behavioral data have been available to correct for the proportion of seals in the water at the time of surveys. Spotted seal haul-out behavior likely varies based on many factors such as time of year and time of day, daily weather conditions, and age and sex. During March and April in the Bering Sea, Burns and Harbo (1977) found that adults with pups occupied lower seal-density areas and spent 25-50% of their time hauled out on sea ice while seals in higher density areas (mostly subadults) spent less than 14% of their time out of the water. Current research is just beginning to address these limitations and no current and accurate abundance estimates have been published.

Table 2. -- Spotted seal abundance estimates (in thousands). Several of the reported estimates were based on surveys with incomplete coverage, and researchers used various survey and analysis techniques which may not be directly comparable; therefore, caution is advised when interpreting these data.

Year	Bering Sea	Sea of Okhotsk	Sea of Japan	Yellow Sea	Source
1930s				7.1[L]	Dong and Shen 1991
1940				8.1[L]	Dong and Shen 1991
1968-69		12-13[S]	8-11[T]		Fedoseev 1970
1968			<1[P]		Koysgin and Tikhomirov 1970
1968		67			Fedoseev 1971, 2000
1969		100-168			Fedoseev 1971
1969		177			Fedoseev 2000
1969-70	135	130			Shustov 1972
1974	139[W]	172			Fedoseev 2000
1976	143[W]	268			Fedoseev 2000
1976	13.1[SE]				Braham et al. 1984
1979	134[W]	246			Fedoseev 2000
1979				2.3[L]	Dong and Shen 1991
1981		234			Fedoseev 2000
1985-86			>1[P]		Trukhin and Kosygin 1988
1986		174			Fedoseev 2000
1987	100				Fedoseev et al. 1988
1987	78[W]				Fedoseev 2000
1988		156			Fedoseev 2000
1989		96			Fedoseev 2000
1990		178			Fedoseev 2000
1990				4.5[L]	Dong and Shen 1991
1996			~1[P]		Trukhin and Kosygin 1988
2000		13.7[S]			Mizuno et al. 2002
mid-2000s			2.5[P]		Nesterenko and Katin 2008
2007				0.8[L]	Han et al. *In press*

[L] Liaodong Bay
[S] southern Sea of Okhotsk
[T] Tatar Strait
[P] Peter the Great Bay
[W] western Bering Sea
[SE] southeastern Bering Sea

2.8.1 Yellow Sea

Using a back-calculation method based on 1990 survey data, historic harvest records, and an estimate of the population's maximum net recruitment rate, Dong and Shen (1991) estimated that the Liaodong Bay population of spotted seals increased from about 7,100 in 1930 to a maximum of 8,137 in 1940. The population then declined over the next four decades to a minimum of 2,269 in 1979, before increasing again to about 4,500 in 1990, which the authors credited to protective laws implemented in the 1980s (Don and Shen 1991). It is believed that spotted seals that breed in Liaodong Bay regularly use off-shore islands and the western coast of South Korea's Tae-An Peninsula as resting spots between foraging trips in spring, summer and autumn (Won and Yoo 2004). Ship-based surveys conducted between 2000 and

2002 indicated that most spotted seals use haul-out sites near or on Bak-ryoung Island, with daily counts approaching 300 seals (Won and Yoo 2004). The Chinese and South Korean governments began affording protection status to spotted seals and banned hunting during the early 1980s, and the Chinese established a nature reserve for their protection in the early 1990s (Wang 1998, Won and Yoo 2004, Bo 2006; Yong-Rock An, Cetacean Research Institute of South Korea, May 6, 2009, pers. comm.). Despite these efforts, the Liaodong Bay population continued to decline to around 800 individuals by 2007 (J. B. Han, unpubl. data, cited in Han et al. *In press*).

2.8.2 Sea of Japan

Based on aerial surveys conducted during 1968-1969, Fedoseev (1970) reported an estimate of 8,000-11,000 spotted seals in the Tatar Strait. No other abundance estimates for this small region could be found, and it is possible that the Tatar Strait was included in surveys and abundance estimates of the Sea of Okhotsk (e.g., Fedoseev 1971).

Based on historic harvest records, Trukhin and Mizuno (2002) suggested that there were probably several thousand spotted seals in Peter the Great Bay at the end of the 19th century. Abundance likely decreased considerably until the 1930s as the human population and hunting increased in this region. Shipboard surveys conducted in 1968 placed the spotted seal population at roughly several hundred individuals (Kosygin and Tikhomirov 1970, cited in Trukhin and Mizuno 2002). Aerial surveys conducted during 1985-1986 indicated that spotted seal numbers may have increased to over 1,000 seals, perhaps as a result of the establishment of the Far Eastern Marine Reserve in 1978 (Trukhin and Kosygin 1988, cited in Trukhin and Mizuno 2002). Results of aerial surveys conducted a decade later in 1996 suggested that the spotted seal population in Peter the Great Bay had remained stable at about 1,000 seals (Trukhin 1997, cited in Trukhin and Mizuno 2002) despite favorable environmental conditions, reductions in hunting, and protection of their whelping and breeding areas. Trukhin and Mizuno (2002) suggested that fishery bycatch and perhaps pollution may be limiting the growth of this population. Nesterenko and Katin (2008, 2009) reported that more recent, year-round studies have revealed that about 2,500 spotted seals inhabit Peter the Great Bay in the spring, producing about 300 pups annually, and now reproducing on shore rather than on ice.

2.8.3 Sea of Okhotsk

Based on surveys conducted during 1968-1969, Fedoseev (1970) reported an estimate of 12,000-13,000 spotted seals in the southern Sea of Okhotsk. Abundance estimates for the entire Sea of Okhotsk were reported as 67,000 in April 1968, 168,000 in April 1969, and 100,000 in May 1969 (Fedoseev 1971); however, the author believed the 1968 estimate was low due to incomplete survey coverage that year. Fedoseev (1971) did not make adjustments for seals in the water since the estimated survey error (±20%) was greater than the assumed correction coefficient (16-17%). Shustov (1972) reported an estimate of 130,000 spotted seals in the Sea of Okhotsk based on aerial surveys during 1969-1970, and suggested that seal numbers had stabilized at very low levels after years of intensive harvesting. Popov (1976) repeated Shustov's (1972) estimate, although his number (13,000 instead of 130,000) was apparently a typographical error (Quakenbush 1988).

Summarizing the results of 10 aerial surveys conducted in the Sea of Okhotsk during 1968-1990, Fedoseev (2000) reported abundance estimates ranging between 67,000 and 268,000 spotted seals, and stated that the multi-year average for this period was 180,000-240,000 seals. Aerial survey coverage was incomplete in many years, especially in the northern Sea of Okhotsk where spotted seal haul-out areas were far from shore and airports, making them logistically difficult to survey sufficiently. Fedoseev (2000) also suggested that the highest estimates (i.e., about 250,000-270,000 spotted seals in the mid- to late 1970s) were closer to the true abundance levels of this population because survey coverage was more complete during that time.

Mizuno et al. (2002) reported conservative estimates of 13,653 and 6,545 spotted seals in the southern Sea of Okhotsk based on aerial surveys conducted in March and April 2000, respectively. The authors reported possible aircraft disturbance, a lack of correction for uncounted seals in the water, and unidentified seals excluded from their analyses (21.6%) as reasons for the conservative estimates.

2.8.4 Bering Sea

Despite repeated attempts to survey the Bering Sea pack ice over the past three decades, there are no current, accurate abundance estimates for spotted seals in the Bering Sea. Shustov (1972) reported an estimate of 135,000 spotted seals in the Bering Sea based on a 1969 aerial survey, and suggested that spotted seal numbers had remained stable since 1964. Surveys of the Bering Sea ice front were conducted by NMFS, the Alaska Department of Fish and Game (ADFG), and the Soviet Pacific Institute of Fisheries and Oceanography (TINRO) in 1976 (Braham et al. 1984). Unstratified density estimates of spotted seals in the southeastern Bering Sea were calculated to be 0.37 spotted seals per square nautical mile (nmi^2). Abundance estimates for that region were reported as 10,876 (stratified) and 13,125 (unstratified); however, only seals on the ice were counted and no adjustment was made for seals in the water. This research was a joint U.S.-Soviet effort and is the most thorough survey of the Bering Sea to date, though the results were reported primarily in units of seals sighted per unit of surveying time, and therefore do not represent abundance estimates.

Based on extensive surveys of the Bering Sea ice field in 1987, Fedoseev et al. (1988) reported raw counts of 432 spotted seals in April and 179 in May; these counts were converted into densities and then extrapolated over the whole survey area, yielding estimates of 58,811 spotted seals in April and 43,708 in May. The April estimate was rounded up to 60,000 seals which was again extrapolated to account for the proportion of the Bering Sea that was not surveyed (estimated to be 40%), yielding a minimum estimate of 100,000 spotted seals in the entire Bering Sea. Four aerial surveys in the western Bering Sea during 1974-1987 produced abundance estimates ranging between 78,000 and 143,000 spotted seals (Fedoseev 2000), with a multi-year average of 140,000 seals. Burkanov et al. (1988) criticized the aerial survey methods used by Fedoseev and others during 1979 and 1987 in the western Bering Sea, and argued that significant errors may have resulted from incorrect determinations of the area inhabited by seals.

The Alaska Fisheries Science Center’s National Marine Mammal Laboratory (NMML) conducted aerial surveys of the Bering Sea pack ice in 1992 and calculated the density of spotted seals to be 0.28

seals/nmi^2 (Rugh et al. 1995). These surveys were shore based and limited to the areas around Bristol Bay, Nunivak Island, and between Nome and St. Lawrence Island. In March 2001, an area southwest of St. Lawrence Island was surveyed by NMML for the purpose of investigating ice seal habitat selection (Simpkins et al. 2003). Only four spotted seals were seen during these surveys which were not designed to determine density and abundance. More thorough aerial surveys by NMML in 2007 (Cameron and Boveng 2007, Moreland et al. 2008), and 2008[1] were conducted from U.S. Coast Guard icebreakers that provided greater access to the central and eastern Bering Sea pack ice. Preliminary results from 2007 surveys indicate a density estimate of 0.95 spotted seals/nmi^2 for the area surveyed. As total ice coverage for the Bering Sea decreased during the survey period, densities of spotted seals appeared to increase and the number of spotted seals per group increased. The difference between density estimates in 1992 and 2007 is likely due to the difference in areas covered and overall sea-ice coverage at the time of these surveys. The data from the 2007 and 2008 surveys are currently being analyzed to construct estimates of abundance for the central and eastern Bering Sea from frequencies of sightings, ice distribution, and the timings of seal haul-out behavior. In the interim, NMML researchers have developed a provisional population estimate of 101,568 (SE = 17,869) spotted seals in the areas surveyed within the eastern and central Bering Sea (Appendix 1).

2.8.5 Coastal Surveys

Spotted seals have been surveyed at coastal haul-out sites during the summer and fall in some parts of their range. These surveys have typically reported smaller numbers than the spring sea-ice surveys, likely due to the seals' propensity to spend less time hauled out during the ice-free season. Based on a satellite telemetry study of 12 spotted seals tagged in Kasegaluk Lagoon, Alaska, Lowry et al. (1998) reported that the seals made infrequent but relatively long visits to coastal haul-out sites during the ice-free season, where individuals hauled out about 2-3 times per month for periods of 1-7 days. The authors also indicated that the seals only spent about 16% of their time on average at haul-out sites (Lowry et al. 1998). The following coastal survey counts have not been corrected for seals missed in the water, and should not be directly compared with estimates made from sea-ice surveys described above.

Based on surveys conducted in the Sea of Okhotsk during July to October 1982-1985, Kosygin et al. (1986) reported about 10,000 seals on the coast of Sakhalin Island, about 3,000 seals on the Kurile Islands (citing Kuzin et al. 1984), about 13,000 seals on the western coast of Kamchatka, and about 4,000 seals in the Shantar Islands, for a total of about 29,000 spotted seals. The authors also stated that the numbers of spotted seals on shore can increase 2 to 3 times during the peak of the salmon runs, and suggested that up to 90,000 seals may be hauled out at this time (Kosygin et al. 1986). Lagarev (1988) reported raw counts of 22,265 spotted seals on the coasts of the Sea of Okhotsk and Tatar Strait during June to October 1986, and stated that the total abundance at coastal haul-out sites, including areas surveyed by others (Kuzin et al. 1984, Burkanov 1986), was 48,000-50,000 seals in the Sea of Okhotsk. Rugh et al. (1995) flew aerial surveys along the western coast of Alaska from Bristol Bay to Point Barrow including Nunivak and St. Lawrence Islands during August 1992 and September 1993. Based on mean

[1] Unpubl. data, National Marine Mammal Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115.

counts from days with the highest estimates, they counted a total of 3,356 seals hauled out. This may have included a mix of harbor and spotted seals though, since the observers could not positively identify the two species from the air. Excluding numbers from the region where harbor seals may have been hauled out left a count of only about 613 spotted seals. Smaller scale coastal surveys of spotted seals have been conducted in several parts of the species' range, including Kotzebue Sound, Alaska (Frost and Lowry 1987b), Bak-ryoung Island in the Yellow Sea (Won 2001), Kasegaluk Lagoon, Alaska (Frost et al. 1993), Piltun Lagoon, Sakhalin Island in the Sea of Okhotsk (Bradford and Weller 2005), and Peter the Great Bay (Nesterenko and Katin 2008).

2.8.6 Trends

Because of the imprecision and incompleteness of abundance estimates for spotted seals, there are no accurate quantitative estimates of population trends (Taylor et al. 2007) for the species as a whole or for the major breeding concentrations. Although it is sometimes possible to monitor trends by indexes of population size (e.g., Small et al. 2003) rather than complete abundance estimates, this method has not been applied to spotted seals, likely because of the remoteness of their seasonal concentrations and high costs of monitoring. Perhaps the most that can be said about trends or lack thereof in the Bering Sea is that the BRT is unaware of any reports by communities of Alaska Native subsistence hunters, of extreme changes or fluctuations in availability of spotted seals over large regions. Because these communities have a regular presence in spotted seal habitat and a keen interest in the well-being of the seal populations they would likely detect major demographic perturbations. Similarly, a small number of researchers (Trukhin 2003, Trukhin and Blokhin 2003, Vertyankin and Nikulin 2004, Trukhin 2005) has conducted regular studies of spotted seals in the Sea of Okhotsk and southeastern Kamchatka. Even though these studies have not included comprehensive surveys, the researchers would likely have detected and reported large-scale changes in abundance if those had occurred. Overall, long-term declines in the Sea of Japan and Yellow Sea are evident from the chronologies of abundance estimates reported above.

3 SPECIES DELINEATION

To be considered for listing under the ESA, a group of organisms must constitute a "species", which according to the ESA includes "any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature". The term "distinct population segment" is not commonly used in scientific discourse, so the USFWS and NMFS developed the *Policy Regarding the Recognition of Distinct Vertebrate Population Segments Under the Endangered Species Act* (partially quoted below) to provide a consistent interpretation of this term for the purposes of listing, delisting, and reclassifying vertebrates under the ESA:

“Three elements are considered in a decision regarding the status of a possible DPS as endangered or threatened under the Act. These are applied similarly for addition to the lists of endangered and threatened wildlife and plants, reclassification, and removal from the lists:

1. *Discreteness of the population segment in relation to the remainder of the species to which it belongs,*

2. *The significance of the population segment to the species to which it belongs, and*

3. *The population segment’s conservation status in relation to the Act’s standards for listing (i.e., is the population segment, when treated as if it were a species, endangered or threatened?).*

Discreteness: A population segment of a vertebrate species may be considered discrete if it satisfies either one of the following conditions:

1. *It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation.*

2. *It is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the Act.*

Significance: If a population segment is considered discrete under one or more of the above conditions, its biological and ecological significance will then be considered in light of Congressional guidance (see Senate Report 151, 96th Congress, 1st Session) that the authority to list DPSs be used ‘‘… sparingly’’ while encouraging the conservation of genetic diversity. In carrying out this examination, the Services will consider available scientific evidence of the discrete population segment’s importance to the taxon to which it belongs. This consideration may include, but is not limited to, the following:

1. *Persistence of the discrete population segment in an ecological setting unusual or unique for the taxon,*

2. *Evidence that loss of the discrete population segment would result in a significant gap in the range of a taxon,*

3. *Evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range, or*

4. *Evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.*

Because precise circumstances are likely to vary considerably from case to case, it is not possible to describe prospectively all the classes of information that might bear on the biological and ecological importance of a discrete population segment.

Status: If a population segment is discrete and significant (i.e., it is a distinct population segment) its evaluation for endangered or threatened status will be based on the Act's definitions of those terms and a review of the factors enumerated in section 4(a). It may be appropriate to assign different classifications to different DPSs of the same vertebrate taxon" (U.S. Fish and Wildlife Service and National Marine Fisheries Service 1996).

The BRT applied this policy to determine whether the spotted seal species merited delineation into DPSs. This analysis is described in the following sections.

3.1 Evaluation of Discreteness

3.1.1 Separation by Physical, Physiological, Ecological, or Behavioral Factors

Eight areas of spotted seal breeding concentrations (Figure 3) have been identified in the southern margins of the seasonally ice covered portions of the species' range (Shaughnessy and Fay 1977). The extent to which these areas are actually separated by gaps in the breeding distribution, at least in the Bering Sea, is not clear. For example, (Lowry et al. 1998) questioned whether the Gulf of Anadyr and eastern Bering Sea breeding areas delineated by (Shaughnessy and Fay 1977) were truly separate, in view of substantial east-west movements of seals that they tracked by satellite telemetry during February-May. Recent observations (Cameron and Boveng 2007, Cameron et al. 2008) indicated that spotted seal distribution during April continued throughout most or all of the gap shown by Shaughnessy and Fay (1977) between the eastern Bering Sea and Anadyr breeding concentrations, suggesting that those breeding areas may be contiguous, similar to the distribution presented by Burns (1970).

Spotted seals are known to undertake foraging trips and seasonal movements of greater than 1,000 km (Lowry et al. 1998), easily sufficient to travel between adjacent breeding areas. Given this capability for long-distance movements, only very large geographical barriers would have the potential for maintaining any discreteness that there may be between adjacent breeding concentrations.

Distances between the Bering Sea breeding concentrations and the nearest Sea of Okhotsk breeding concentrations are large relative to the distances between adjacent breeding concentrations within each of these seas, due to the great southerly extent of the Kamchatka Peninsula. The peninsula itself may not be an obstacle to capable travelers like spotted seals, that have been observed to make long foraging trips and seasonal migrations (Lowry et al. 1998). Still, spotted seals have habits that may cause the Kamchatka Peninsula to be an effective barrier between Bering Sea and Sea of Okhotsk breeding concentrations. The seals' affinity for ice during winter, combined with the fact that the seasonal ice does not extend south to the tip of the peninsula, may help to confine spotted seals to their respective sea basins. They follow the ice front as it grows and expands to the south in autumn. In the Bering Sea, they make extensive east-west movements during the ice-covered period (Lowry et al. 1998). But, they are not known to move extensively out of the ice field, or off of the continental shelf, at least in the Bering Sea. Therefore, the typical annual pattern would seem to be one of moving south and offshore as the ice forms, staying in the ice during the ice covered period, then moving back to the north and toward shore with the spring ice retreat. If this scenario is correct, and unless long-distance movements were undertaken during the period of extensive ice cover, the seals would be unlikely to disperse between the two seas.

Most of the range of the species occurs in cold, seasonally ice covered, sub-Arctic waters, without conspicuous intrusions of warm water or conditions that would pose potential physiological barriers. There is, however, a considerable climatic difference from the southern to the northern extremes of the species' range. This is reflected as a cline in the timing of reproductive and molting seasons (Figure 4) among the major regions of distribution. The overlapping and continuous nature of this cline indicates that no obvious ecological separation factors, such as disjoint breeding seasons, are apparent.

Recognizing that factors in separation of populations – especially behavioral factors – may be inconspicuous, the most reliable information is likely to come from quantitative measures of genetic or morphological discontinuities. An important behavioral factor in maintaining separation of populations is natal philopatry, the tendency to reproduce in the same area as one's birthplace. Because long-term tracking of individual spotted seals has not been practical or feasible, evidence for natal philopatry must be sought indirectly, for example, by analysis of genotypic frequencies or relatedness of individuals that reflect the history of breeding dispersal. Only about 1 to 10 migrants per generation between breeding areas is typically sufficient to preclude genetic discreteness (Mills and Allendorf 1996). Thus, strong natal philopatry is required to maintain discreteness when no other barriers exist.

Fedoseev (1984b) conducted a study of phenotypic differences between spotted seals in the central and the eastern Bering Sea, the areas we have called the Gulf of Anadyr and eastern Bering Sea, respectively (Figure 3). He reported strong differences between the areas in non-metrical characteristics of skulls, and cited similar results from previous studies by himself and others of specimens from the western Bering Sea (Karaginsky breeding area) and the breeding areas in the Sea of Okhotsk. All of these studies, however, relied upon flawed statistical analyses that did not report nor take into account any covariation between the skull characteristics when considered across individual seals. As it is extremely unlikely that the characteristics are independent, the significance of the statistical tests cannot be relied upon or taken at face value. Moreover, the phenotypic characters used in these studies do not necessarily reflect genetic structure. Fedoseev (2000) indicated that much of the variation in cranial characteristics is likely to reflect regional variation in diet, ice conditions, and ecological communities. Thus, two populations differing substantially in characteristics that reflect residence in or development under local conditions will still be relatively homogeneous genetically if there is sufficient breeding dispersal. Many of the characteristics used by Soviet researchers to investigate population structure in the 1970s-1980s were later shown to vary both by locale and by year, perhaps indicating sampling variation in seasonal timing and/or age structure (Fedoseev 2000). The degree of separation between some adjacent breeding concentrations may vary with ice extent, such that genetic exchange is greatest in years of low ice coverage (Fedoseev 1984b). Fedoseev (2000) was critical of Sobolevskii (1988) and others who sampled from the aggregated distributions of seals found on remnant ice in late May and June. In summary, the morphological studies of differences between putative breeding areas may reflect some actual structure in the population, but the strength of the discreteness, and the details of which areas were reported to differ from which other areas should not be relied upon until more rigorous sampling and analysis can be applied to the problem.

In addition to morphology, helminth faunal composition and dominant regional prey have been used to investigate spotted seal population structure (e.g., Gol'tsev et al. 1978, Delyamure et al. 1984). Like morphological characters, helminth fauna may reflect prey composition and developmental conditions rather than breeding population origin; it may indicate site fidelity over relatively long periods, but it does not seem well suited to identification of natal philopatry or, conversely, breeding dispersal.

Genetic information, when obtained from representative samples of animals in their breeding locales is likely to be a more direct reflection of taxonomic structure, and for that reason has become a common and important tool for supplementing or replacing morphometrics in studies of both phylogeny and population structure. O'Corry-Crowe and Bonin (2009) examined mtDNA from 247 spotted seals, and micro-satellite DNA at 18 loci from 207 spotted seals, sampled in the Chukchi Sea, Bering Sea, NW Pacific Ocean (i.e., off the southeast coast of the Kamchatka Peninsula), Sea of Okhotsk, Sea of Japan, and Yellow Sea. Their preliminary conclusions drawn from analyses of both types of marker supported a phylogeographic break between seals of (A) the Yellow Sea-Sea of Japan region, and (B) the Okhotsk, Bering, and Chukchi Seas (Figure 5 and Figure 6). Although the mtDNA haplotypic diversity was very high, that marker indicated that some structure may also exist between the Sea of Okhotsk and the Bering-Chukchi Sea seals. The nuclear markers on the other hand, did not support that structure, and even indicated that some gene flow may occur between the Yellow Sea-Sea of Japan sampling region and the Okhotsk-Bering Chukchi sampling region.

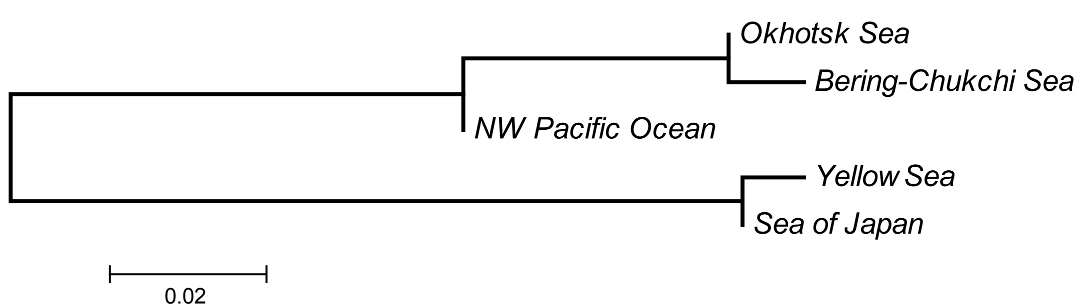

Figure 5. -- A neighbor joining tree of mtDNA samples from spotted seals in five geographic regions, based on genetic distance (Φ_{st}). From O'Corry-Crowe and Bonin (2009).

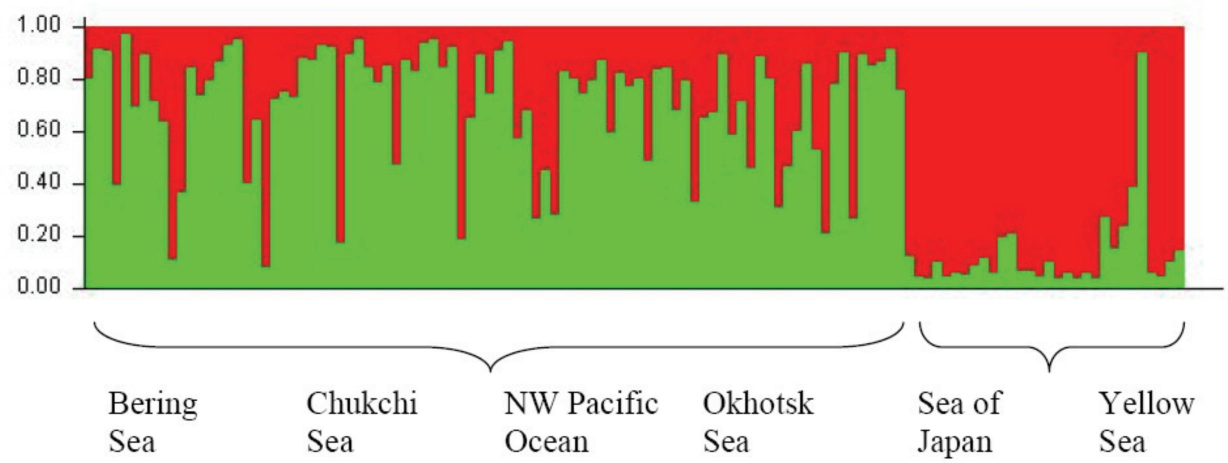

Figure 6. -- Inferred ancestry of spotted seals from a landscape genetic approach that identified two geographic clusters. From O'Corry-Crowe and Bonin (2009).

One possible explanation for the difference in structure inferred from mtDNA and micro-satellite DNA is that females are less apt to disperse than males. Because mtDNA is matrilineally inherited, haplotype frequencies reflect only female dispersal, whereas micro-satellite markers reflect dispersal of both sexes. Male-biased dispersal is common in mammals (see examples compiled by Herreman et al. (2009)) and is likely the norm in harbor seals (Goodman 1998, Burg et al. 1999, Herreman et al. 2009), the closest relative of spotted seals. So, the structure suggested by the mtDNA may reflect discreteness of the Bering Sea and Sea of Okhotsk with respect to exchange of females, but not, or less so, for males. Because these genetic results are preliminary and based on relatively small samples, the BRT placed somewhat greater weight on the mtDNA results than the micro-satellite results to err toward discreteness and an approach that would be conservative of genetic diversity.

Han et al. (*In press*) found low nuclear genetic variability among 176 spotted seals from Liaodong Bay, the primary breeding area in the Yellow Sea. This result was consistent with a previous report of low diversity in mtDNA haplotypes (Han et al. 2007). Moreover, Han et al. (2007) reported a single base-pair insertion in the threonine tRNA gene that was present in all seals from Liaodong Bay but not in samples tested from the Sea of Japan and Sea of Okhotsk, indicative of little or no immigration of females into the Yellow Sea population.

Mizuno et al. (2003) also found high haplotypic diversity in mtDNA from 66 spotted seals sampled in three regions along the northern coasts of Hokkaido in autumn and winter. They found no phylogenetic structure in the samples, and could not dismiss the possibility that spotted seals on the northwest Hokkaido coast during winter, in the far northeastern portion of the Sea of Japan, are part of the southern Sea of Okhotsk breeding concentration. This is currently the only information available on where in the Sea of Japan to place a boundary corresponding to the break identified by O'Corry-Crowe and Bonin (2009). Because no samples from the Tatar Strait have been included in genetics studies, and the samples from Hokkaido have not been obviously distinct from Sea of Okhotsk samples, the division with the most support from the genetics is a line along 43°N latitude that divides the spotted seal range into a southern segment composed of the breeding concentrations of the Yellow Sea and Peter the Great Bay, and the remaining breeding areas (Tatar Strait, southern and northern Sea of Okhotsk, Karaginsky Gulf, Gulf of Anadyr, and eastern Bering Sea).

Although no single source of evidence provided unequivocal support for a division between the Bering Sea and Sea of Okhotsk, the BRT recognized the combined weight of evidence for discreteness found in the mtDNA results, and the argument given above for the Kamchatka Peninsula functioning as a potential barrier between breeding populations behaviorally confined to the separate sea-ice zones in their respective seas. Therefore, the Bering Sea and Sea of Okhotsk were also considered for designation as DPSs.

3.1.2 Delimitation by International Differences in Management and Regulatory Mechanisms

Several conservation efforts have been undertaken by foreign nations specifically to protect spotted seals. In 1978, Russia established the Far Eastern Marine Reserve in Russia's Peter the Great Bay. The islands of the Reserve provide protection from human disturbance and suitable haul-out sites for spotted seals. The vast majority of the Peter the Great Bay spotted seal population uses the Marine Reserve during the spring, particularly for breeding and molting (Trukhin 2005, Nesterenko and Katin 2008, Nesterenko and Katin 2009). Protection of breeding and pupping areas resulting from the establishment of the marine reserve may have resulted in some growth of the population (Trukhin and Mizuno 2002). However, this population is still vulnerable to other threats outside of the reserve, such as bycatch or poaching by fishermen. Other than a permit requirement for taking any marine mammal (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, May 1, 2009, pers. comm.), there is apparently no special protection for spotted seals throughout the remainder of Russia.

The South Korean government designated the spotted seal as a natural monument in 1982, an endangered species (criteria II) in 2004, and a protected species in 2007, while the Chinese government designated them as a protected species (criteria I) in 1988 (Yong-Rock An, Cetacean Research Institute of South Korea, May 6, 2009, pers. comm.). Wang (1998) reported that spotted seals are listed in the Second Category (II) of the *State Key Protected Wildlife List* in China and listed as Vulnerable (V) in the *China Red Data Book of Endangered Animals.* In 1983, China's Liaoning provincial government banned the hunting of spotted seals, and in the early 1990s, two national protected areas were established for the protection of spotted seals in the Liaodong Bay area of China, including the Dalian National Spotted Seal Nature Reserve (Wang 1998, Bo 2006). However, as of 2004, no "conservation action, public awareness or education programmes have been carried out for the species in this region" (Won and Yoo 2004), and in 2006, the Dalian Nature Reserve's boundaries were adjusted to accommodate industrial development (Bo 2006). So despite these protection efforts, the Liaodong Bay population continued to decline (J. B. Han, unpubl. data, cited in Han et al. *In press*). There is no known information on spotted seals from North Korea (Yong-Rock An, Cetacean Research Institute of South Korea, May 6, 2009, pers. comm.), but it is unlikely that they are managed or protected there.

Within the Bering Sea ice front, spotted seals move east and west between U.S. and Russian waters (Lowry et al. 1998). When the ice retreats, some individuals move to the Alaskan coast and others move to the Russian coast (Boveng et al. 2007, Cameron et al. 2009). Therefore, the seals in any breeding group cannot be considered to be subject solely to the management and regulatory mechanisms of either country, and a division of the population along this international boundary would not be logical. Within the Sea of Okhotsk, the spotted seal breeding concentrations are within Russian waters. Finally, the conservation status and management of habitat (e.g., designation of reserves) are sufficiently similar between the Liaodong Bay and Peter the Great Bay breeding concentrations that dividing them on the basis of the China-Russia-Korea boundaries is unwarranted. In summary, considerations of cross-boundary management and regulatory mechanisms do not outweigh or contradict the divisions proposed above on biological grounds.

3.2 Evaluation of Significance

3.2.1 Persistence in an Unusual or Unique Ecological Setting?

Some unknown portion of the Yellow Sea breeding concentration whelps and nurses on shore (Wang 1986) and all or nearly all seals breeding in Peter the Great Bay apparently now do so on shore (Trukhin 2005, Nesterenko and Katin 2008, Nesterenko and Katin 2009). Pups born ashore have been observed to enter the water prior to weaning in Peter the Great Bay (Katin and Nesterenko 2008), a behavior that is not typical among seals on the ice (Burns 2002). Although it is not clear for how long these behaviors have occurred within the southern segment of the species range, they may reflect responses or adaptations to changing conditions at the range extremes, and their uniqueness may provide insights about the resilience of the species to the effects of climate warming.

The spotted seal is the only phocid inhabiting the waters of the Yellow Sea and Sea of Japan (the southern segment), whereas 4 to 5 phocid species overlap with the range of spotted seals in the Sea of Okhotsk and Bering Sea.

3.2.2 Would Loss of a Segment Result in a Significant Gap in the Range?

Loss of the Okhotsk segment of the spotted seal population would result in a substantially large, central gap in the range. This segment contains three breeding areas extending over a vast area. Similarly, the loss of either the southern or Bering Sea segments would result in a substantial contraction of the overall extent of the range. The Bering Sea segment contains three breeding areas, and the southern segment contains two breeding areas.

3.2.3 Population Segment is the Only Surviving Natural Occurrence?

None of the three segments under consideration for designation as DPSs could be considered to be the sole surviving naturally occurring unit of the population. All three segments are naturally occurring and the species is thought to inhabit its entire historic range.

3.2.4 Segment Differs Markedly in Genetic Composition?

The southern segment was distinguished primarily on the basis of its genetic composition. Spotted seals in the Yellow Sea portion of the southern segment appears to be less genetically diverse than seals in the remainder of the range, possibly reflecting a severe population reduction or “bottleneck” (Han et al. *In press*). It is not clear from the information currently available whether these genetic differences would have significant implications for the species’ survival, but only a small fraction of the genome has been examined.

3.3 Determination of Distinct Population Segments

The southern, Okhotsk, and Bering population segments have been shown to be distinct, primarily on population biology grounds, and significant because of ecological uniqueness of the southern unit and importance of all three to the overall species range. The BRT recommends designation of these units as the Southern, Okhotsk, and Bering DPSs and has considered them as such for the assessment of extinction risk (Figure 7).

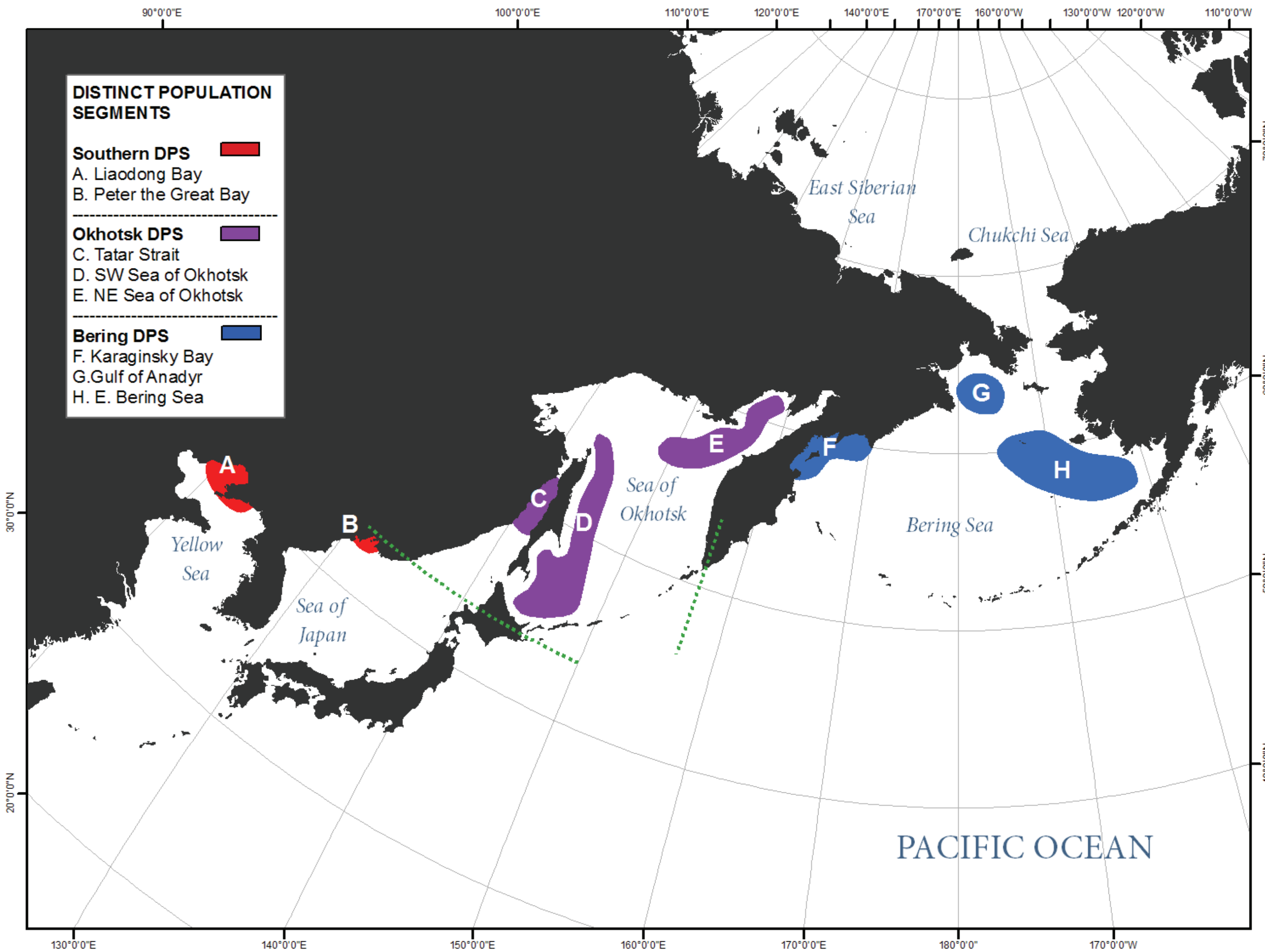

Figure 7. -- Eight spotted seal breeding concentrations are currently recognized: two in the Southern Distinct Population Segment (DPS), three in the Okhotsk DPS, and three in the Bering DPS. The dotted green lines are drawn along 43° N latitude and 157° E longitude, which were considered to be the boundaries between the Southern and Okhotsk DPSs and the Okhotsk and Bering DPSs, respectively.

4 EXTINCTION RISK ASSESSMENT

4.1 Time Frame: The Foreseeable Future

The purpose of this status review is to conduct an extinction risk assessment for support of decisions about whether spotted seals should be listed under the ESA and, if so, whether they should be listed as *threatened* or *endangered*. The ESA defines the term *endangered species* as "any species which is in danger of extinction throughout all or a significant portion of its range". The term *threatened species* is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range". Making a determination of whether a species is threatened, therefore, requires consideration of the time frame over which the population status can be said to be "foreseeable", in the sense of a credible prediction of the likely outcome. To be credible, a prediction must have a substantial element of rigor that derives from factors such as relevant data, consideration of uncertainty (to assess whether an outcome is more likely than not to occur), and concurrence of relevant subject-matter experts. Speculation alone does not constitute credible prediction or foreseeability.

The foreseeability of a species' future status depends upon both the foreseeability of threats to the species and foreseeability of the species' response to those threats. When a species is exposed to a variety of threats, each threat may be foreseeable on a different time frame. For example, a threat stemming from well-established, observed trends in a global physical process may be foreseeable on a much longer time horizon than a threat stemming from a potential episodic process such as an outbreak of disease that may never have been observed to occur in the species.

4.1.1 Factors in the Forseeability of Threats to Spotted Seals

The petition by the CBD to list spotted seals cited global warming as the foremost concern, and others have speculated similarly that spotted seals and other ice-associated marine mammals are at risk from loss of sea-ice habitat in a warming climate (Tynan and DeMaster 1997, Lowry 2000, Learmonth et al. 2006, Simmonds and Isaac 2007, Kovacs and Lydersen 2008, Laidre et al. 2008, Moore and Huntington 2008). Other potential threats, such as modification of spotted seals' prey community by ocean acidification may be related to warming by the common driver of greenhouse gas (GHG) emissions, the root cause of the largest portion of observed and projected climate change. Therefore, the predictability of GHG emissions is of primary consideration in the foreseeability of climate-related threats to spotted seals.

The analysis and synthesis of information presented by the Intergovernmental Panel on Climate Change (IPCC) in its *Fourth Assessment Report* (AR4) (IPCC 2007a) represents the scientific consensus view on the causes and future of climate change (but see Oppenheimer et al. (2007) for a reminder that achieving consensus may preclude consideration of the full range of uncertainty and plausible outcomes). The AR4 is the most recent comprehensive summary of observations, analyses, and models that collectively have been found to be compelling by all major scientific bodies in the United States with directly relevant expertise (Oreskes 2004). The IPCC AR4 used a range of future GHG emissions produced under six "marker" scenarios from the Special Report on Emissions Scenarios (SRES; IPCC 2000) to project plausible outcomes under clearly-stated assumptions about socio-economic factors that will influence the emissions. Conditional on each scenario, the best estimate and *likely* range of emissions were projected through the end of the 21st century.

The factors that distinguish the SRES marker scenarios include economic and population growth rates, technological development, and the mix of energy sources used to meet global needs. The policy of the IPCC is to consider all six SRES marker scenarios equally likely. The differences in emissions under these scenarios, however, reflect an important source of uncertainty that must be recognized in association with any particular projection or prediction of future conditions, especially in the latter half of the 21st century.

Conditions such as surface air temperature and sea-ice area are linked in the IPCC climate models to GHG emissions by the physics of radiation processes. When anthropogenic carbon dioxide (CO_2) is added to the atmosphere, it has a long residence time and is only slowly removed by ocean absorption and other processes. Based on IPCC AR4 climate models, expected global warming, defined as the change in global mean surface air temperature (SAT), by the year 2100 depends strongly on the assumed emissions scenario. By contrast, warming out to about 2040-2050 will be primarily due to emissions that have already occurred and those that will occur over the next decade. Thus, conditions projected to mid-century are less sensitive to assumed future emission scenarios (Figure SPM.5 in IPCC 2007c). Uncertainty in the amount of warming out to mid-century is primarily a function of model-to-model differences in the way that the physical processes are incorporated, and this uncertainty can be addressed by incorporating the range in projections from different models.

The IPCC AR4 emphasized the importance of this consideration for evaluating its 21st-century projections (Meehl et al. 2007b):

> *"There is close agreement of globally averaged SAT multi-model mean warming for the early 21st century for concentrations derived from the three non-mitigated IPCC Special Report on Emission Scenarios (SRES: B1, A1B and A2) scenarios (including only anthropogenic forcing). . . this warming rate is affected little by different scenario assumptions or different model sensitivities, and is consistent with that observed for the past few decades. . . Possible future variations in natural forcings (e.g., a large volcanic eruption) could change those values somewhat, but about half of the early 21st-century warming is committed in the sense that it would occur even if atmospheric concentrations were held fixed at year 2000 values. By mid-century (2046–2065), the choice of scenario becomes more important for the magnitude of multi-model globally averaged SAT warming. . . About a third of that warming is projected to be due to climate change that is already committed. By late century (2090–2099), differences between scenarios are large, and only about 20% of that warming arises from climate change that is already committed."*

The USFWS used this guidance from the IPCC AR4 to define the horizon of the foreseeable future as the year 2050 in its decision to list the polar bear (*Ursus maritimus*) as threatened (U.S. Fish and Wildlife Service 2008). The NMFS used the same guidance and time horizon in its decision not to propose any listing for the ribbon seal (National Marine Fisheries Service 2008a).

In this review of spotted seal population status, the BRT recognized that the physical basis for some of the primary threats faced by the species have been projected, under certain assumptions, through the end of the 21st century, and that these projections currently form the most widely accepted version of the best available information about future conditions. Therefore, in the risk assessment that follows, the BRT used the full 21st-century projections as the basis for the foreseeability of threats stemming from climate change.

Because the current consensus is to treat all SRES scenarios as equally likely, one option for representing the full range of variability in potential outcomes would be to project from any model under all six scenarios. This may be impractical in many situations, so the typical procedure for projecting impacts is to use an intermediate scenario, such as A1B or B2 to predict trends, or one intermediate and one extreme scenario (e.g., A1B and A2) to represent a significant range of variability or uncertainty.

It is important to note that the SRES scenarios are non-mitigated, that is they do not contain explicit assumptions about implementation of agreements or protocols on emission limits beyond current mitigation policies and related sustainable development practices. Recent studies have begun to explore the projected outcomes of emissions mitigation scenarios (Van Vuuren et al. 2008, Strassmann et al. 2009). The mitigated scenarios produce substantially less 21st century warming than the SRES scenarios, though even the most stringent mitigation scenarios result in an average of about 1.4°C warming (range of 0.5-2.8°C) above 1990 levels (Van Vuuren et al. 2008). However, incorporating the likelihood of further mitigation policies being adopted and implemented, and the likely effectiveness of the mitigation, into an assessment of risks to spotted seals is beyond the purview and capabilities of the BRT. It is left as a policy choice as to whether anticipation of climate mitigation measures should be a factor in the decision of whether to list spotted seals under the ESA.

Not all potential threats to spotted seals are climate related, and therefore not all can be regarded as foreseeable through the 21st century. As a simple example, morbillivirus infections have caused mass mortality in European harbor seals but spotted seals are not known to have been affected or even exposed to these pathogens, raising the specter of an immunologically naïve population. Evidence of morbillivirus (phocine distemper) exposure in sea otters has recently been reported from Alaska (Goldstein et al. 2009). Thus, distemper may be considered a threat to spotted seals, but the time frame of forseeability of an inherently episodic and novel threat is difficult or impossible to establish.

4.1.2 Factors in the Foreseeability of Spotted Seal Responses to Threats

A threat to a species, and the species' response to that threat are not, in general, equally predictable or foreseeable. The demographic, ecological, and evolutionary responses of spotted seals to threats from a warming climate are very difficult to predict, even though future warming is highly likely to occur. The difficulty stems both from uncertainty about the species' current status (i.e., abundance, trends, vital rates) and uncertainty about the species' habitat requirements and resilience to the effects of climate change. As discussed in more detail in Sections 4.2 and 4.3, the data on size and trends of the populations are very imprecise, especially in the Bering and Okhotsk DPSs, and there is virtually no information available to quantitatively link projected environmental conditions to spotted seal vital rates of survival and reproduction. In our limited understanding of spotted seal biology, there is no analog to the relatively well understood processes that link GHG emissions to warming. Projecting spotted seal populations forward from an uncertain beginning state is subject to further uncertainty that increases with time into the future. The range of uncertainty in forward projections of spotted seal population size is bounded above by the maximum growth rate that is feasible for the species' life history, approximately 12% annually. Of course, there is no theoretical lower bound on the rate of population change, as any population could conceivably go extinct instantly from a sufficiently severe perturbation. These extreme scenarios of hypothetical population responses, however, are not very helpful in the practical matter of judging whether spotted seals are likely to reach some threshold conservation status within a particular period of time.

4.1.3 Lack of a Single Time Frame for the Foreseeable Future

Many of the anticipated effects of GHGs have been projected through the end of the 21st century, and a broad consensus has formed around various outcomes in those projections, subject to certain inputs and assumptions. These nearly century-long projections should be considered in the assessment of the outlook for spotted seals, yet there is no single period of time that is appropriate for consideration of the risks from all the apparent threats faced by the species, and the species' responses to the threats. The foreseeability of each threat should be considered separately, and the foreseeability of the species' response to each threat should be included in the assessment of what time frame is reasonably foreseeable with respect to whether spotted seals are more likely than not to become endangered (i.e., they should be considered currently threatened if they are likely to become in danger of extinction within the foreseeable future). Finally, for a species like the spotted seal, composed of multiple DPSs, these assessments should be made separately for each DPS.

4.2 Analysis of Factors Listed Under Section 4(a)(1) of the Endangered Species Act

Section 4(a) of the ESA requires the determination of whether a species is endangered or threatened because of any of the following factors:

(A) the present or threatened destruction, modification, or curtailment of its habitat or range;

(B) overutilization for commercial, recreational, scientific, or educational purposes;

(C) disease or predation;

(D) the inadequacy of existing regulatory mechanisms; or

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

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

4.2.1.1 Global climate change

4.2.1.1.1 Overview

Research, monitoring, and modeling of global climate change have progressed rapidly during the past several decades, yielding a vast body of information on causes of climate change, effects, and ways to mitigate the problems. 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 this complex issue (IPCC 2008). 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 two 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 (ACIA 2005, Meehl et al. 2007b; Fig. 10.6c), 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 (e.g., Weatherly et al*.* 1991). A vast and rapidly growing body of information documenting this and other Arctic climate processes, and projecting future changes, has been comprehensively reviewed and assessed in widely available formats (ACIA 2005, IPCC 2007c), notwithstanding the very recent findings, which seem to be published on an almost weekly basis (e.g., Stroeve et al*.* 2008).

Our focus in this section is to assess the observed and projected changes with significant potential to impact the spotted seal's range and habitat, including both the physical and biological components of habitat. We address changes in sea ice, ocean temperature, ocean pH (acidity), and associated changes in spotted seal prey species.

4.2.1.1.2 Effects of climate change on annual formation of spotted seals' sea-ice habitat

Sea-ice extent at the end of summer (September) 2007 in the central Arctic Ocean was a record low, nearly 40% below the long-term climatology and 23% below the previous record set in 2005 (a monthly mean ice extent of 4.3 versus 5.6 million km^2) (Stroeve et al. 2008). Most of this loss was on the Pacific side of the Arctic. Arctic Ocean ice extent in the summer of 2008 was the second lowest on record (National Snow and Ice Data Center 2008, Wang and Overland 2009). Sea-ice projections at the end of summer for the years 2045-2054 from the IPCC AR4, combined with the recent result that Arctic sea ice is on a faster track for loss compared to these projections, provided support for the recent listing of polar bears as threatened under the ESA (U.S. Fish and Wildlife Service 2008). However, the breeding habitat of spotted seals occurs over both sub-Arctic and temperate zones; sea ice and other climatic conditions for spotted seals in the Bering Sea, Sea of Okhotsk, Sea of Japan, and Yellow Sea are quite different than for polar bears in the Arctic with regard to their habitats.

The Bering Sea ice cover is seasonal and forms every winter as *first-year* sea ice. This region contrasts with the central Arctic where loss of *multi-year* sea ice means that it is very difficult for the central Arctic to now return to previous climatological conditions. We present evidence for the decoupling of the climate system between summer ice extent in the Arctic Basin and spring ice extent in the Bering Sea, and thus the climate impact on the habitat for spotted and other ice-associated seals of the Bering Sea.

There will continue to be large year-to-year variations in the spring sea-ice conditions in the Bering Sea, to which spotted seals are already well adapted.

Our analysis is in three parts: climatological conditions, the consideration of previous warm years as analogs for future conditions, and the use of IPCC AR4 results for sea-ice projections in the Bering Sea. Much of this material is taken from Stabeno and Overland (*Submitted*).

4.2.1.1.2.1 Climatological conditions

The main thermodynamic physical influence at high latitudes is that it gets cold and dark in winter. The future central Arctic will continue to be an ice-covered sea in winter, but will contain more first-year sea ice than multi-year ice, similar to sea ice presently around Antarctica. Ice extent in marginal seas such as the Bering Sea is characterized not by summer minima – since these seas have been ice-free in summer throughout recorded history – but rather by winter maxima. Freezing conditions in the northern Bering Sea persist from December through April. Mean monthly maximum temperatures at Nome, Alaska (a sub-Arctic maritime climate station located at 64°N), are -3°C or below for all months November through April. Freezing rather than thawing should still predominate in these months even if a hypothesized ~3°C global warming signal (Walsh 2008) were realized.

4.2.1.1.2.2 Warm year analogs for future conditions

4.2.1.1.2.2.1 Case study of 2008

The Bering Sea begins cooling in September and typically during November ice has formed over parts of the shallow coastal regions. Cold winds out of the north continue to cool the ocean, form ice in the polynyas, and advect the ice southward, with maximum ice extent typically occurring during March or April. Because it requires cold winds out of the north to form large amounts of ice in the Bering Sea, it has been suggested the Arctic must freeze before the Bering Sea can freeze, implying that any delay in Arctic freeze-up would mean less seasonal sea ice would form in the Bering Sea (Napp 2008, Stabeno and Overland *Submitted*). In contrast, sea-ice coverage in the Arctic and Bering Sea *can be* decoupled as occurred in fall 2007 through spring 2008.

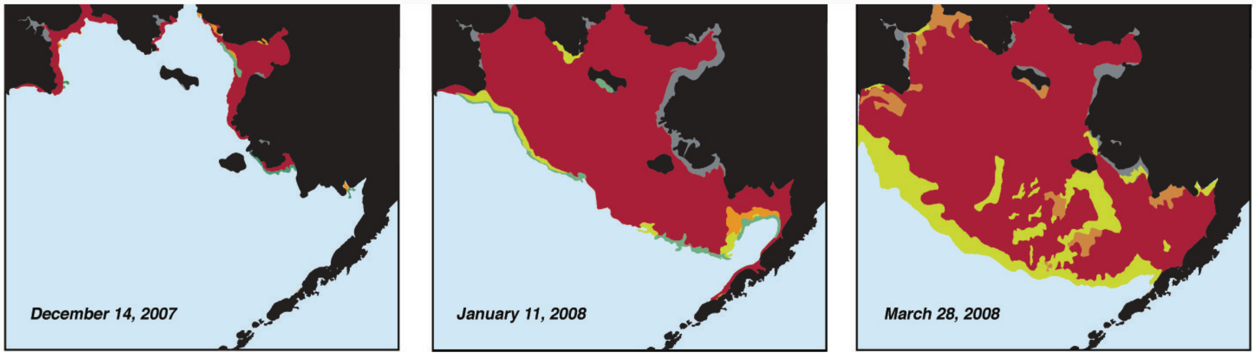

Figure 8. -- Sea ice extent in the Bering Sea on December 14, 2007; January 11, 2008; and March 28, 2008.

In 2007, the Chukchi Sea did not freeze until early December and the Bering Sea remained largely ice-free until the middle of December (Figure 8, Left). Despite this late onset of freezing, rapid cooling ensued and resulted in most of the eastern Bering Sea shelf being ice covered by mid-January (Figure 8, Center). This was an advance of 900 km or 30 km/day. Maximum ice extent occurred in late March, with ice covering much of the shelf, and a near record maximum ice extent (Figure 8, Right). Ice then slowly retreated and the Bering Sea was not ice-free until almost July. Thus, 2008 provides a clear example of summer Arctic Ocean and spring Bering Sea ice conditions being largely decoupled.

4.2.1.1.2.2.2 Sea ice in the northern Bering Sea in other years

Figure 9 shows the ice coverage, averaged within each year from December through May, in the southern (57-58°N), central (59-60°N), and northern (62-63°N) continental shelf regions of the Bering Sea during 1972-2008. 2008 was a heavy ice year. There was, however, a period during 2001-2005 when sea temperatures over the southern Bering Sea shelf were ~3°C above normal with reduced maximum sea-ice extents (blue line) and strong southerly wind anomalies. Other minimum sea-ice years in the southern Bering Sea were 1979 and 1987. These warm years provide possible analogs of conditions to be encountered in the Bering Sea due to global warming from anthropogenic sources. For example, in 2005, warm conditions delayed the advance of sea ice. Such conditions could limit the future arrival of sea ice over the southern shelf. Even within these warm years, however, there was always considerable sea ice over the northern shelf (red line), with variation mostly limited to a range of about 70-90% coverage.

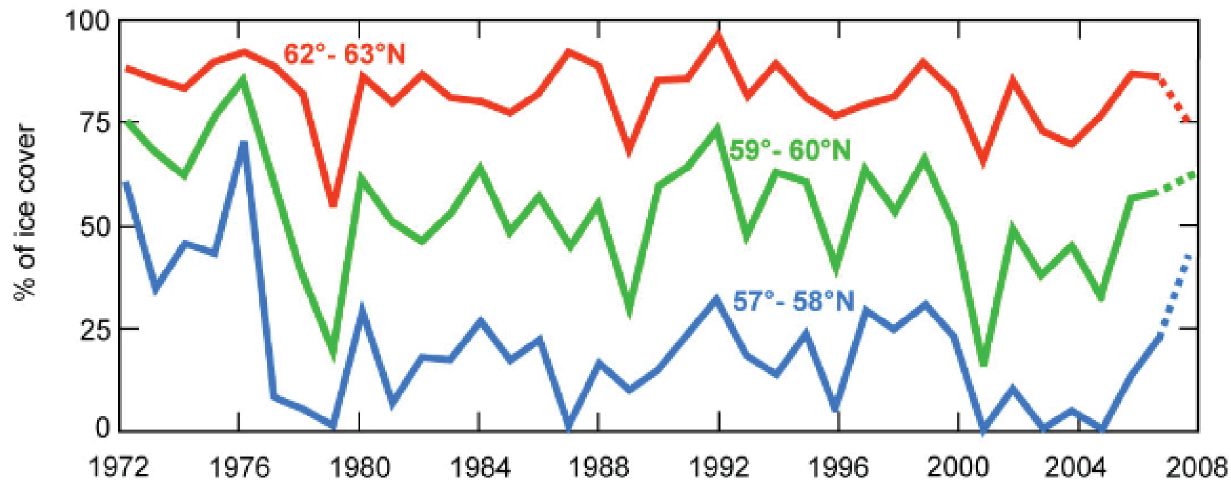

Figure 9. -- Percentage of ice coverage, averaged within each year from December through May, in the southern (blue), central (green), and northern (red) regions of the Bering Sea.

4.2.1.1.2.3 IPCC model projections

Comprehensive atmosphere-ocean general circulation models (AOGCMs) are the major objective tools to account for the complex interaction of processes and feedbacks that determine future climate. Such model projections formed the basis of the IPCC AR4 (IPCC 2007a), and are now archived as part of the Coupled Model Intercomparison Project Phase 3 (CMIP3) (Meehl et al. 2007a). The CMIP3 models have been used to provide projections of future sea-ice conditions over the entire Arctic (Holland et al. 2006, Stroeve et al. 2007, Wang and Overland 2009). Considering the uncertainties associated with regional sea-ice simulations by these global climate models, and following Wang and Overland (2009), we assessed these models' sea-ice simulation capabilities for selected regions over the North Pacific and the Chukchi Sea. We then projected future regional sea-ice conditions from models that were found to have suitable capabilities.

4.2.1.1.2.3.1 Data and analytical methods

The CMIP3 model simulations were obtained from the Program for Climate Model Diagnosis and Intercomparison on-line at http://www-pcmdi.llnl.gov/. There are several sources of sea-ice data available; we chose to use the gridded sea-ice concentration analysis from the Hadley Center (http://hadobs.metoffice.com/hadisst/) as the observed values in this study. Sea-ice extent was then defined as the area where the ice concentration is more than 20% in a grid box.

The AOGCMs are built upon known dynamical and physical principles and many large scale aspects of present-day climate are simulated quite well by these models (Knutti et al. 2008). However, because of numerical approximations for solving the physical equations, and different parameterization schemes used among the models, not all models perform equally well in representing the observed sea-ice concentration, extent, or area from the satellite data period, 1980-1999. According to Wang and Overland (2009), our regional sea-ice projections are based on a subgroup of six models (CCSM3, CNRM, ECHO-G, IPSL, MIROC3.2(medres), and UKMO-HadGEM1) identified as those that simulated the mean and the magnitude of the seasonal cycle of Northern Hemisphere sea-ice extent in reasonable agreement with the observed values. Since climate models generally perform better on continental or larger scales, we further evaluated these six models on their performance at each region independently. The boundaries of each selected region are outlined in Figure 10. Considering the significant differences in physical oceanic conditions resulting from the underlying bathymetry, we further divided the Bering Sea into the western Bering (54-66°N, 165°E-175°W), and eastern Bering (54-66°N, 175-155°W).

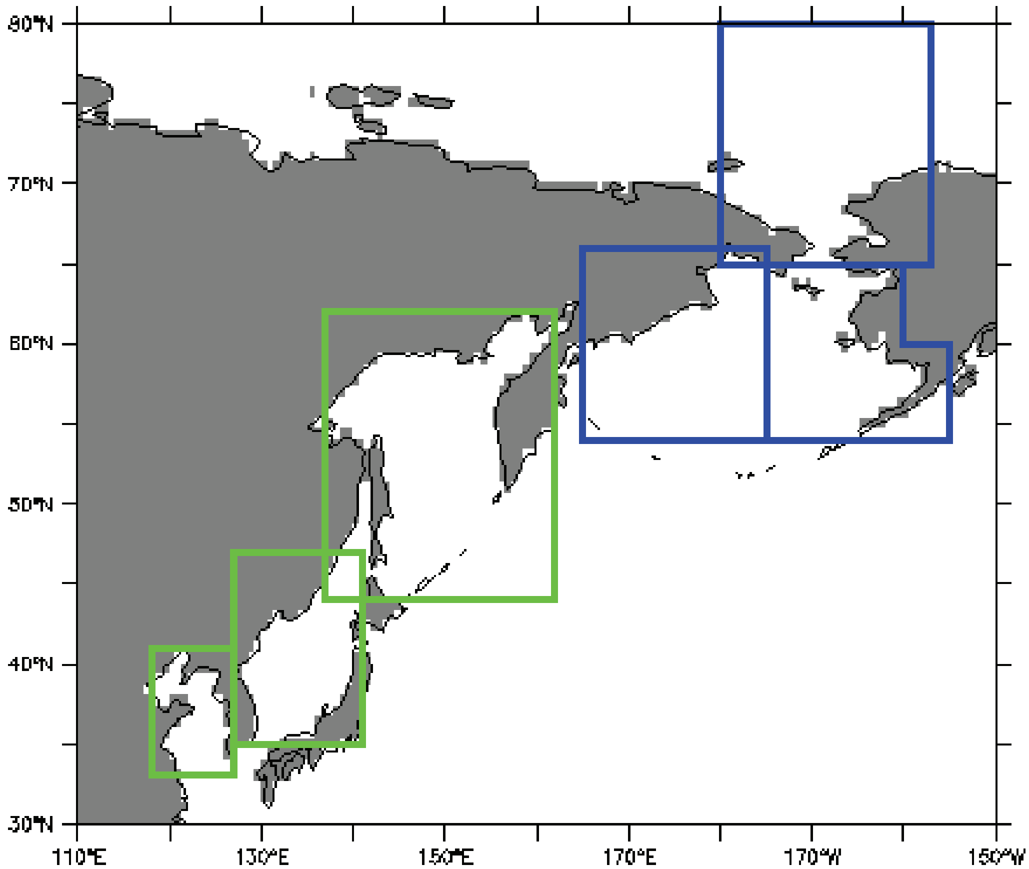

Figure 10. -- Boundaries of selected regions over the North Pacific (from left): the Yellow Sea, the Sea of Japan, Sea of Okhotsk, western Bering Sea, eastern Bering Sea, and the Chukchi Sea. The green boxes around the Yellow Sea, Sea of Japan, and Sea of Okhotsk indicate that sea-ice models performed poorly in these regions, and inference about future sea-ice extent was drawn from sea surface temperature or surface air temperature projections relative to the climatology of the recent past.

Because sea-ice conditions in the spring may be important for spotted seals (Figure 4), we investigated how the models performed over the selected regions in spring, and what their projections were for the future. To evaluate the models we required that they produce spring sea-ice conditions that agree reasonably well with the observations, i.e. the average of April and May sea-ice extent must be within 20% of the observed value.

4.2.1.1.2.3.2 Results of model evaluation

All six of the models identified by Wang and Overland (2009) met the performance criteria for sea ice in the Chukchi Sea (65-80°N, 180-157°W) and four of the six models (CCSM3,CNRM, ECHO-G, and MIROC3.2(medres)) met the criteria for the eastern Bering Sea (54-66°N, 175°W-155°W), allowing projections to be made from a basis that includes model-to-model variation and sufficient numbers of available model runs. Yet, only one of the six models met the performance criteria for the western Bering Sea (54-66°N, 165°E-175°W); most of the other models tended to overestimate the observed ice extent year-round. We used the single model as the basis for projecting sea ice in the western Bering Sea, with caveats about the reliability described below. None of the models performed satisfactorily for the Sea of Okhotsk (44-62°N, and 137°E-162°E), where they also tended to overestimate the ice extent year-round. Because of this, we did not have enough confidence in any model to provide projections of the sea-ice extent in the Sea of Okhotsk. Instead, we investigated the model forecasts of air temperature from the IPCC-CMIP3 models relative to the current climate conditions. If future monthly mean temperatures approach the melting point of sea ice, ~0°C, there are grounds for concern about the stability of the sea-ice conditions.

In the Yellow Sea (33-59°N, 119-141°E) and the Sea of Japan (44-62°N, 140-163°E), sea ice exists only for a very short period of time annually, and in small areas. The models and the Hadley Centre sea-ice analysis, which have a resolution of 1° latitude/longitude or coarser, were not able to resolve the sea-ice conditions in these smaller regions. Therefore, we investigated the use of sea surface temperature (SST) for projecting future ocean and ice conditions in these two regions. As we did for the sea-ice models, we assessed models' SST simulation over the region before the projections were made. Overland and Wang (2007) identified 10 models that simulated the major mode of the SST variability, termed Pacific Decadal Oscillation (PDO) very well over the North Pacific. Wang et al. (2009) updated that study with addition of another 3 models into the group. Thus, we evaluated these 13 models for their utility in projecting SST for the Yellow Sea and Sea of Japan.

Below we present our specific analysis for each of the selected regions, including projections of the temperatures and consideration of recent climatology for the Sea of Okhotsk, Sea of Japan, and Yellow Sea, where ice projections could not be obtained. Whenever the relevant model outputs were available, we analyzed the conditions projected under the “medium” A1B and “high” A2 emissions scenarios (IPCC 2000). By including both the A1B and A2 emissions scenario, we doubled the number of ensemble members and represented much of the range of variability contained in the SRES scenarios.

4.2.1.1.2.3.3 Chukchi Sea

The Chukchi Sea is located well north of the Arctic Circle, with its northern boundary adjoining the Arctic Ocean. Sea ice starts to retreat in late May or later, and part of the region will be covered by ice during summer. We found no significant ice reduction projected for winter and early spring (January to May), in contrast to a sharp declining trend near the end of the 21st century for the late autumn (e.g., December shown in Figure 11). The downward trend is especially apparent after 2070 in the projection for December and only significant by the end of the century for June, but by then the difference between the emissions scenarios (blue for A1B, and magenta for A2) becomes a major contributor to the trends. It is also obvious from the figures that the uncertainty is larger after the mid-century, which is shown by a wider spread of the area covered by the grey lines.

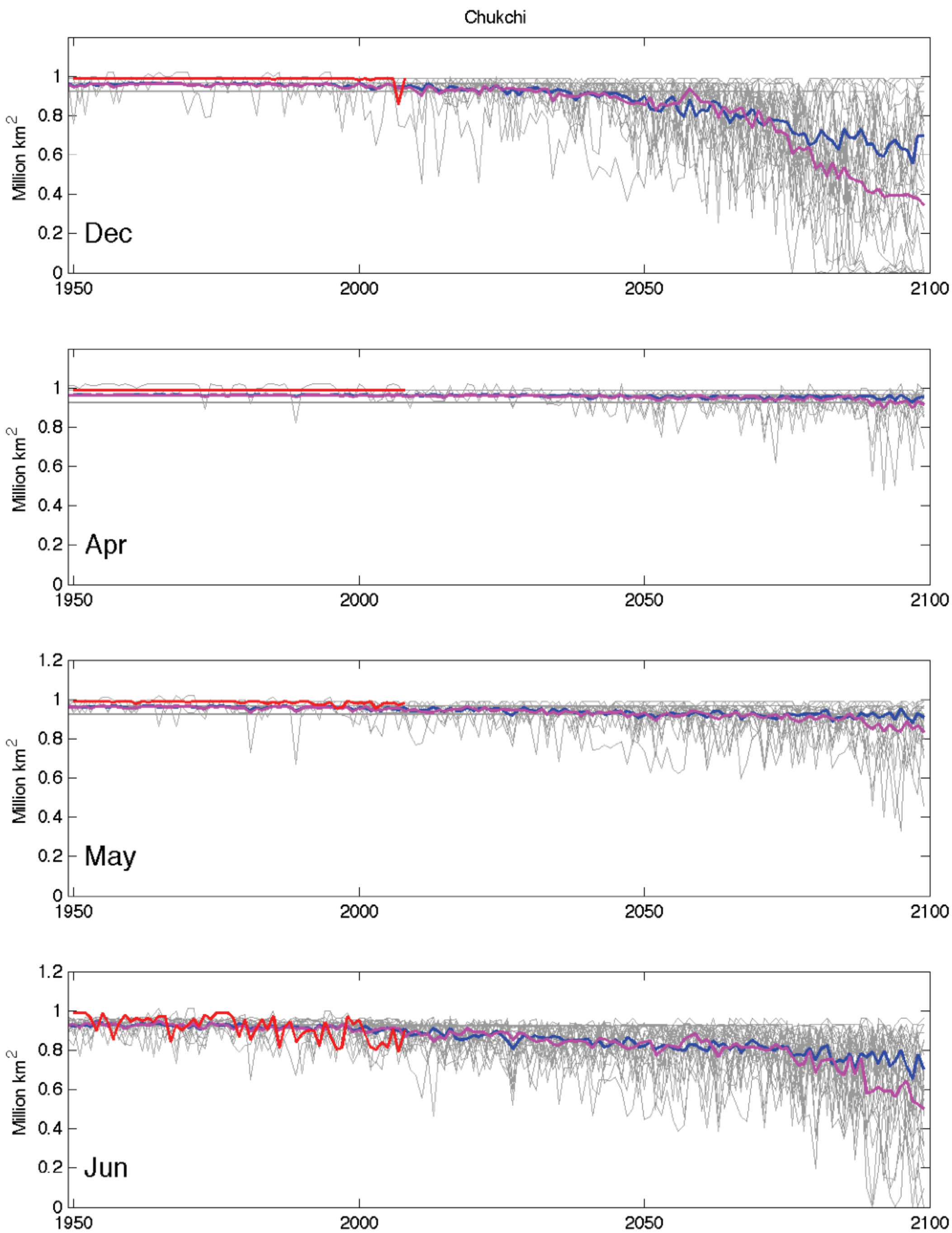

Figure 11. -- Model simulated sea-ice extent over the Chukchi Sea for late autumn (December) and spring (April-June). The red lines (observations) are based on HadISST analysis and the other colored lines are the ensemble means of the six models (CCSM3, CNRM, ECHO-G, IPSL, MIROC(medres), and UKMO-Hadgem1) under A1B (blue) and A2 (magenta) emission scenarios. Each grey line represents one realization by one of these models.

4.2.1.1.2.3.4 Eastern Bering Sea

Sea ice begins to cover the eastern Bering Sea in November, and advances south gradually to reach its maximum in March. Figure 12 shows the projections of sea-ice extent over the eastern Bering Sea for March, April, May, and June. For March to May the interannual variability of the sea-ice extent is large, and the overall trend is small, but the downward trend in the sea-ice extent in all three spring months is visually obvious. In June, there is not much trend apparent because, at the scale of these models, very little ice has remained in the eastern Bering since the mid-1970s. The largest decline in sea-ice extent is projected to occur in the late autumn months of November and December (not shown). By 2050, the averaged sea-ice extent would be 28% of present day value (relative to 1980-99 period mean), whereas the average spring sea-ice extent (average of March to May) would be at 58% of the present value. By 2075, the average spring sea-ice extent would decline to 37% of present day value, and the autumn average extent (not shown) would be at only 12% of present day value.

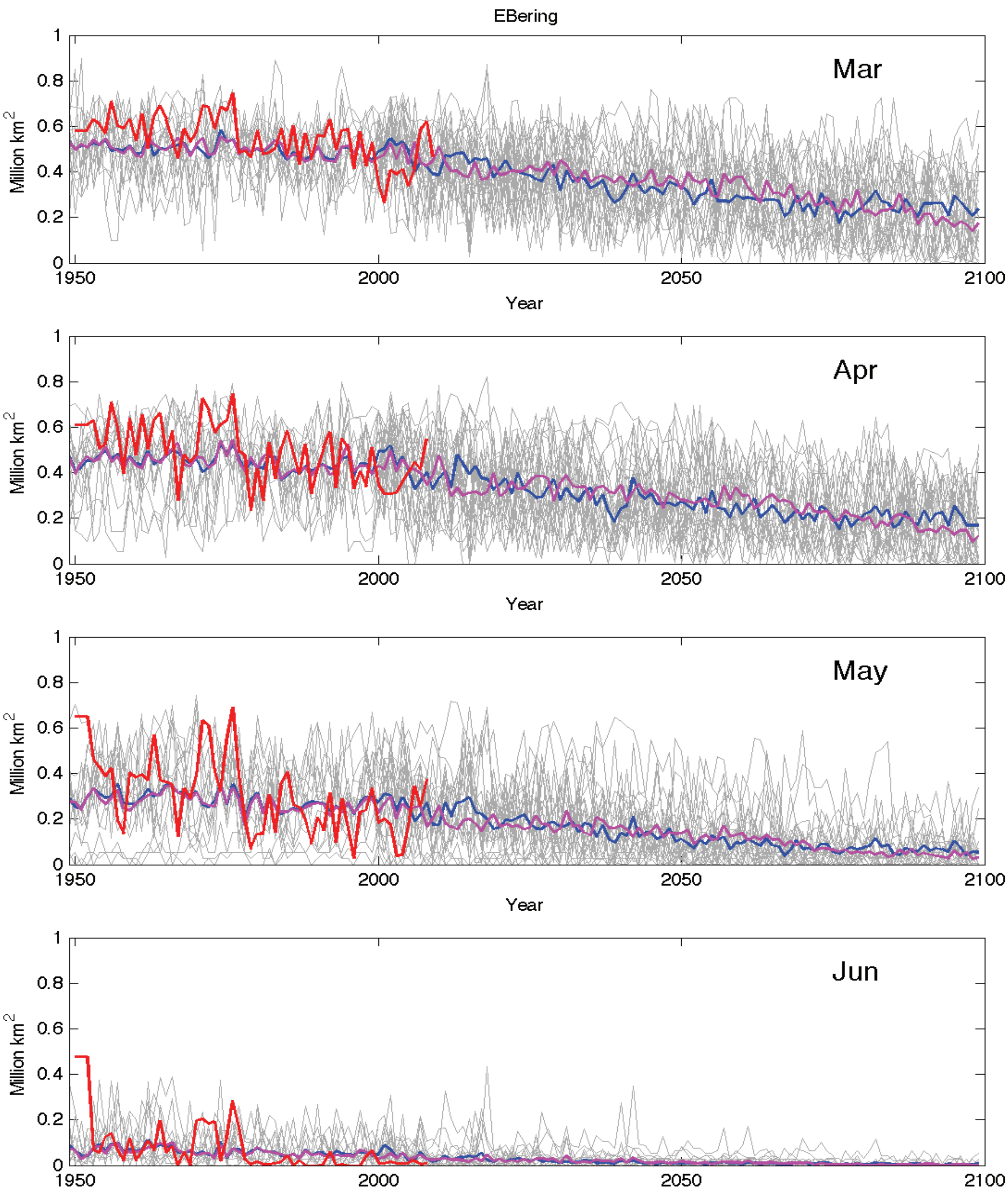

Figure 12. -- Model simulated sea-ice extent over the eastern Bering Sea for the months of March to June. The red lines (observations) are based on HadISST analysis and the other colored lines are the ensemble means of the four models (CCSM3, CNRM, ECHO-G, and MIROC(medres)) under A1B (blue) and A2 (magenta) emission scenarios. Each grey line represents one realization by one of these models.

4.2.1.1.2.3.5 Western Bering Sea

As noted above for the western Bering Sea, we discovered that the majority of models tend to overestimate the sea-ice coverage in winter, with one model underestimating the ice conditions, and only one model (CCSM3) passing the selection criteria. For reference, we provide this single model's output, and we caution that the results must be interpreted in the context of possibly large bias and lack of model-to-model variation. Projections from a single model may fail to represent the full range of uncertainty or may be subject to biases of a particular model formulation, perhaps reducing confidence in the output for this region. The western Bering Sea projections are shown in Figure 13 for spring. Compared with the observations, this model overestimated sea-ice extent in both March and April, but performed reasonably well for May and June. It projected a rapid decline in sea-ice extent over the first half of the 21st century, then relative stability, particularly under the A1B scenario, to the end of the century (top 2 panels of Figure 13). The mean linear trends estimated from the CCSM3 model were $28x10^3$ km^2/decade (8%/decade) and $17x10^3$ km^2/decade (9%/decade) for April and May, respectively during the 21st century. Under these scenarios, the western Bering Sea is projected always to have ice in March and April, through nearly the end of the 21^{st} century, though the average extent in the latter half-century would be approximately 25% of the present-day extent. The projection for May indicates that there will commonly be years with little or no ice beyond mid-century.

Figure 14 shows an example of the projected ice concentration for May and December by one of the models, CCSM3 in the coming decades. Colored contour lines outline the 15% ice concentration position, which is defined as the ice edge, or the boundary of the sea-ice extent. This clearly shows that the average December ice extent is projected to decrease faster than the average May ice extent.

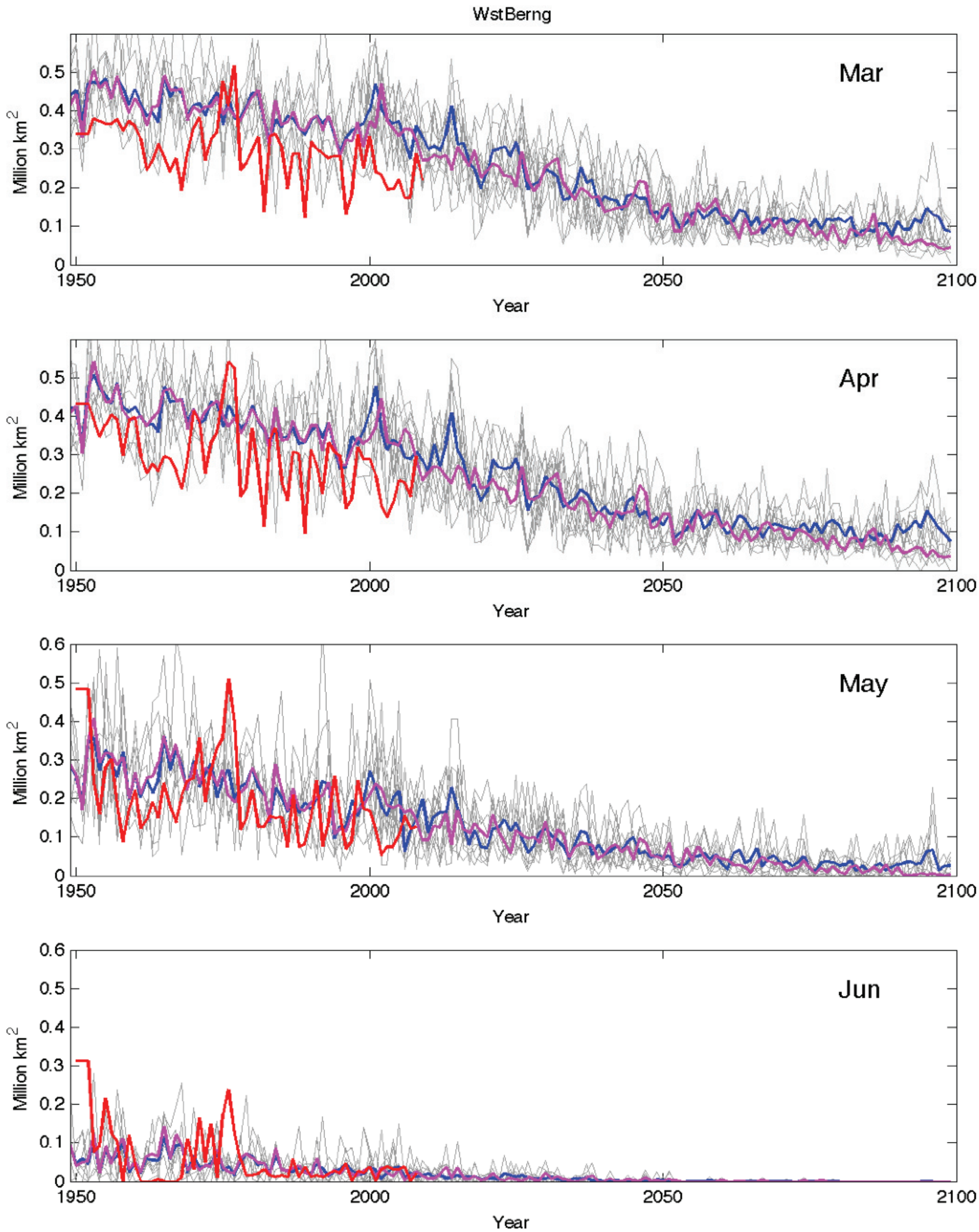

Figure 13. -- Model simulated sea-ice extent over the western Bering Sea for spring (April-June). The red lines (observations) are based on HadISST analysis and the colored lines are the ensemble means of the CCSM3 model under A1B (blue) and A2 (magenta) emission scenarios. Each grey line represents one realization by this model.

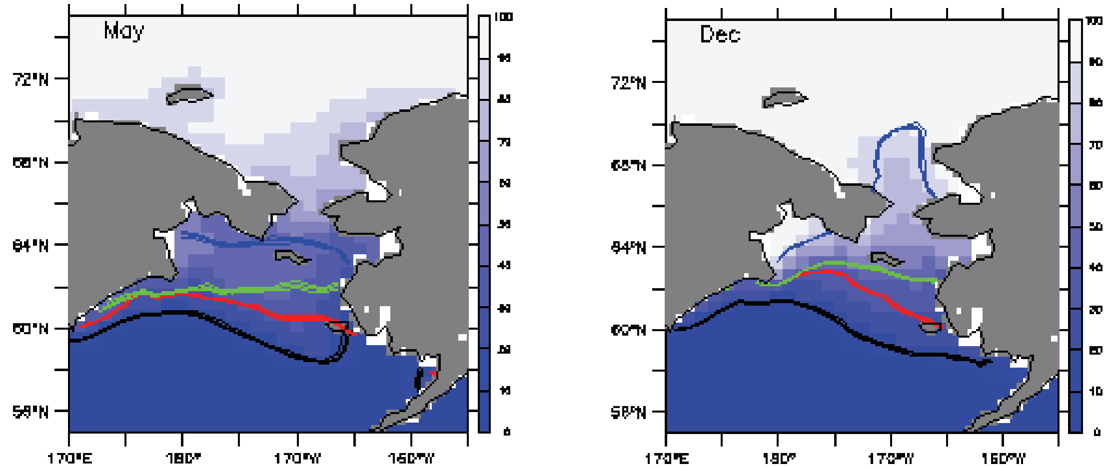

Figure 14. -- The shaded area shows an example of projected sea-ice concentration under the A1B emission scenario from one run of the CCSM3 model for May (left) and December (right). The colored lines indicate the average position of the ice edge, which is defined as 15% ice concentration in a grid box, in the recent past (1980-99, black), in 2011-2019 (red), in 2031-2039 (green), and in 2051-2059 (blue).

4.2.1.1.2.3.6 Sea of Okhotsk

The sea-ice forecasts for the Sea of Okhotsk are not sufficiently reliable for the spotted seal assessment due to model deficiencies and the small size of the region compared to the spatial resolution of the climate models. Instead we look at the model forecasts of air temperature from the IPCC-CMIP3 models relative to the current climate conditions. If future monthly mean temperatures during spring warm to approach the melting point of sea ice, ~0°C, the conditions will presumably be unsuitable for ice persistence.

The Sea of Okhotsk lies to the southwest of the Bering Sea and thus can be expected to have earlier radiative heating in spring. However, the region is dominated in winter and spring by cold continental air masses and offshore flow (Wang et al*.* 2007). During winter and spring, typical air temperatures in the northern Sea of Okhotsk are colder than in the northern Bering Sea (Wang et al*.* 2007). Sea ice is formed rapidly and is generally advected southward (Sasaki et al*.* 2007). As this region is dominated by cold air masses for much of the winter and spring, we would expect the present seasonal cycle of first year sea ice to continue to dominate the future habitat of the Sea of Okhotsk, similar to the Bering Sea. The Sea of Okhotsk in winter and spring lies between the extreme cold region of Siberia to the west and a storm track that brings warm air northward from Japan to the east. We show three maps giving the surface temperature climatology for the months of March, April, and May. March (Figure 15) is dominated by the cold continental air mass with temperatures below -6°C for most of the Sea of Okhotsk.

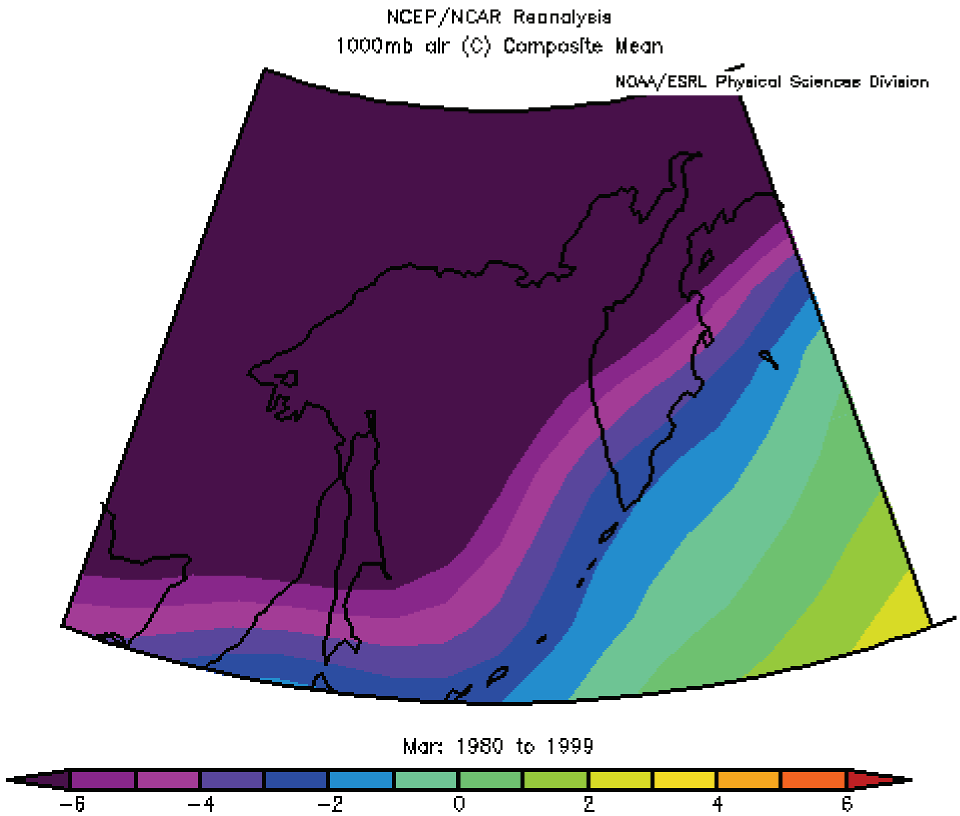

Figure 15. -- Average surface air temperature in March over the Sea of Okhotsk from 1980 to 1999.

During April (Figure 16) there is a large gradient in surface temperatures between the northern and southern portions of the Sea of Okhotsk. There are -4°C temperatures to the north and 0°C to the south. During May (Figure 17) there are relatively warm air temperatures to the west and the Sea of Okhotsk region has warmed to the melting point of sea ice throughout the region. These data fields are from the NCEP-NCAR reanalysis project which combines observational data with model interpolation to create the data fields. Plots are available through http://www.cdc.noaa.gov/cgi-bin/data/composites/comp.pl.

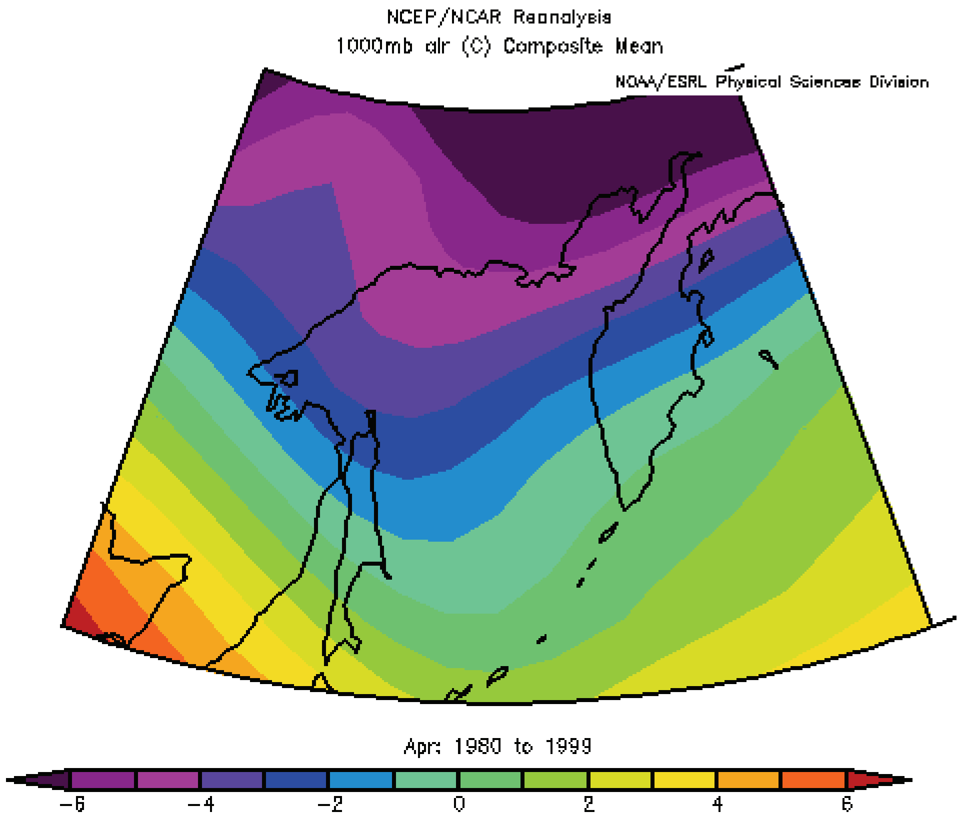

Figure 16. -- Average surface air temperature in April over the Sea of Okhotsk from 1980 to 1999.

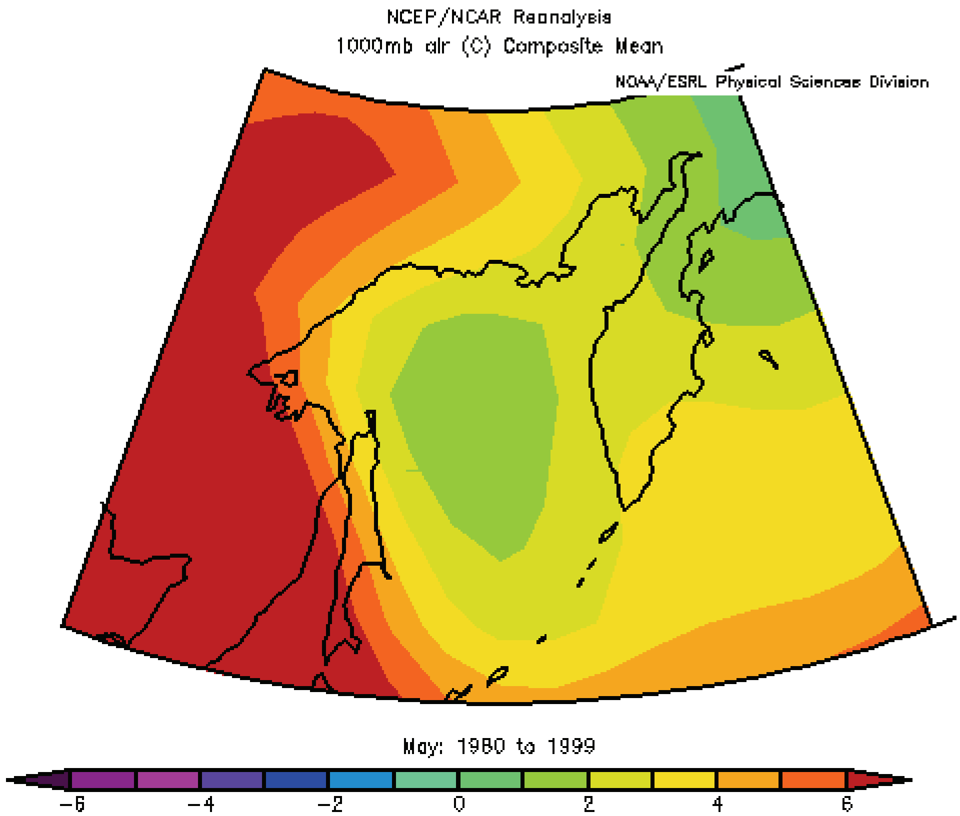

Figure 17. -- Average surface air temperature in May over the Sea of Okhotsk from 1980 to 1999.

For the projection of future air temperatures we used 13 of the 23 available IPCC-CMIP3 models, selected for their ability to represent the climate of the North Pacific (Overland and Wang 2007), and two scenarios for increases in anthropogenic gas increases, A1B and A2. The major scenario difference is that A1B slows the rate of CO_2 increase in the second half of the 21st century. Over the Sea of Okhotsk region for the future period of 2045-2054, temperatures increases for March, April and May relative to 1980-1999, are projected to be 2.9°, 2.0°, and 1.5°C for the A1B scenario, and 2.6°, 1.9°, and 1.3°C for the A2 scenario. Further out to the 2090-2099 period the temperature increases for March, April and May relative to 1980-1999, are projected to be 4.9°, 3.4°, and 2.7°C for the A1B scenario, and 5.6°, 3.9°, and 3.2°C for the A2 scenario. Sea water freezes at about -1.8°C and sea ice melts at about 0°C. Thus, we predict a continuation of sea-ice formation or presence in the Sea of Okhotsk for March through the end of this century because 4.9-5.6°C of warming (A1B and A2, respectively) on top of the -7°C recent climatology would still result in ice-forming or ice-preserving conditions, though the ice may be limited to the northern region in most years after mid-century. Conditions for sea ice in April are likely to be limited to the far northern reaches of the Sea of Okhotsk or non-existent if a 3.4°-3.9°C warming occurs by 2100.

4.2.1.1.2.3.7 Sea of Japan and Yellow Sea

Following our two-step strategy, we further evaluated the model simulated SST over the Yellow Sea and the Sea of Japan on those 13 models that passed the PDO tests (Overland and Wang 2007). For each subregion, we compared the model simulated SST seasonal cycle with the observations. We found that all but six models (CCSM3, CNRM, ECHAM5/MPI, MIROC3.2(hires), MIROC3.2(medres) and PCM1) underestimated the seasonal cycle of the SST over the Yellow sea. The projected SST anomaly over the Yellow Sea is shown in Figure 18. Only one model (MIROC3.2(hires)), with a single run, generated the seasonal cycle of the SST over the Sea of Japan with satisfaction, whereas the remaining models produced SST seasonal cycles too small in amplitude. As there was only one single run available from the single model for the Sea of Japan, we did not have enough confidence to present projections for that region.

Compared to the present climatology, at the beginning of the 21st century, the SST over the Yellow sea showed slight negative anomalies relative to its mean state (averaged over 1982-1999). The models agreed reasonably well with the observed time series, and projected a continuous increase in the SST over the region until nearly the end of the 21st century. The selected six models (blue line) showed slightly higher temperature anomalies relative to the all model ensemble mean (yellow line). By the 2050s the temperature would increase by 1-2°C over the region for all the 4 months shown, which compose the period for spotted seals' reproduction and molting. By the end of the 21st century, the models projected ~3°C temperature increase in all of the 4 months considered here.

The Bohai Sea in the northern Yellow Sea is the southernmost sea in the Northern Hemisphere that forms annual sea ice. Air temperatures there were 1.0-1.4°C warmer in 1986-1995, relative to the average in 1956-1995, associated with a notable decline in sea ice in the 1990s (Zhang et al. 1997). Bohai Sea-ice severity, a function of thickness and extent, has been very low since about 1970, a feature unprecedented in the time series going back to the 1880s (Gong et al. 2007). Although the SST anomalies depicted in Figure 18 do not translate directly into a measure of ice extent or freezing potential, the projected warming of 1°-2°C by mid-century and 3°C by the end of the century seems likely to portend the demise of reliable ice formation in this region.

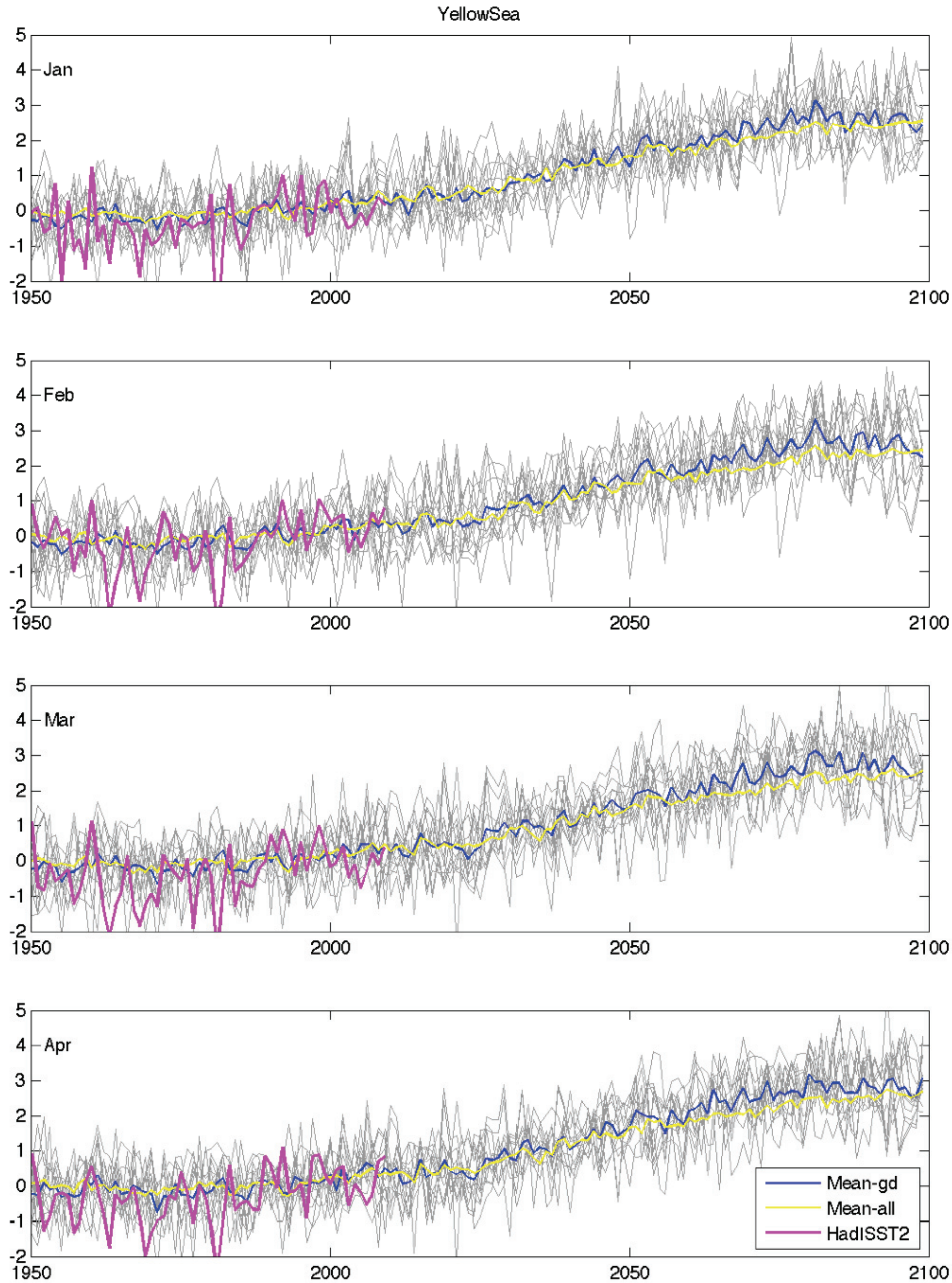

Figure 18 -- Sea surface temperature (SST) anomalies relative to the 1982-1999 period for January to April, based on six models that passed selection criteria both for the North Pacific and Yellow Sea regions. For reference, the ensemble mean based on all (63) model runs is shown by the yellow lines. Each grey line represents one realization from the selected six models (13 runs). The observations are based on UK Hadley SST analysis (HadISST2).

4.2.1.1.3 Effects of climate change on the quality of spotted seals' sea-ice habitat

Despite the expectation that large areas of sea ice in the spotted seal's range will form and persist in most years through much of the breeding and molting periods, there could be changes in the quality of ice that impact the amount of suitable habitat in the geographic areas that spotted seals have preferred in the past. Spotted seals tend to breed on relatively small, snow-covered and ridged ice floes with access to surrounding water; post-breeding basking and molting on remnant ice is not very restricted to particular ice forms (Section 2.4).

The petition to list spotted seals as threatened or endangered cited declining sea-ice thickness as a threat to spotted seals (Center for Biological Diversity 2008). Regional sea-ice thickness is difficult to quantify with current sensing methods, though there is evidence for thinning ice in the Northern Hemisphere. Sea ice in the Arctic Ocean declined during the past several decades (Rothrock et al. 1999, Maslanik et al. 2007), from both thinning of undeformed ice and loss of thick ridged ice (Rothrock and Zhang 2005). There are no reliable time series of ice thickness for the spotted seal range in the Bering Sea and Sea of Okhotsk. The part of the thinning process in the Arctic that has been due to loss of multi-year ice is not a concern for these sub-Arctic seas that form only annual ice. Shorter ice-forming seasons in the future may produce thinner ice *in situ* than in the past, but a broad range of floe thicknesses would still be expected due to rafting and ridging processes (Parmerter 1975). Much of the sea ice in the eastern and northern Bering Sea and the Chukchi Sea during spring is very densely compacted and heavily ridged, such that spotted seals are not found there in significant numbers during the breeding season. A decline in ice extent and thickness could conceivably result in new breeding habitat in such areas in the future, perhaps mitigating losses of previously-used habitat. In the Southern DPS, ice thickness in the Bohai Sea and Peter the Great Bay is likely to depend more on the thickness of *in situ* formation because smaller fetches and shorter durations of ice cover would be expected to cause less ridging and rafting than in the Bering Sea and Sea of Okhotsk. Thus, a decline in ice thickness may be of consequence to spotted seals in the Southern DPS, but is not likely to be a significant concern for the Okhotsk or Bering DPSs.

4.2.1.1.4 Effects of climate change on ocean conditions

4.2.1.1.4.1 Ocean warming

The western Beaufort Sea, the Chukchi Sea, and northern Bering Sea surface waters have warmed by as much as 3.5^{o}C since 1990 (Steele et al. 2008). Summer temperatures of the southeastern Bering Sea warmed 2^{o}C from 1995-2003 (Overland and Stabeno 2004).

The warming of sea surface temperatures would likely not have much direct impact on spotted seals, except slight benefits to the efficiency of molting and thermoregulation in water (Boily 1995, Harding et al. 2005), perhaps even somewhat mitigating the potential impacts from reduced quantity or quality of sea ice. Indirect effects of ocean warming, however, could be substantial, particularly through altered distributions of prey (Grebmeier et al. 2006), predators, and pathogenic vectors. These effects are considered in Sections 4.2.1.1.4.3, 4.2.3.3 , and 4.2.3.1 , respectively.

4.2.1.1.4.2 Ocean acidification

Approximately 30-50% of global anthropogenic CO_2 emissions are absorbed by the world's oceans (Feely et al. 2004, Sabine et al. 2004). Increased CO_2 uptake by the oceans is expected to reduce ocean surface pH by 0.3-0.5 units over the next century, which would be the largest change in pH to occur in the last 20-200 million years (Feely et al. 2004). Dissolved CO_2 increases the hydrogen ion (H^+) concentration in the ocean, and thus reduces ocean pH. The use of the term "ocean acidification" to describe this process was introduced by Caldeira and Wickett (2003). As the pH of the ocean decreases (i.e., becomes less alkaline), the equilibrium between calcium carbonate ($CaCO_3$) and the dissolution products (Ca^{2+} and CO_3^{2-}) favors dissolution. Ocean acidification reduces the calcium carbonate saturation point, which stresses calcifying organisms by making calcification more difficult. Dramatic reductions in calcium carbonate saturation have been observed in the North Pacific Ocean since the industrial revolution (Feely et al. 2004). The carbonate saturation horizon is shoaling (becoming shallower), shrinking the layer of carbonate-saturated surface waters in which calcification of organisms can occur (Feely et al. 2004). The observed and expected future shoaling of the saturation depth in the North Pacific are greater than in most of the other oceans due to respiration processes as ocean water circulates along the deep conveyor belt from the Atlantic to the Indian and Pacific Oceans (Feely et al. 2004).

Waters below the calcium carbonate saturation horizon are corrosive for calcifying organisms. The calcium carbonate saturation horizon is relatively shallow in the North Pacific Ocean. For example, aragonite (one of two naturally occurring polyforms of calcium carbonate) has a saturation horizon of about 200 m in the North Pacific Ocean compared to about 2,000 m in the North Atlantic Ocean (Feely et al. 2004). In the North Pacific Ocean, the shoaling (rising toward the surface) of the aragonite saturation horizon from pre-industrial times to present has been between 30 and 100 m (Feely et al. 2004). By comparison, the aragonite saturation horizon has changed little in the North Atlantic Ocean (Feely et al. 2004). The saturation horizon is projected to reach the surface of the North Pacific Ocean during the 21st century (Orr et al. 2005). At that point, a wide range of North Pacific species will be exposed to corrosive waters.

Ocean acidification will impact the ability of marine animals, most importantly pteropod mollusks, foraminifera, corals, shellfish and some benthic invertebrates, to make shells and skeletons from calcium carbonate (Fabry et al. 2008). This will occur principally because of a reduction in the availability of the chemical constituents needed for calcified shells and plates. These authors also note that high CO_2 influences the physiology of marine organisms through acid-base imbalance and reduced oxygen transport capacity (Fabry et al. 2008). Ocean acidification also may affect fish, marine mammal, and seabird species through reduced abundance of calcareous plankton at the base of the food web. Non-calcifying organisms also may be affected through less obvious pathways, such as the availability of nutrients to phytoplankton, the bioavailability of marine toxins to bacteria and phytoplankton, internal CO_2 concentrations of marine animals, and reduced demersal egg adhesion or fertilization success of eggs broadcast into the ocean (The Royal Society 2005). The numerous pathways for effects (both direct and indirect) imply that ocean acidification will impact many marine species.

Increased atmospheric CO_2 and reduced ocean pH may impact fish and shellfish through two distinct pathways: direct physiological stress manifested as reduced rates of growth and survival (Michaelidis et al. 2007) and reduced abundance of calcareous plankton that are prey for fish and shellfish (The Royal Society 2005, Fabry et al. 2008). Thus, the impact of acidification on the lower trophic level has direct implications for the forage base of spotted seals.

The impacts of ocean acidification on spotted seals would likely be both direct and indirect. Spotted seal diets are very flexible. Younger seals predominately consume crustaceans and older animals mainly eat fish (see Section 2.7). Young seals, consuming crustaceans, would be the most vulnerable to the direct affects of ocean acidification. But older animals could be indirectly affected by dependence on fish that, during their early life stages, are connected to lower trophic levels sensitive to ocean acidification. For example, upper trophic level pelagic species' abundance may decline if their early life stages consume prey items (e.g., pterapods (Comeau et al. 2009)) that cannot survive the added stress of ocean acidification. Pteropods are important food sources for larval and juvenile walleye pollock, Pacific herring, and cod – all of which are major components of spotted seal diets. Unfortunately, our limited understanding of planktonic and benthic calcifiers in the Arctic (e.g., even their baseline geographical distributions) means that future changes will be difficult to detect and evaluate (Orr et al. 2009).

New studies (Orr et al. 2009, Steinacher et al. 2009) show the impacts of ocean acidification may appear sooner than previously expected (Orr et al*.* 2005), with impacts perhaps becoming evident in the Arctic and North Pacific within the coming decade predicted by models under most SRES scenarios. The spatial and temporal distribution of aragonite undersaturation at the end of the 21st century depends strongly on the assumed emissions scenario (Steinacher et al. 2009). Under SRES A2, with relatively high GHG emissions, undersaturation at the surface in 2100 was projected to encompass all of the Southern Ocean, Arctic Ocean, Bering Sea, Sea of Okhotsk, and much of the north Pacific Ocean; under SRES B1, with declining GHG emissions after 2050, the global extent of undersaturation at the surface in 2100 was limited to the Arctic Ocean, Bering Sea, and Sea of Okhotsk. The Yellow Sea and Sea of Japan did not reach surface undersaturation in either of the scenarios but were part of the subtropical region in which the largest absolute changes in aragonite saturation were projected. Also, there is considerable scope for ecosystem impacts prior to undersaturation actually reaching the surface. For example, pteropods undergo vertical migrations that can cover several hundreds of meters per day (Wormuth 1981). With the shoaling of the aragonite saturation state (Orr et al*.* 2005), pteropods could be exposed to increasingly corrosive waters during their daily migrations even earlier than anticipated (Comeau et al. 2009).

Ocean acidification appears likely to impact the food webs upon which spotted seals depend. However, determining exactly what those impacts will be or when they will occur is not currently possible. A workgroup of the European Science Foundation comprised of 28 internationally recognized experts on ocean acidification recently stated the following about our current ability to forecast ocean acidification impacts (European Science Foundation 2009):

> *"Based on the presently-available data, little is known about the responses of genetically diverse populations, the life-history stages of animals and plants, synergistic effects from other stressors*

(e.g., temperature, hypoxia, nutrients), and the ability of organisms to undergo physiological and genetic adaptations to decreasing pH. A large gap in our understanding concerns the accumulation of responses from individual organisms to community and ecosystem levels. In view of these uncertainties, it is presently not yet possible to define critical thresholds (tipping points) for tolerable pH decline or to predict the pathways of ecosystem changes where threshold levels have been surpassed. In summary, our present knowledge of the effects of ocean acidification on marine biota is largely based on limited experimental work with single species and strains, maintained in short-term incubations, often exposed to abrupt and extreme changes in carbonate chemistry."

Thus, at present, it is unclear to what extent ocean acidification will impact spotted seal populations in the foreseeable future.

4.2.1.1.4.3 Spotted seal prey communities

4.2.1.1.4.3.1 Current status and trends of spotted seal prey

While the list of known prey species of spotted seals may become more extensive as additional diet studies expand the geographic, seasonal, and ontogenetic extent of coverage, the main prey species will remain those that can be encountered frequently, are densely aggregated, possess sufficient energy content, and are appropriately sized (Węsławski et al. 2006). Several groups of fishes and squid are recognized to fulfill these conditions and provide the greatest portion of the prey base for a suite of marine mammals, sea birds, and large fishes in the Bering Sea and neighboring waters (Loughlin et al. 1999). The North Pacific Fishery Management Council defines several groups as forage species for management purposes that are represented in the spotted seal diet, including sand lance, smelts, gunnels, pricklebacks, and euphausiids (Lauth 2007). In addition, walleye pollock and Arctic cod are very important forage species for spotted seals and they are recognized as nodal species in sub-Arctic and Arctic food webs, respectively (Bradstreet and Cross 1982, Frost and Lowry 1984, Springer 1992, Schabetsberger et al. 2003). Information about seasonal and regional patterns in abundance varies a great deal across the suite of potential prey – rare, small, non-commercial prey occurring in rarely surveyed locales are the least known, while abundant, large, commercially targeted prey occurring in closely monitored locales are the best known.

4.2.1.1.4.3.1.1 Bering and Okhotsk DPSs: Abundance and distribution

The species of small pelagic crustaceans identified in Table 1 (Mysidacea, Euphausiacea, and Amphipoda) are primarily preyed upon by newly weaned and first year spotted seals. The identified species occur over continental shelves of the Chukchi and Bering Seas, the Sea of Okhotsk, and the Sea of Japan (Bowman 1960, Kathman et al. 1986, Jumars 2007). These species may be abundant near the sea ice over continental shelves in spring, feeding on algae or algal grazers under the ice, similar to ice-edge-associated zooplankton in the Arctic Ocean and Barents Sea (Bradstreet and Cross 1982, Dalpadado et al. 2001), and feeding on the bloom associated with melting ice. *Thysanoessa raschii* and *Thysanoessa inermis* are Arctic to sub-Arctic species (Boden et al. 1955). *Thysanoessa raschii* occurs over continental shelves throughout the year, but it appears to have become less abundant over the southern eastern Bering Sea shelf in recent years (Hunt et al. 2008). Similarly, the range of *Themisto libellula*, a large, cold-water Hyperiid amphipod, has contracted northward based on the diets of fur seals and sea birds nesting in the Pribilof Islands and on zooplankton sampling over the southern eastern Bering Sea shelf (Hunt et al. 2008). Congeners that may be potential prey for young spotted seals include *Themisto pacifica* and *Themisto japonica*, which occur in sub-Arctic waters of the spotted seal distribution (Bowman 1960). Overall, total zooplankton biomass has been low in all areas of the eastern Bering Sea from 1999-2004 (Napp and Shiga 2005, Hunt et al. 2008), but the biomass now appears to be increasing (Napp and Yamaguchi 2008). In the Sea of Okhotsk, zooplankton abundance decreased from the mid-1980s to a low in 1997-1998, but returned to higher levels in 1999-2002 (PICES 2005).

A variety of benthic prey occurs in the spotted seal diet, but few of these prey were identified as major prey items (see Section 2.7). Based on the distribution of the benthic prey (Hart 1973, Butler 1980, Mecklenberg et al. 2002) and the diving capabilities of spotted seals, these prey are primarily eaten over the continental shelf. They include shrimp, crab, Pacific cod, *Octopus* sp., eelpouts, pricklebacks, flatfishes, sculpins, rockfish, greenlings, poachers, and others. Many species of shrimp listed in Table 1 occur on continental shelves across most of the spotted seal's range in the Chukchi and Bering Seas, Sea of Okhotsk, and Sea of Japan (Butler 1980, Jensen 1995). Several species of *Pandalus* shrimp vertically migrate within the water column at night and feed on zooplankton (Butler 1980). This may make them more available to predation by younger spotted seals that have limited diving capability if the seals feed at night or during crepuscular periods. In the Gulf of Alaska, a shift from cold- to warm-regime community structure resulted in a reduced abundance of pandalid shrimp (Anderson and Piatt 1999). The relative abundance of pricklebacks (stichaeids) has been generally lower in 1999-2008 than in previous years of the bottom trawl survey (Lauth 2007). The abundance of smaller Pacific cod that are available as prey in the eastern Bering Sea can be extremely variable due to tremendous interannual variation in year-class strength (Hollowed et al. 2001). Major demersal fish species in the Sea of Okhotsk have decreased in abundance in recent years. Total demersal fish biomass declined by about one-half between 1997 and 2000 and benthic invertebrates (including shrimps) decreased to about one-third (PICES 2005).

Schooling, mobile prey species in the diet of spotted seals are distributed primarily over the continental shelves (Hart 1973, Whitehead 1985, Cohen et al. 1990, Mecklenberg et al. 2002, Xu and Jin 2005, Tokranov 2007, Fisheries Interaction Team 2008, Froese and Pauly 2009) and have combined geographical ranges that exceed the range of spotted seals. These species include Pacific sand lance, Pacific herring, capelin, rainbow smelt, Japanese smelt, saffron cod, Arctic cod and walleye pollock (Table 1). The southward extent of Arctic cod into the Bering Sea in summer is limited by the extent of cold water formed by melting sea ice. Conversely, the extent of this cold water inhibits the northward feeding migration of walleye pollock in the summer (Kotwicki et al. 2005), although small pollock have recently been found in the Beaufort Sea (Fisheries Interaction Team 2008). Since 1979 in the eastern Bering Sea, age 3+ walleye pollock biomass has ranged from 3.4 to 13.6 million metric tons and is currently relatively low due to the absence of a strong recruiting year class in recent years. The abundance of smaller pollock that are available as prey in the eastern Bering Sea can be extremely variable due to tremendous interannual variation in year-class strength (Ianelli 2005). The relative abundance of Pacific sand lance has been lower in 1999-2008 than in previous years of bottom trawl surveys of the eastern Bering Sea (Lauth 2007). In the western Bering Sea and Sea of Okhotsk, the abundance of herring and capelin decreased substantially from 1975 through the late 1980s, then rebounded (Shuntov et al. 1996, Brodeur et al. 1999). In the Sea of Okhotsk, pollock biomass decreased significantly from a relative high observed in 1995 to a low in 2000; it has since rebounded to some extent – showing potential for increasing pollock resources in the second half of the current decade (Dulepova and Radchencko 2004). The total biomass of the epipelagic fish community in the Sea of Okhotsk declined by approximately one-half, as assessed in 2002, from a peak in 1988 (PICES 2005).

4.2.1.1.4.3.1.2 Southern DPS: Abundance and distribution

The diet of spotted seals in the Sea of Japan and Yellow Sea has not been investigated, but this species appears to consistently and effectively exploit aggregations of fishes in other parts of its range. Schooling species such as Pacific herring, walleye pollock, Arctic cod, saffron cod, capelin and Pacific sand lance are referenced multiple times in Table 1 and are considered major prey items in at least a couple of the geographic regions studied (see Section 2.7). It seems reasonable to expect some of the most important prey types in the Yellow Sea, East China Sea, and Sea of Japan to be abundant and schooling in habit. Many of the more abundant species in these seas have not been reported in the diet of spotted seals in the literature, but given the potential for them to be major prey items, some information is presented here.

Small pelagic crustaceans are primarily preyed upon by newly weaned and first-year spotted seals. In the range of the southern DPS, the species identified in Table 1 are generally not abundant (Boden et al. 1955, Bowman 1960). Other species of euphausiids that are abundant include *Euphausia pacifica* (Yoon et al. 2000), which is among the dominant zooplankton species found in the Bohai and Yellow Seas (PICES 2005, McGinley 2008). A hyperiid amphipod that may be a potential prey for young spotted seals in the southern DPS is *Themisto gracilipes*, a dominant species in the zooplankton complex of the Bohai and Yellow Seas (PICES 2005, McGinley 2008). Since the late 1980s, along the Korean Peninsula in the Sea of Japan, zooplankton abundance (most notably amphipods and euphausiids) has increased along with increasing sea surface temperature (PICES 2004). Surveys (1959, 1982, 1992, 1998) in the Bohai Sea reveal a decreasing trend in zooplankton biomass with the exception of a large increase in 1998 postulated to be related to a low anchovy (predator) biomass that year (Tang et al. 2003).

Benthic prey were not identified as major prey items in the range of the Bering and Okhotsk DPSs (see Section 2.7) and this pattern may also be present in the range of the Southern DPS. Pacific cod, a known prey of spotted seals, are known to occur in the Yellow and Bohai Seas (Cohen et al. 1990, Xu and Jin 2005). Along with other commercially important, demersal fishes in the Yellow Sea, Pacific cod decreased in abundance through the 1985-2002 period (Xu and Jin 2005). In the Yellow Sea, trawl survey results indicate that while the biomass of pelagic fish has grown since the 1950s, the contribution from demersal fishes (e.g. *Pseudosciaena polyactis, Trichiurus haumela*) has declined (Oozeki and Nakata 2002, PICES 2004). Similarly, the Korean catch of demersal fish species decreased by more than two-thirds between 1980 and 2002, whereas catches of pelagic fishes and invertebrates increased by a comparable amount over this time period (PICES 2008).

Schooling, mobile prey species may be very important in the diet of spotted seals in the southern DPS. Known prey of spotted seals, including walleye pollock, Pacific herring, rainbow smelt, and saffron cod, occur within the range of the southern DPS (Whitehead 1985, Cohen et al. 1990, Xu and Jin 2005, Froese and Pauly 2009). The Bohai Sea and the shallow waters along the coast in the Yellow Sea are important spawning grounds for most species distributed in the Yellow Sea (PICES 2008). In the Sea of Japan near the Korean Peninsula, pollock catches increased through the 1970s reaching a peak in 1983, and then declined through the late 1980s to very low levels in 2000-2002 (PICES 2008). In the early 1970s, Pacific herring dominated the biomass in the Yellow Sea for several years, and in the 1980s, other small pelagic species increased (Xu and Jin 2005). Current low levels of abundance of adult herring are unable to support a fishery in the Yellow Sea (PICES 2008). While the Japanese anchovy (*Engraulis japonicus*) has not been identified in the diet of spotted seals, it is preyed upon by large fishes in the Yellow Sea (Xu and Jin 2005) and would likely be susceptible to predation by spotted seals as well. Since the mid-1980s, the Japanese anchovy has been the most abundant fish species in the Yellow Sea (Xu and Jin 2005) and among the most abundant fish species in the East China Sea (Ohshimo 2004). However, fishing pressure increased significantly through the 1990s and by 2001-2002, the biomass had dropped to less than 10% of its peak of 4.1 million metric tons in 1993 (Zhao et al. 2003). For the two major stocks of anchovy in Japanese waters – Sea of Japan and Pacific coasts – estimates of spawning stock biomass show an upsurge beginning in 1998 (PICES 2008). Another potential prey species, not appearing in the diet studies of Table 1 is the Japanese common squid (*Todarodes pacificus*). It is a major commercial fishing species along the Korean Peninsula in the Sea of Japan, accounting for 70% of the total catch of Korean marine fisheries (PICES 2008). In the Sea of Japan, Korean catches of this squid through the 1970s and 1980s averaged about 50,000 metric tons and, after an upswing in the early 1990s, maintained an average catch at over 200,000 metric tons from 1994-2002 (PICES 2008). A third potential prey species not cited in spotted seal diet studies is the Japanese sardine (*Sardinops melanostictus*). In the Sea of Japan, sardine abundance levels were quite high in the late 1970s and through the 1980s, but are currently at very low levels (PICES 2008).

4.2.1.1.4.3.2 Projected changes in spotted seal prey

Using evidence from recent past warming episodes to forecast climate change effects on ecosystems may not be generally appropriate. Bakun (1990) cautions about performing these types of extrapolations because of the different causal mechanisms at work in controlling marine ecosystem dynamics; however, his caution is most appropriate for very complex oceanographic systems such as upwelling zones.

4.2.1.1.4.3.2.1 Abundance and distribution

Fish populations exhibit a wide array of distribution patterns, reflecting their relative sensitivities to the seasonal temperature cycle (Taylor et al. 1957, Colton 1972, Scott 1982, Murawski and Finn 1988) and climate change and the subsequent warming of the oceans is predicted to drive species ranges toward higher latitudes (Parmesan and Yohe 2003).

Climate change can strongly influence fish distribution and abundance (Wood and McDonald 1997) through changes in growth, survival, reproduction, and spawning distribution (Sundby and Nakken 2008). The responses can be mediated by changes at other trophic levels (Beaugrand et al. 2002, Beaugrand et al. 2003) as in some warm-water calanoid copepod species that expanded northward more than 1,000 km. For example, nearly two-thirds of exploited and non-exploited fish species in the North Sea showed a northward shift (average shift was 172.3 km/°C or 12 km per decade; Perry et al. 2005) in response to recent (post-1980s) rapidly warming water temperatures. The rapid warming led to the northward migration of southern species and the ecosystem changed from one dominated by cold-water species to the one dominated by warm-water species. It is unclear whether the northward shift in distribution of pelagic fishes is related to the observed shift in zooplankton communities, is a direct response to increasing temperatures, or reflects some other indirect mechanism. In the northwest Atlantic Ocean, centroids of mean catches also shifted north by 0.5-0.8 degrees of latitude for each 1°C increase in average water temperature (Murawski 1993). A global meta-analysis of range shifts in terrestrial species showed an average displacement of 6.1 km per decade, suggesting that latitudinal shifts in marine ecosystems may occur at a faster rate than in terrestrial ecosystems (Parmesan and Yohe 2003). In the eastern Bering Sea, Mueter and Litzow (2008) showed that reductions in sea ice have been responsible for shrinking the cold pool, a large pool of water less than 2°C. The southern edge of the cold pool, which defines the ecotone between Arctic and sub-Arctic communities, has retreated approximately 230 km northward since the early 1980s (Mueter and Litzow 2008). The northward expansion of warmer water resulted in an increase in total biomass, species richness, and average trophic level in the area formerly occupied by the cold pool as sub-Arctic fauna colonized newly favorable habitats. Since many fishes avoid the low temperatures of the cold pool, winter surface conditions, especially the extent of sea ice, are the dominant factor controlling summer conditions for demersal taxa (Wyllie-Echeverria and Wooster 1998, Hunt and Stabeno 2002). Mueter and Litzow (2008) concluded that the retreat of sea ice has been responsible for the northern shift of the Arctic/sub-Arctic ecotone on the continental shelf. Although biological response to past temperature changes provide some basis for predicting future changes, extrapolating observed relationships beyond historical ranges of temperatures is difficult because they cannot account for potential thresholds or nonlinearities. Rapid warming might exceed the ability of local forage species to adapt, thereby causing a major restructuring of regional ecosystems as was observed in the North and Baltic Sea ecosystems (Mackenzie and Schiedek 2007). What we can predict with some certainty is that further shifts in spatial distribution and northward range extensions are inevitable and that the species composition of the plankton and fish communities will continue to change under a warming climate (Mueter et al. 2009).

Factors influencing recruitment will have a direct impact on the abundance and age-structure of prey. If good recruitment is favored, then the population of any forage fish stock will likely increase in abundance and be composed of younger, smaller individuals. Poor recruitment will favor a less abundant population of older, larger individuals.

4.2.1.1.4.3.2.2 Vital rates

Potential biological effects of global warming on marine fish populations include acceleration of a variety of temperature-dependent processes such as growth (Brander 1995), maturity, and feeding rates (DeAngelis and Cushman 1990, Frank et al. 1990, Glantz and Feingold 1990, Hill and Magnuson 1990).

As waters warm, respiratory demands on fish bioenergetics will increase nonlinearly and assimilation efficiencies will decrease. Bioenergetic implications suggest that, even if food remains constant, growth will slow. If spotted seals have size preferences for forage fishes, then this could impact their feeding dynamics either positively or negatively.

Effects of warming on recruitment are more sensitive, since recruitment rates are in part related to dynamic physical processes (such as upwelling, existence of frontal zones, and water column stratification), which may be influenced differentially by incremental temperature change (Bakun 1990, Frank et al. 1990). Temperature has been shown to influence walleye pollock recruitment in the eastern Bering Sea (Quinn and Niebauer 1995), with temperature showing a positive relationship with recruitment.

The influence of large-scale patterns of atmospheric circulation variability, such as the North Atlantic Oscillation (NAO; Hurrell 1995) and PDO (Hare and Mantua 2000), have direct effects on local air and sea temperature conditions. These have been shown to have indirect effects on fish recruitment, such as for North Atlantic cod recruitment (Solow 2002, Stige et al. 2006, Solow and Beet 2007) and growth (Brander 2007). Barents Sea herring (Toresen and Østvedt 2000, Fiksen and Slotte 2002) also exhibit temperature effects on spawning and recruitment, with the presumption that NAO affects sea temperatures as measured on the Kola Meridian transect, a standard oceanographic transect in the Barents Sea (Stige et al. 2006). Regional differences in North Atlantic cod recruitment in response to temperature (Drinkwater 2005) have been reported as well as unspecified influences on New England groundfish stocks (Brodziak and O'Brien 2005). Sometimes the effects are localized. For example, warmer temperatures in northern areas of the Northeast Atlantic support good cod recruitment, whereas warmer temperatures in areas to the south are detrimental to cod recruitment (O'Brien et al. 2000).

4.2.1.1.4.3.2.3 Trophic dynamics

Sea surface warming has been shown to decrease phytoplankton production in the Northeast Atlantic Ocean (Richardson and Schoeman 2004), an impact that propagates up the food web by bottom-up control through copepod herbivores to zooplankton carnivores to fishes. Beaugrand et al. (2003) showed that this tight trophic coupling has direct impacts on cod recruitment in the North Sea. Increased heating of the water enhances stratification (Roemmich and McGowan 1995) and reduces turbulence-induced mixing, which prevents nutrient replenishment from colder bottom water. It is likely that warming will create nutrient-limited situations and may reduce large-celled phytoplankton abundance (i.e., diatoms) leading to a more microbial-dominated community (Cushing 1989).

In the Bering Sea, there is already strong evidence of rapid warming (Stabeno et al*.* 2007), retraction northward of the southern edge of the cold pool (Mueter and Litzow 2008), and reductions in zooplankton density throughout all of the six Bering Sea domains (Hunt et al. 2008). A downward adjustment of about 14% below the maximum permissible allowable biological catch level for eastern Bering Sea walleye pollock quota was recently adopted as a precautionary step taken by the North Pacific Fishery Management Council in response to several concerns, one of which was observations regarding changes in ecosystem productivity.

The global warming trend and increasing emissions of CO_2 and other GHGs are already affecting environmental conditions and biota in the world's oceans. We do not fully appreciate how large and deep these effects will be in the near future and we do not understand the mechanisms and processes converting the individual responses of single species into shifts in the functioning regime of marine ecosystems. It is clear that the effects of climate change and future warming will affect the base of the marine food web and its productivity as well as the abundance and distribution of upper trophic-level consumers. Changes in the distribution of key forage species will affect the degree of overlap with predators, and therefore affect overall ecosystem structure and productivity, particularly near the edges of their range. Although the direct consequences of these changes for fisheries are not clear, it seems inevitable that fish, seabirds, and marine mammals will need to adapt to a changing spatial distribution of primary and secondary production within the pelagic marine ecosystem.

4.2.1.1.5 Effects of climate change on spotted seals' habitat on shore

A warming climate might affect spotted seals' coastal habitat by physical alteration of the coastline or by changing the patterns of use of the coastline by humans and predators. Erosion rates on the Beaufort Sea coast are increasing, likely because of declining sea ice (lengthened ice-free season), increasing sea surface temperature, rising sea-level, and increases in storm power (Mars and Houseknecht 2007, Jones et al. 2009). The process is not limited to the Beaufort Sea, as several coastal villages in the Chukchi and Bering Seas already are in need of repair or relocation projects to mitigate erosion losses of coastal land (Mesquita 2008). In the Sea of Okhotsk, Sea of Japan, and Yellow Sea, the risk of habitat loss from erosion may be less than in the Chukchi and Beaufort Seas because the increase in erosion rates from the warming climate is likely to be most prevalent in permafrost coastlines (Jones et al. 2009). The BRT was unable to locate documentation of observed impacts to existing spotted seal haul-out sites ashore from erosion or deposition of sediments. The complex coastal processes of erosion, deposition, waves, and currents make it difficult to project the net effect of climate-induced changes to coastal spotted seal habitat. Loss of some habitat might be offset by creation of new habitat, or isolation of parts of existing coastline that might be currently unsuitable because of predation or disturbance.

4.2.1.2 Impacts of global climate change on spotted seals

4.2.1.2.1 Sea-ice-related impacts

In light of the heightened public attention to sea-ice loss in the Arctic, as well as the recent decision to list the polar bear as threatened under the ESA (U.S. Fish and Wildlife Service 2008), the BRT noted that the nature of spotted seals' relationship to sea ice is different from that of polar bears in several significant respects. Spotted seals' strong association with sea ice occurs in sub-Arctic seas, whereas polar bears are distributed throughout most ice-covered seas of the Northern Hemisphere, and particularly in the Arctic Ocean (U.S. Fish and Wildlife Service 2008). The seasonal contrast in the two species' relationships with sea ice is also important. Spotted seals use annually-formed sea ice for reproduction and molting in the spring, but are largely unassociated with sea ice during summer and autumn whereas most polar bears remain on the sea ice year-round or spend only short periods of time on land. Most polar bears rely on the persistence of sea ice over productive continental shelf waters, where they have both access to food (primarily ringed seals) within the sea-ice habitat and proximity to terrestrial denning areas. Thus, the recent severe decline in the extent of summer sea ice, particularly multi-year ice, of the Arctic Ocean was a primary factor in the conclusion that the polar bear should be considered threatened. The further retreat of the summer sea ice into the Arctic polar basin will force polar bears into increasingly marginal sea-ice habitat over relatively unproductive polar basin waters or into terrestrial areas lacking preferred prey and associated with increased competition and human interactions. The increasing separation between the summer ice edge and terrestrial denning areas will also subject polar bears to increased open-water swimming and risk of drowning. Spotted seals, on the other hand, are anticipated to experience little or no direct effects from the further retreat of summer sea ice in the Arctic polar basin, as they mostly forage in open water over the continental shelf during summer, making long trips to sea interspersed with relatively short visits to haul-out sites on shore, or congregating in estuaries and rivers to exploit anadromous fish runs.

4.2.1.2.1.1 Bering DPS

The seasonal formation of sea ice in the Bering Sea is substantially decoupled from the summer ice extent in the Arctic Ocean, and is expected to continue forming annually through the foreseeable future, along with typical, large interannual variations in extent and duration of persistence (Stabeno and Overland *Submitted*). Large areas of sea ice in the spotted seal's range are expected to form and persist in most years through April; the occurrence of extensive ice in May is projected to be highly variable, as it has been in the past; in June, ice will likely persist only in occasional years after mid century. Nevertheless, in association with a long-term warming trend, there will be changes in the frequency of years with extensive sea ice, and the duration of ice persistence, that may impact the amount of suitable habitat in the geographic areas that spotted seals have preferred in the past.

The general trends in the projections of sea ice for the eastern Bering Sea are toward a longer ice-free period resulting from later autumn freeze-up and more rapid spring melt. Until at least the middle of the 21st century, the variability among model runs includes nearly all of the historical range, meaning that there will still be some years with near-maximum ice extent. But, there will be less ice, on average, manifested as more frequent years in which freeze-up occurs later, spring retreat occurs earlier, and peak ice extent is lower. These trends are projected to continue through the foreseeable future, conditional on the assumptions underlying SRES scenarios A1B and A2.

Under these scenarios, the western Bering Sea is projected always to have ice in March and April through nearly the end of the 21st century, though these were outcomes of a single model. The average ice extent in the latter half-century would be approximately 25% of the present-day extent. The projections indicated that there will commonly be years with little or no ice in May beyond mid-century in the western Bering Sea.

An assessment of the risks posed by these changes must consider the spotted seal life-history functions associated with sea ice and the potential effects on the vital rates of reproduction and survival. The main life-history functions associated with sea ice are whelping, nursing of pups, pup maturation, and molting.

Whelping, nursing, and pup maturation: Our analysis indicates that the late-March to mid-May period in which the bulk of spotted seal whelping and nursing occurs will continue to have substantial ice for the foreseeable future. Similarly, Serreze et al. (2007, Fig. 3) showed that a high proportion of IPCC model simulations (with realistic 20th century performance) predicted substantial March sea-ice coverage in the Bering Sea and Sea of Okhotsk during the decade from 2075-2084; concentrations of at least 15% occurred in nearly all simulation runs in the areas that have been observed to be the core spotted seal breeding areas. Still, there will likely be more frequent years in which the ice is confined to the northern regions of the observed breeding range. The low ice years, which will come more frequently than in the past, may have impacts on recruitment via reduced pup survival, particularly if pregnant females are ineffective or slow at adjusting their breeding locales for interannual and longer-term variation in the position of the ice front.

Molting: The pelage molt of phocid seals is generally thought to be facilitated or enhanced by elevated skin temperatures that can be achieved when hauled out versus in the water (Feltz and Fay 1966). Boily (1995) concluded on the basis of a theoretical model that a small phocid, the harbor seal (similar in size and body composition to a spotted seal), could not complete its molt entirely in the water at temperatures that the species would normally encounter in the wild. As is evident from Figure 12, sea-ice coverage in June will likely be low or absent more frequently in the foreseeable future. The implications of loss of access to a haul-out substrate during this period are unknown, but spotted seals are typically moving toward coastal haul-out sites at this time of year and are capable of completing their molt in the water or on shore (Burns 2002). Also, if sea ice is preferred or required for adequate completion of the molt, spotted seals in the Bering Sea would likely adjust their molting distributions northward, even into the Chukchi Sea, where many of them already go when the heavy ice recedes. The overall effect on molting, and ultimately on spotted seal survival rate is expected to be slight.

The mechanisms identified above for impacts on spotted seal survival in years of low ice extent or early melting are all of a sort that would not necessarily be significant in any one year; a year of low ice extent seems unlikely to cause widespread mortality through disruption of the adult molt, or increased energetic costs for pups developing their foraging capabilities. Rather, the overall strength of the impacts is likely a function of the frequency of years in which they occur, and the proportion of the population's range over which they occur. Also, the effects on different age classes might be expected to be correlated, though not always in concert because they involve ice characteristics at different times in the breeding-molting period; low ice extent during breeding may not always be accompanied by early melting, and vice versa

How resilient will spotted seals in the Bering Sea be to these changes? Potential mechanisms for resilience on relatively short (i.e., behavioral and ecological as constrasted with evolutionary) time scales include adjustments to the timing of breeding in response to shorter periods of ice cover, and adjustments of the breeding range in response to reduced ice extent.

The extent to which spotted seals might adapt to more frequent years with early ice melt by shifting the timing of reproduction is uncertain. Jemison and Kelly (2001) documented shifts in whelping dates of harbor seals at Tugidak Island, Alaska. The peak of whelping was 9-14 days earlier in 1964 and in the mid-1990s than it was in the late 1970s. They showed that the changes were unlikely to be caused by shifts in the age structure coupled with age-specific differences in timing of reproduction, and therefore may have been a response to changes in environmental conditions. There are many examples of shifts in timing of reproduction by pinnipeds and terrestrial mammals in response to body condition and food availability (Boyd 1984, Skogland 1984, Stewart et al. 1989, Duck 1990, Bowyer 1991, Rachlow and Bowyer 1991, Lunn and Boyd 1993, Lunn et al. 1994, Ruthven et al. 1994, Boyd 1996, Ben-David 1997). In most of these cases, sub-optimal conditions led to later reproduction, which would not likely be beneficial to spotted seals for a phenotypic response to earlier spring ice melt. A shift to an earlier mean melt date may however, over the longer term, provide selection pressure for an evolutionary response over many generations toward earlier reproduction.

Burns (2002) speculated that the effects of global warming may well be to increase suitable habitat for spotted seals in the north, offset by a decrease of habitat in the south. Presumably, the potential increases in northern habitat would result from thinning and breaking of ice that would open up large areas of the northern Bering Sea and Chukchi Sea that in present-day winters are too heavily ice covered to be suitable for spotted seals. Shorter annual periods of ice cover, and thinner ice that is more susceptible to breakage into the types of floes preferred by spotted seals, might lead to large areas of new breeding habitat that is near or over foraging areas that are currently used during the ice-free season only. Northward shifts in distribution of important prey species (Mueter and Litzow 2008) such as walleye pollock may complement northward shifts in the distribution of suitable sea ice. Over the very long term, the Bering Strait provides seals of the Bering DPS with the prospect of adjusting their breeding range northward – as they currently do in response to interannual variation – even if the winter ice front were to contract as far north as the shelf break of the Arctic Ocean, a scenario not envisioned in any current consensus projections. Also, adult spotted seals may be less constrained to a specific geographic area or region of the ice pack once breeding is complete, around the onset of the adult molt (Boveng et al. 2007, Cameron et al. 2009). They may therefore be capable of considerable shifts in distribution to ensure contact with suitable ice through the molt period, especially in the Bering

Sea with access through Bering Strait to the Chukchi Sea, where substantial June ice cover is projected to persist throughout the 21st century (Figure 11).

Although the trends in projections of sea ice from IPCC climate models are downward, judging the timing of onset of potential impacts to spotted seals is complicated by the coarse resolution of the models. The models available for assessment of future sea-ice conditions are global in scale with a typical spatial resolution (~1^{o} of latitude) that is much coarser than the scale at which spotted seals are likely to interact with fields of sea ice. Model scenarios, and the remote-sensed ice data that have been used to fit and tune the models, may depict zero ice at times, even in areas where spotted seals remain capable of finding suitable ice. For example, the data on which Figure 12 is based show zero ice for June 2008 in the eastern Bering Sea. Yet, on 27 June 2008, the NOAA ship *Oscar Dyson* encountered a field of ice with numerous ribbon and spotted seals at 60^{o}N near St. Matthew Island (K. Hough, NOAA Office of Marine and Aviation Operations, June 28, 2008, pers. comm.), an area where no ice was visible on even the relatively high resolution (12.5 km) satellite images of sea ice for that day and hundreds of miles south of the apparent southern edge of the ice (Cavalieri et al*.* 2004, updated daily). Thus, both the observed time series and the model projections likely understate the availability of suitable ice for spotted seals so that a downward trend in ice extent is likely to appear problematic some years before actually becoming so.

4.2.1.2.1.2 Okhotsk DPS

The sea-ice related threats faced by spotted seals in the Sea of Okhotsk are largely the same as those in the Bering Sea, but the projections of future conditions are less certain. In consideration of the observed climatology and projected air temperatures, much of the region may have ice-deteriorating conditions in April by the mid-21st century and little or no sea ice in April by the end of the century. This region is characterized by some differences from the Bering Sea that may be significant to the status of spotted seals. Unlike in the Bering Sea, ice in the Sea of Okhotsk often extends beyond the continental shelf, over deep water. Spotted seals on ice in the Sea of Okhotsk apparently prefer to remain over the continental shelf (Trukhin 2003), as they do in the Bering Sea (Lowry et al. 1998). Therefore, in the Sea of Okhotsk, they seemingly avoid the ice front when the ice extends over much deeper water. Trukhin (2003) described changes in spotted seal distribution in response to interannual variability in sea-ice coverage, noting that they disperse more in years of extensive ice, and become denser when ice is below average extent. There has not been, however, any study that would verify whether vital rates of reproduction or survival have been affected by interannual variations in ice extent and breeding. Whelping, nursing of pups, and maturation of weaned pups might be little impacted in years when the ice does not extend as far south as it has typically in the past; the breeding areas would then be nearer the ice front and in the ice types that seem to be preferred, at least in the Bering Sea. The ice-covered area is much smaller in the Sea of Okhotsk than the Bering Sea and, importantly, there is no marine connection to the Arctic Ocean, unlike in the Bering Sea. Over the very long term, spotted seals in the Sea of Okhotsk do not have the prospect of following a shift in the average position of the ice front northward into the Arctic, as Bering Sea spotted seals would.

4.2.1.2.1.3 Southern DPS

Although we were not able to project sea-ice conditions for the Yellow Sea and Sea of Japan, a suite of models for SST was found that was acceptable for hindcasting observed data for the Yellow Sea (Figure 18). The SST models and observations exhibit very little trend since 1950, including the period of observations since 1982. However, by the year 2050, a SST increase of nearly 2^{o} C is projected for the months of December-March. By the end of the 21st century, a warming of nearly 3^{o} C is projected, perhaps leveling off somewhat in the final decade. The prospects for continued annual ice formation in this region appear to be bleak for the foreseeable future. These projections encompassed almost the entire Yellow Sea. The current area of annual ice formation is limited to the Bohai Sea (the northern part of the Yellow Sea) (Gong et al. 2007), so the actual trends in SST and sea-ice formation in these areas might not proceed as quickly toward regular ice-free winters as indicated by the projections. Nonetheless, the long-term prospects for spotted seal reproduction and molting on sea ice in the Yellow Sea breeding area appear to be very poor.

In the absence of projections specifically for the Sea of Japan, which encompasses the spotted seal breeding area of Peter the Great Bay, the BRT recommends assuming that the SST and sea-ice formation in the future will be similar to that in the Yellow Sea. Sea-ice formation in both seas is driven by cold winds emanating from the Siberian High, a dominant circulation system in the Eurasian winter (Gong et al. 2007). The spotted seal breeding areas in both seas are at similar latitudes. Therefore, the long-term prospects for continued annual occurrence of suitable sea-ice habitat in Peter the Great Bay are bleak, as they are for the Yellow Sea.

The question of whether a future lack of sea ice will cause the Southern DPS of spotted seals to go extinct depends in part on how successful the populations are at moving their reproductive activities from ice to shore-based haul-out sites. Some unknown portion of the Yellow Sea breeding concentration presently reproduces on shore (Wang 1986) and all or nearly all breeding in Peter the Great Bay apparently now takes place on shore (Trukhin 2005, Nesterenko and Katin 2008, Nesterenko and Katin 2009). A shift toward breeding on land may pose a problem of lack of suitable space; spotted seals breeding on land in Liaodong Bay and Peter the Great Bay seem to use only offshore rocks and small islands (Bo 2006, Nesterenko and Katin 2008). Breeding on shore may expose spotted seals to new threats from terrestrial predators, disease vectors, and human disturbance. Phocid seals, especially the pups, are vulnerable to predators while hauled out, probably the major reason that the species that breed ashore avoid predation by selecting areas that are relatively inaccessible to predators (e.g., offshore rocks, small islands, and sandbars or mudflats with unobstructed views). Although no quantitative inventory is available, there seems to be fewer of these types of sites in the Southern DPS than in the Okhotsk or Bering DPSs.

4.2.1.2.2 Ocean-condition-related impacts

Ocean acidification may impact spotted seal survival and recruitment through disruption of trophic regimes wherever they are dependent on calcifying organisms. The nature and timing of such impacts are uncertain and the possible ecological pathways and outcomes are complex. Several changes already documented in the Bering Sea and the North Atlantic are of a nature that could be ameliorative or beneficial to spotted seals. For example, several fish species, including walleye pollock (a common spotted seal prey), have shown northward distribution shifts and increased recruitment in response to warming, at least initially. These ecosystem responses may have very long lags as they propagate through trophic webs. Because of spotted seals' apparent dietary flexibility, this threat should be of less immediate concern than the direct effects of potential sea-ice degradation.

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

4.2.2.1 Commercial, subsistence, and illegal harvest

4.2.2.1.1 Okhotsk and Bering DPSs

Russian Natives have hunted spotted seals for many centuries, primarily to fulfill their basic subsistence needs for meat, hides, and oil, and more recently, to also feed their fur-bearing animals on collective farms (Krylov et al. 1964, Fedoseev 1984a). Fedoseev (2000) estimated that, prior to the 1950s, the subsistence harvest from the Sea of Okhotsk ranged between 3,750 and 5,250 spotted seals per year (based on an estimated total annual catch of 25,000-35,000 seals, of which 15% were spotted seals). Spotted seals were taken in insignificant numbers by Russian Natives along the Bering and Chukchi coasts, who preferred to harvest ringed and bearded seals instead (Krylov et al. 1964, Fedoseev 1984a).

Soviet sealers began commercially harvesting spotted seals in the Sea of Okhotsk during the early 1930s. Spotted seals comprised a small proportion of the ship-based harvest (which also included ringed, bearded, and ribbon seals), averaging only 6.5% of the total catch from 1937 to 1939 (Heptner et al. 1976a). Over two-thirds of the commercial harvest came during the summer-fall hunting season from beach rookeries in the western Sea of Okhotsk and Tatar Strait where about 500-1,000 spotted seals were caught annually (Heptner et al. 1976a). Despite its success, state-sponsored hunting at beach rookeries was discontinued by the end of the 1930s. The ship-based commercial harvest in the Sea of Okhotsk increased substantially in the mid-1950s as the sealing fleet grew in size, skill, and intensity (Krylov et al. 1964, Heptner et al. 1976a). Hunting was unregulated until 1969 (Fedoseev 2000). According to Fedoseev (1984a), the annual catch during this time ranged between 1,507 and 9,264 spotted seals and averaged 4,634 (Table 3). Fedoseev (2000) also noted that the actual number of seals killed was always greater than the reported number of seals harvested, since on average 25-30% of spotted seals that were shot escaped into the water or sank before they could be collected.

Table 3. -- Number of spotted seals harvested annually by commercial sealing ships in the Sea of Okhotsk during 1955-1980 (Fedoseev 1984a) and 1990-1994 (Grachev 2006).

Year	Number harvested	Year	Number harvested
1955	1,987	1971	4,497
1956	2,740	1972	4,221
1957	7,728	1973	4,510
1958	1,507	1974	4,500
1959	4,872	1975	no data
1960	9,264	1976	5,089
1961	4,329	1977	2,562
1962	2,598	1978	4,942
1963	8,305	1979	5,149
1964	5,003	1980	1,540
1965	3,996	1981-1989	no data
1966	1,790	1990	6,263
1967	4,009	1991	5,659
1968	6,752	1992	4,503
1969	5,689	1993	4,169
1970	4,399	1994	1,094

Ship-based commercial sealing began in the Bering Sea in 1961 and also was unregulated until 1969. During this time, approximately 2,000 spotted seals (2,600 accounting for losses) were harvested each year in the Bering Sea (Fedoseev 2000), which in the early 1960s, accounted for only 2.1% of the total ship-based harvest including all species (Heptner et al. 1976a). In fact, spotted seals never comprised more than 9.3% of the total ship-based seal harvest, even in the best years (Tikhomirov 1966a, cited by Heptner et al. 1976). Soviet sealers harvested spotted seals in comparatively low numbers for a variety of reasons. The sealers apparently had difficulty accessing large numbers of spotted seals in the early spring when the seals were spread out in low-density “family groups” in the relatively dense ice pack. And when the seals became more accessible in the late spring as the ice began melting and the seals formed large molting herds, they also became much more wary and a single rifle shot would spook the entire herd into the water where they could not be hunted effectively (Krylov et al. 1964, Heptner et al. 1976a). Spotted seals were also less commercially valuable than bearded and ribbon seals, which were preferred for their oil and meat (Fedoseev 2000). By the mid-1960s, some Soviet scientists recognized that the stocks of ribbon, bearded, and ringed seals were being depleted by overharvesting and recommended hunting spotted seals in greater numbers to relieve the pressure from the other species (Krylov et al. 1964, Heptner et al. 1976a). Hunting regulations were established in 1969-1970 to protect all seal species, even though spotted seals were not thought to be depleted. Annual catch limits for the ship-based harvest were set at 5,000 spotted seals in the Sea of Okhotsk and 6,000 in the Bering Sea, while coastal harvest quotas were set at 2,000 spotted seals per year in each sea (Popov 1976).

Between the mid-1950s and mid-1970s, the combined annual catch from ship and shore-based harvests in the Sea of Okhotsk and Bering Sea did not exceed 10,000-15,000 spotted seals per year (Popov 1976). This level of exploitation was not thought to have affected the species’ stocks. In the southern Sea of Okhotsk near Hokkaido, Japan, sealing was done on a small-scale by fishermen during their off-season.

Approximately 1,100 spotted seals were harvested annually from Hokkaido during 1968-1970 (Naito 1971). Kosygin and Gol'tsev (1971) noted that spotted seals were the predominant species in the Tatar Strait and comprised 80% of the subsistence harvest by the local inhabitants. The authors also noted that this species was being underutilized by commercial hunters and recommended establishing an initial quota of 1,000 spotted seals in this region (Kosygin and Gol'tsev 1971). Lowry (1985) reported that the total annual Soviet harvest in the Bering and Chukchi Seas during 1966-1976 ranged between about 1,800 and 5,600 spotted seals, with an average of about 3,850. About 89% of these seals were taken by commercial vessels and 11% by coastal hunters. An increasing demand for furs in the Soviet Union during the early 1970s made spotted seals (especially pups and juveniles) more commercially valuable, and the annual ship-based harvest increased to about 3,000 spotted seals (4,800 accounting for losses) in the Bering Sea during 1969-1985 (Fedoseev 2000), while slightly decreasing in the Sea of Okhotsk to an average of 4,282 seals during 1969-1980 (Table 3). The annual shore-based harvest in the Bering Sea ranged between 14 and 707 spotted seals, with average of 347 per year during 1969-1983, and the maximum shore-based harvest in the Chukchi Sea was 325 spotted seals in 1979 (Quakenbush 1988).

Little information could be found concerning the harvest levels in Russia from the mid-1980s on. Fedoseev (2000) reported that the annual ship-based quota in the Bering Sea was reduced to 1,600 spotted seals during 1986-1990, but it is unknown how many seals (if any) were actually harvested during this period. Grachev (2006) reported that an average of 4,338 spotted seals were harvested annually in the Sea of Okhotsk during 1990-1994 (Table 3). Following the collapse of the Soviet Union in 1991, commercial sealing became less economically viable as the traditional raw materials and products obtained from sealing (e.g., meat, oil, furs, animal food, and fertilizer) became unprofitable under the new economic conditions (Grachev 2006). Large-scale, ship-based harvests ended in the Bering Sea in 1991 and in the Sea of Okhotsk in 1994 (Burns 2002; V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, May 1, 2009, pers. comm.). A small-scale commercial harvest continued in the Sea of Okhotsk with a total annual take (including all species) averaging around 400 seals during 1995-2005 (Grachev 2006). The Russian Federation set high allowable catches ranging between 11,300 and 14,800 spotted seals per year during 2002-2005 (Marine Mammal Council 2008); however, the actual harvest levels were only a small fraction of these figures (Grachev 2006). In 2008, the allowable catches were set at 1,700 in the Bering Sea, 2,800 in the Sea of Okhotsk, and 1,700 in the East Siberian and Chukchi Seas, and in 2009 no allowable catch figures were listed for spotted seals (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, August 31, 2009, pers. comm.). Grachev (2006) reported that studies were conducted to develop new, more profitable uses of marine mammal products for the medical, pharmaceutical, and veterinary industries in Russia, and proposed that 33,000 seals (of which 4,500 would be spotted seals) could be harvested annually by three commercial sealing vessels. There are no known plans to implement this proposal.

Commercial harvesting of spotted seals still occurs in several areas of the Russian Far East, but it is believed to be relatively limited, with a maximum take of perhaps a couple thousand individuals annually. In addition, a similar number may be taken illegally each year by Russian Natives for their own local use (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, May 1, 2009, pers. comm.). Hovelsrud et al. (2008) reported that recent subsistence harvests in the Chukotka region were small-scale and sustainable. Spotted seals are also reportedly killed by fishermen in many parts of the Russian Far East in order to stop them from eating fish from salmon traps or nets. Although there are no accurate records of this illegal take, it may be "quite high" (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, May 1, 2009, pers. comm.).

Spotted seals are an important resource to Alaska Native subsistence hunters in the coastal regions of the Bering and Chukchi Seas (Lowry 1985, Burns 2002) and have been for many generations. Between about 1966 and 1976, annual harvests in Alaska were reported to range between 850 and 3,600 spotted seals with an average of about 2,400 per year (Lowry 1985). From September 1985 to June 1986, the combined harvest from five Alaskan villages was 986 spotted seals (Quakenbush 1988). During 1992-2006, the annual subsistence take (including losses) from six villages in northern Bristol Bay ranged between 62 and 437 spotted seals with an average of 210 per year (Wolfe et al. 2008), though some of these may have been harbor seals as both species occur in Bristol Bay during summer. As of August 2000, information in the ADFG subsistence harvest database provided an estimate of 5,265 spotted seals harvested for subsistence use in Alaska per year (Angliss and Allen 2009). This represents the best estimate of harvest levels in Alaska currently available.

Commercial harvesting of marine mammals in U.S. waters is prohibited by the Marine Mammal Protection Act (16 U.S.C. 1361 et seq.) (MMPA) and is not considered a threat to spotted seals in this part of their range.

4.2.2.1.2 Southern DPS

Little information could be found concerning harvest levels in Peter the Great Bay. Trukhin and Mizuno (2002) reported that daily harvests of spotted seals reached 80 or more in Peter the Great Bay at the end of the 19th century. Seal numbers decreased considerably until the 1930s, likely reflecting high hunting pressure that accompanied the influx of people into the area. The establishment of the Far Eastern Marine Reserve in 1978 prohibited hunting of spotted seals in parts of Peter the Great Bay, but it is unknown what level of hunting (if any) occurs outside of the reserve's boundaries. Bycatch in fishing nets (Trukhin and Mizuno 2002) and illegal shooting by fishermen (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, May 1, 2009, pers. comm.) are believed to be the greatest threats to spotted seals in this region.

Spotted seals have existed for centuries in the northern Yellow and Bohai Seas, though their numbers there have dwindled during the past century due to excessive hunting (Dong and Shen 1991). The total number harvested in this region during 1930-1990 was estimated to be 30,395 seals (Dong and Shen 1991), or an average of 507 per year. In the 1950s, hunting pressure was high and as many as 1,000 seals were killed per year; in the 1960s and 1970s, about 400-500 seals were hunted annually (Wang 1998). The population became seriously depleted during this time so the species was provided protection under the Fishery Resources Protection Regulation of 1979 (Dong and Shen 1991, Wang 1998). In 1983, the Liaoning provincial government banned the hunting of spotted seals, and in the early 1990s, China established the Dalian National Spotted Seal Nature Reserve in Liaodong Bay for their protection; however, poaching pressure on spotted seals apparently remained high because of demand for furs, meat, oil, and male genitalia for use in traditional medicines (Wang 1998). Wang (1986) also believed that overharvesting of young seals was the major cause for their decline at the time. Currently, there is not believed to be any commercial or subsistence take of spotted seals in the Yellow or Bohai Seas, and the incidence of poaching is believed to be decreasing due to strengthened monitoring and enforcement (Yong-Rock An, Cetacean Research Institute of South Korea, May 6, 2009, pers. comm.).

4.2.2.2 Scientific and educational utilization

4.2.2.2.1 Bering and Okhotsk DPSs

The MMPA generally prohibits the "taking" (defined as "harass, hunt, capture, kill or collect, or attempt to harass, hunt, capture, kill or collect") of marine mammals in U.S. waters, but does provide some exceptions, such as for scientific and educational purposes. The NMFS permitting and authorization process regulating these activities is fairly stringent and the number of allowed lethal takes is usually low. Furthermore, the number of researchers granted permits to take spotted seals in the United States is also very limited; therefore, the scientific and educational utilization of spotted seals in U.S. waters is not considered a threat to the species.

The BRT is not aware of any laws that provide a similar level of protection to marine mammals in Russian or Japanese waters; however, government-issued permits are required for killing marine mammals for any purpose in Russia. Researchers from TINRO are permitted to collect tens to a couple hundred spotted seals each year to analyze the seals' diet during salmon runs in the western Kamchatka Peninsula, northern Sea of Okhotsk, and Chukotka (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, May 1, 2009, pers. comm.). This level of scientific utilization is not considered a threat.

4.2.2.2.2 Southern DPS

There is no known scientific or educational utilization of spotted seals in Peter the Great Bay (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, May 1, 2009, pers. comm.), and information from China and Korea is limited. Wang (1998) reported that the Lushui Zoo in China purchased a total of 395 spotted seals between 1976 and 1982. Wang (1998) also stated that about 10-20 young seals were allowed to be collected alive for zoos each year, but only a few were taken in 1987 and 1988. Captive spotted seals are also held in the Marine Museum of Qingdao, and 15 pups have been born there (Wang 1998). These facilities currently house tens of spotted seals, of which about ten are released into the wild each year due to the facilities' limited capacity (Yong-Rock An, Cetacean Research Institute of South Korea, May 6, 2009, pers. comm.). In South Korea, two aquariums, three zoos, and one dolphinarium keep a total of about 20 spotted seals, which were mostly imported or born in captivity (Yong-Rock An, Cetacean Research Institute of South Korea, May 6, 2009, pers. comm.). One research institute in South Korea and two in China currently conduct studies on spotted seals; these are not known to cause any mortality and are not considered a threat to the species (Yong-Rock An, Cetacean Research Institute of South Korea, May 6, 2009, pers. comm.).

4.2.3 Diseases, Parasites, and Predation

4.2.3.1 Diseases

Relatively little is known about diseases in spotted seals (Lowry 1985). Transmission of many known diseases of pinnipeds is facilitated by animals crowding together and continuous or repeated occupation of a site (Fay 1974, Fay et al. 1979). The pack ice habitat and more solitary behavior of spotted seals may limit disease transmission (Fay 1974). During winter and spring, while in the pack ice, spotted seals do not crowd together and rarely share the ice floes with more than a few other seals, so conditions that favor disease transmission do not exist for much of the year (Fay 1974).

Some caliciviruses are known to have a marine origin and are able to spread and cause disease in both marine and terrestrial species, including humans (Barlough et al. 1987, Smith et al. 1998). A couple of well-known examples of these types of caliciviruses are vesicular exanthema of swine and San Miguel sea lion virus, which was the first virus isolate from a pinniped (Smith et al. 1998). Barlough et al. (1987) conducted a study to investigate whether Tillamook calicivirus (TCV), which infects bovines, has a marine origin. Blood samples from several species of marine mammals from Pacific populations, including 10 spotted seals, were tested for the presence of serum neutralizing antibodies to TCV (Barlough et al. 1987). Spotted, ribbon, ringed, and bearded seals, a few non-ice associated phocids, northern fur seals (*Callorhinus ursinus*), Pacific walruses, and a few cetaceans were all negative for antibodies to TCV (Barlough et al. 1987). Only California sea lions (*Zalophus* californianus) and Steller sea lions (*Eumetopias* jubatus) tested positive for antibodies , which was not completely unexpected because most caliciviruses that have been isolated from marine mammals have been from species in the subfamily Otariinae (Barlough et al. 1987).

Herpesvirus infections have been found in several marine mammal species from the northern hemisphere (Kennedy-Stoskopf et al. 1986, Zarnke et al. 1997) (Harris et al. 1990) cited in (Zarnke et al. 1997). Herpesviruses have been associated with both fatal and nonfatal infections of harbor seals from the north Pacific, central and northern California, and the Netherlands (Borst et al. 1986, Spraker et al. 1994, Gulland et al. 1997). Two types of phocid herpesviruses have been identified. Phocid herpesvirus-1 (PhHV-1) is an alpha herpesvirus, related to both canine herpesvirus and felid herpesvirus, and phocid herpesvirus-2 (PhHV-2) is a gamma herpesvirus (Osterhaus et al. 1985, Harder et al. 1996, Zarnke et al. 1997). PhHV-1 caused the death of 11 harbor seal pups in a nursery in the Netherlands and has caused disease in other pinnipeds with clinical signs that include pneumonia, adrenocortical necrosis, and hepatic necrosis (Osterhaus et al. 1985, Borst et al. 1986, Kennedy-Stoskopf et al. 1986, Gulland et al. 1997). PhHV-1 is highly contagious, and natural transmission of the virus occurs through aerosols or direct contact (Zarnke et al. 1997). It is unknown how PhHV-2, the gamma herpesvirus, is transmitted, and there is no evidence that PhHV-2 causes clinical disease in pinnipeds (Zarnke et al. 1997). Zarnke et al. (1997) tested marine mammals from off the coasts of Alaska and Russia for antibodies to PhHV-1 and PhHV-2. They examined walrus, two species of otariids, and five species of phocids, which included 32 spotted seals. In spotted seals, serum antibody prevalences for PhHV-1 and PhHV-2 were 72% and 16%, respectively, and antibody prevalence for neither virus was 28%. Antibody prevalences for PhHV-1 were higher than for PhHV-2 in most of the species examined, and the three highest prevalences of antibodies to PhHV-1 were found in phocid seals. The effects of age, sex, and year of collection on antibody prevalences for both viruses were examined as well. In spotted seals, antibody prevalence of PhHV-1 was higher in females than males, but the difference was not significant (Zarnke et al. 1997). Zarnke et al. (1997) suggested that serum antibody prevalences found in this study indicate that marine mammals off the coasts of Alaska and Russia are regularly exposed to PhHV-1 and PhHV-2 and possibly to other related herpesviruses. Quakenbush et al. (2009) tested serum from spotted seals collected from the Bering and Chukchi Seas, between 1998 and 2008. They found 33.3% of spotted seals were positive for PhHV-1 antibodies, but they found no antibodies for PhHV-2. PhHV-1 may be an important cause of morbidity in harbor seals; however, the pathogenicity of PhHV-1 is not well understood, and the fact that seals often have concurrent bacterial infections complicates the situation (Gulland et al. 1997). Although there have not been any documented herpesvirus epizootics in marine mammals off the coasts of Alaska and Russia, the exposure to herpesviruses allows for the possibility of epizootics (Zarnke et al. 1997).

Quakenbush et al. (2009) also reported on tests of spotted seal sera for the morbilliviruses phocine distemper virus (PDV) and canine distemper virus (CDV); PDV has been found in harbor seals and has been known to cause large die-offs (Zarnke et al. 1997; Quakenbush et al. 2009). However, no antibodies for PDV or CDV were found in spotted seals from the Bering and Chukchi Seas, collected between 1998 and 2008 (Quakenbush et al. 2009).

The family Poxviridae includes the largest known virus particles found in terrestrial and marine mammals. Poxviruses generally replicate in the skin and mucosa and produce localized or generalized lesions (Buller and Palumbo 1991, Bracht et al. 2006). Many terrestrial poxviruses have had their DNA sequenced either partially or completely, but few marine poxviruses have been sequenced, despite the fact that poxviruses in marine mammals have been well documented (Bracht et al. 2006). Bracht et al. (2006) examined lesions and identified parapoxvirus infection in spotted seals for the first time. They sequenced several fragments of parapoxvirus DNA, including parts from the DNA polymerase gene, the DNA topoisomerase I gene, and the major envelope protein gene (Bracht et al. 2006).

Brucella abortus is a bacterium that is known to cause reproductive problems in marine mammals and has been found in harbor seals in Alaska (Zarnke et al. 2006). *Brucella* antibodies were identified in 16.2% of spotted seals collected from the Bering and Chukchi Seas between 1998 and 2008 (Quakenbush et al. 2009). This low level is comparable to what has been found in other Arctic species (Quakenbush et al. 2009).

A spotted seal that stranded on the coast of Toyama Bay, Sea of Japan, had cancerous growths in several different organs (Honma et al. 2000, Honma et al. 2001). It had signet ring cell carcinoma associated with scirrhous cancer in the stomach, cortical adenoma in the kidney, and adenocarcinoma and extensive proliferation of macrophages in the gastric lymph nodes (Honma et al. 2000, Honma et al. 2001). They suggested that carcinomatous cells from the stomach cancer may have transferred through vascular canals to the marginal sinuses of the gastric lymph nodes, and subsequently established the tumors in the lymph nodes and kidney. Adenocarcinoma in the gastric lymph nodes of marine mammals has not been previously documented (Honma et al. 2000, Honma et al. 2001).

Neospora caninum and *Toxoplasma gondii* are protozoans that can cause encephalitis and toxoplasmosis, both of which may lead to mortality in several species of domestic and wild animals (Van Pelt and Dieterich 1973, Migaki et al. 1977, Holshuh et al. 1985, Lapointe et al. 1998, Cole et al. 2000, Miller et al. 2001, Dubey et al. 2003). Serum antibody prevalences of *N. caninum* and *T. gondii* have been examined in several species of marine mammals (Dubey et al. 2003, Fujii et al. 2007). Dubey et al. (2003) tested serum samples from nine spotted seals that were collected in Alaska between 1976 and 1998, and only one was positive for *T. gondii* antibodies. None of the nine seals were positive for *N. caninum* antibodies (Dubey et al. 2003). In contrast, Fujii et al. (2007) collected serum from 46 spotted seals from around Hokkaido, Japan, and also examined them for antibodies to *N. caninum* and *T. gondii*. They found two seals that were positive for antibodies against *N. caninum*, but none of the seals tested positive for antibodies against *T. gondii* (Fujii et al. 2007). These results indicate that spotted seals across their range are exposed to both of these protozoans and can become infected, but it is sporadic (Dubey et al. 2003, Fujii et al. 2007). Also, marine mammals around Hokkaido may be exposed more commonly to *N. caninum* than *T. gondii* (Fujii et al. 2007). The two main sources of postnatal *T. gondii* infection are ingestion of oocysts in contaminated food or water and ingestion of *T. gondii*-infected tissues (Dubey et al. 2003, Fujii et al. 2007). Felids and dogs are the only known hosts that can excrete environmentally resistant oocysts of *T. gondii* and *N. caninum*, respectively (Dubey et al. 2003, Fujii et al. 2007). Oocysts from both species may be washed into the ocean in runoff contaminated by excrement (Fujii et al. 2007). *T. gondii* oocysts are extremely resistant to environmental influences, and therefore, likely to survive in the ocean (Dubey et al. 2003). Miller et al. (2002) determined that there was a strong association between *T. gondii* seropositivity in sea otters and locations of maximal freshwater outflow along the California coast; therefore, land-based surface runoff was a significant risk for *T. gondii* infection in sea otters in these locations.

4.2.3.2 Parasites

Many helminth parasites have been found in spotted seals in the Bering Sea and Sea of Okhotsk (Popov 1975, Heptner et al. 1976a, Shults 1977, Fay et al. 1978, Eley 1981, Shults 1982, Delyamure et al. 1984, Takahashi 1999). Helminth fauna from spotted seals include various species of cestodes, trematodes, nematodes, and acanthocephalan worms (Table 4). Popov (1975) identified the first record of *Dipetalonema spirocauda*, a filaroid nematode that frequently infects the cardiovascular system in spotted seals. Eley (1981) examined hearts and pulmonary arteries from marine mammals in Alaskan waters to determine prevalence and distribution of *D. spirocauda*. He only found *D. spirocauda* in spotted, ringed, ribbon, bearded, and harbor seals. The parasite was more common in harbor seals, which are not associated with sea ice, than in any of the four species of ice-associated seals (Eley 1981). *D. spirocauda* were not found in walrus, Steller sea lion, northern fur seal, bowhead whale (*Balaena mysticetus*), beluga whale (*Delphinapterus leucas*), Dall's porpoise (*Phocoenoides dalli*), harbor porpoise (*Phocoena phocoena*), or polar bear (Eley 1981).

Table 4. -- Helminth species from spotted seals in the Bering Sea and Sea of Okhotsk.

Species	Sources[a]
Cestodes	
Diplogonoporus tetrapterus	1, 3, 4, 6, 7
Diphyllobothrium lanceolatum	1
Diphyllobothrium cordatum	1, 6
Diphyllobothrium sp.	1, 3, 4, 7
Diphyllobothriidae gen. sp.	7
Anophryocephalus ochotensis	1, 3, 4, 6
Anophryocephalus skrjabini	2
Anophryocephalus sp.[b]	7
Pyramicocephalus phocarum	1, 2, 7
Trematodes	
Orthosplanchnus fraterculus	1
Orthosplanchnus arcticus	7
Orthosplanchnus pygmaeus	7
Phocitrema fusiforme	1, 3, 4, 6, 7
Microphallus orientalis	7
Nematodes	
Phocanema decipiens	3, 6
Phocanema sp.	1
Contracaecum osculatum	3, 4, 6, 7, 8
Contracaecum sp.	1
Dipetalonema spirocauda	1, 2, 3, 5, 6, 7
Anisakidae gen. sp.	2, 7
Anisakis simplex	7, 8
Anisakis sp.	2
Phocascaris cystophorae	2, 7
Phocascaris sp.	8
Terranova azarasi	2
Terranova decipiens[b]	7
Terranova sp.[b]	7
Pseudoterranova decipiens	8
Pseudoterranova cystophorae	8
Otostrongylus circumlitus	7
Acanthocephala	
Bolbosoma sp.[b]	1, 3, 4, 7
Corynosoma hadweni	1
Corynosoma strumosum	1, 2, 3, 4, 6
Corynosoma semerme	1, 2, 3, 4, 6, 7
Corynosoma validum	1, 2, 4, 6, 7
Corynosoma villosum	1, 4, 6, 7
Corynosoma wegeneri	7

[a] Sources: (1) Shults 1977, (2) Popov 1975, (3) Fay et al. 1978, (4) Fay et al. 1979, (5) Eley 1981, (6) Shults 1982, (7) Delyamure et al. 1984, (8) Takahashi 1999

[b] Species in question in Delyamure et al. 1984; authors disagreed on identification

In spotted seals from the Bering Sea and Sea of Okhotsk, the organs most commonly infected by various helminth species included all sections of the intestinal tract, stomach, duodenum, heart, and rectum (Popov 1975, Heptner et al. 1976a, Shults 1982). Spotted seals from the Bering Sea exhibited helminth-induced damage and local inflammation of the stomach wall, which was associated with moderate to heavy infestations of nematodes of genera *Anisakis, Contracaecum*, and *Phocanema* (Fay et al. 1978). Anisakid nematodes were found attached in clumps to the stomach wall, where they caused non-perforating ulcers (Fay et al. 1979). Shults (1982) generally did not find gross lesions associated with helminth presence, but in a few instances the nematodes, *Contracaecum osculatum* and *Phocanema decipiens*, had caused ulceration of the stomach wall. Spotted seals collected off the coast of Hokkaido were also highly infected with anisakid nematodes, all of which were found in the stomach cavity and attached to stomach walls (Takahashi 1999). Adult seals contained higher nematode numbers than juveniles or pups, and *Pseudoterranova decipiens* was the dominant nematode species, in both adult and larval forms (Takahashi 1999).

Helminthological characteristics of spotted seals from across the Bering Sea are generally similar. Delyamure et al. (1984) compared helminth species composition from spotted seals collected from three regions of the Bering Sea where they concentrate during the breeding season. The three regions were the Karaginsky Gulf, the central Bering Sea from south of Cape Navarin to St. Matthew Island, and the southeastern Bering Sea from the Pribilof Islands to outer Bristol Bay (Braham et al. 1984). Twenty-two helminth species were found in about 300 spotted seals, and most helminths were found in at least two of the regions. Ten of the 22 helminth species were shared among all three regions; eight helminths were common between at least two of the regions; and only five helminths were found in one region only (Delyamure et al. 1984). The great similarity of helminth species' composition among the different regions indicates spotted seal diets in all three regions are probably very much alike (Delyamure et al. 1984). Helminth compositions were more similar between seals from the southeastern Bering Sea and Karaginsky Gulf. This may be because the habitats of these two regions are more similar to each other and generally support subarctic prey species, as opposed to the central Bering Sea region, where it is deeper and colder and primarily has arctic prey species (Delyamure et al. 1984). Shults (1982) determined that helminth species from Bering Sea spotted seals were similar to species found in other phocid seals from the Bering Sea, but helminths from spotted seals from the Sea of Okhotsk and Sea of Japan were different.

In the Bering Sea, larval stages of several helminth species found in spotted seals have also been found in fishes that are common prey of spotted seals (Shults 1977, Fay et al. 1979). Fay et al. (1979) examined 195 individuals of 16 fish prey species and found at least one larval helminth species that was also known to infect spotted seals in 15 of the 16 prey species.

Studies on infections in spotted seals of *Echinophthirius horridus*, a species of anopluran lice, have come to contradictory conclusions. Heptner et al. (1976a) cited "Freund 1993" and "Moore 1995" (but did not list them in their Literature Cited) as reports of large numbers of this parasite on spotted seals, mainly located on the back, upper side of the tail, and at the base of the hind flippers. However, Fay et al. (1979) determined that *E. horridus* were only found rarely on bearded, ringed, and ribbon seals (1-5 lice per seal). The parasite was found in slightly greater numbers on spotted seals, but they were still uncommon (less than 10 lice per seal) (Fay et al. 1979). *Echinophthirius horridus* may have been found in greater numbers on spotted seals because they are more social than the other ice-associated seals (Fay et al. 1979).

Halarachnid mites (Acarina: Halarachnidae) are parasites that inhabit the respiratory tract in mammals, primarily residing in the nasal passages (Fay et al. 1979, Fay and Furman 1982). Nasal mites have been found infrequently in bearded, ringed, ribbon, and spotted seals (Fay et al. 1979, Fay and Furman 1982). Fay and Furman (1982) examined nasal passages from marine mammals collected in the eastern Bering, eastern Chukchi, and western Beaufort Seas. They only found nasal mites in spotted and harbor seals, and Steller sea lions, and no lesions were associated with the nasal mites. All nasal mites in spotted seals were adults of *Halarachne halichoeri* Allman; no larvae were found (Fay and Furman 1982). Although only 6% of spotted seals had nasal mites and no other ice-associated seals were infected, it is likely that these seals are infected by nasal mites, but rarely (Fay and Furman 1982). In another study, only 4 of 202 seals, including ringed, ribbon, bearded, and spotted seals, were infected with nasal mites, and all of these were spotted seals (Fay et al. 1979). Fay and Furman (1982) suggested that transmission of these nasal mites primarily occurs by direct nasal contact or breathing on each other during non-aggressive nosing behavior, which mainly takes place during the breeding season. Spotted seals are also generally more social than the other ice-associated seals, so these factors may explain why nasal mites have been found in greater numbers on spotted seals (Fay et al. 1979).

Dermatitis has been found infrequently in spotted seals (Fay et al. 1978). Nodular lesions, a few of which were ulcerative, were located in the skin of the hind flippers and ankles on only 2 of 37 seals collected from the Bering Sea (Fay et al. 1978, Fay et al. 1979).

4.2.3.3 Predation

4.2.3.3.1 Past and present scenarios

Direct observations or data on predation of spotted seals are limited. Reported predators include polar bears, brown bears (*Ursus arctos*), walruses, killer whales (*Orcinus orca*), Pacific sleeper sharks (*Somniosus pacificus*), foxes, wolves, sea lions, eagles, and gulls (Popov 1982, Quakenbush 1988). Spotted seals are not the primary prey for any of these predators. Ringed seals and bearded seals are the primary prey of polar bears (Derocher et al. 2004). Harbor seals and other marine mammals have been found in the stomachs of Pacific sleeper sharks (Yang and Page 1999); however, whether these prey were carrion or live prey is undetermined. As with ribbon seals (Heptner et al. 1976b), during the period that seals are associated with ice, mortality due to killer whales, polar bears, and sharks only occurs occasionally.

Of the potential predators, polar bears, killer whales, and walruses seem the most likely to encounter spotted seals in the current sea-ice regime. In the Bering Sea, spotted seals are concentrated within the marginal sea-ice zone from March through June. Polar bears in the Bering Sea are rarely observed south of St. Matthew Island. As the sea ice retreats, molting adult spotted seals and weaned pups are often associated with remnant patches of ice and these areas can be farther north and more coastal. It is during this period and in these limited areas when polar bears have the highest likelihood of encountering spotted seals. The naiveté of young pups and physiological constraints of molting for older seals would make them vulnerable to opportunistic predation. In the case of polar bears, some separation might be maintained because polar bears would also tend to move north at this time of year.

Killer whales are known to be highly capable predators of marine mammals throughout the world (Forney and Wade 2006). Three ecotypes have been identified in the North Pacific Ocean: resident (fish-eating), transient (mammal-eating), and offshore (fish-eating) (Ford et al. 1998, Ford et al. 2000, Herman et al. 2005). The transient ecotype is the most likely potential predator of spotted seals. Two recent abundance estimates of mammal-eating killer whales in the coastal waters of the western Gulf of Alaska and Aleutian Islands are 251 (Zerbini et al. 2007) and 345 (J. Durban, NMML, October 7, 2008, pers. comm.). The former estimate comes from line-transect surveys of the number of whales present in these coastal waters during the summer survey months. The latter estimate differs by estimating the number of whales that *use* these coastal waters, but may not necessarily be present at all times. The difference implies movement outside of this area.

Sightings of killer whales in the vicinity of the ice edge have been rare in recent seal research cruises. A group of transient killer whales was observed, and later confirmed with photo identification, in close proximity to hauled-out spotted seals during a research cruise in the central Bering Sea in April 2008[2]. Transient killer whales in the Aleutian Islands and Bering Sea in summer are known to prey on northern fur seals, minke whales, Steller sea lions (Matkin et al. 2007), and beluga whales (Frost et al. 1992); and during the spring months, a large number (~100 per year) aggregate in the eastern Aleutian Islands to feed on migrating grey whales (*Eschrichtius robustus*) (Footnote 2). The extent of predation on spotted seals is currently unknown.

Unlike the case with ringed seals and polar bears, spotted seals are not likely a primary prey of killer whales, though given the overlap in their distribution and killer whales' proficiency as a predator, some level of predation by killer whales is likely. Killer whale predation could occur both during the portion of the year when spotted seals are associated with nearshore habitats as well as during the whelping, weaning and molting period when seals are associated with the sea-ice edge. Sea ice would allow seals to escape or avoid predation by killer whales, but naïve, newly weaned pups venturing into the water would provide an efficient, high energy food source. As spotted seals move to the coastal areas, they are known to haul-out in concentrations of 1,000-2,000 or more. In these habitats, they would represent a concentrated source of prey, and provide similar opportunities as harbor seals, a preferred prey item for many killer whales in the North Pacific.

Lowry and Fay (1984) documented walrus predation on ringed, spotted and bearded seals in the Bering Sea . Stomach contents of walruses from 1952 to 1982 were examined and seal parts were found in 5 of 364 stomachs. The five stomachs contained a total of three spotted seals which were determined to be young of the year.

The coastal habitats used by spotted seals are usually isolated from land and protected from terrestrial predators. Nevertheless, the opportunity for predation by brown bears, wolves and foxes does exist in

[2] Unpubl. data, C. Matkin, North Gulf Oceanic Society, P.O. Box 15244, Homer, AK 99603.

some locations. Popov (1976) reports the brown bear as the main predator of spotted seals in the Sea of Okhotsk with wolves and Arctic fox (*Alopex lagopus*) as less important predators. Popov supposed a natural mortality rate of 10% for spotted seals land-based haul-out sites. Marakov (1967) described occurrences of blue fox feeding on placentae, dead pups, and some live pups at shore-based whelping areas in the Commander Islands. These may have been harbor seals, in which case the observation would still be relevant to assessment of future risks should spotted seals become more dependent upon breeding ashore. Marakov also noted that the shallow nearshore habitats and reefs provide protection from killer whales in these areas.

4.2.3.3.2 Future scenarios

With scarce information on the degree of interaction between spotted seals and potential predators, as well as the distribution and behavior of those predators, it is difficult to project how a changing sea-icescape would impact the vulnerability of spotted seals to predation. In a scenario of reduced sea ice and faster spring melting, spotted seals may be distributed in areas of more persistent sea ice that are further north and more coastal. This redistribution might increase the overlap with polar bears in some areas such as the northern Bering Sea, thus potentially increasing the seals' vulnerability to predation. Yet, a reduction or northward shift in seasonal ice is also likely to impact the distribution and abundance of polar bears and their primary prey (i.e., ringed and bearded seals). Also, a reduction in sea ice may result in more diffuse distribution of sea ice and less favorable conditions for polar bear predation than under the present sea-icescape. Reduced sea ice may also encourage a wider segment of the spotted seal population to breed, whelp, and molt on nearshore, non-ice habitats. Under such a scenario, spotted seal pups would be more vulnerable to predation from foxes, bears, eagles, gulls and ravens. The range of plausible scenarios is large, making it impossible to predict the direction or magnitude of the net impact on spotted seal mortality.

Walrus predation on spotted seals may increase as all the pagophilic species are forced to share less ice and their distributions are compressed. Lowry and Fay (1984) noted increased consumption of seals by walrus during a low ice year. The potential does exists for some increased predation of spotted seals by walrus as the sea-icescape changes. As with polar bear predation, this depends largely on how the sea ice is distributed. If the available sea ice is constrained to the northern region and more coastal areas, then the risk of increased exposure to walrus is higher. A more diffuse distribution of sea ice or a shift in distribution to non-ice, nearshore habitats would likely decrease the potential interaction between walrus and spotted seals.

Reduced availability of sea ice may lead to increased time spent by spotted seals in the water earlier in the spring/summer, especially for molting adults and recently weaned pups; they would then be more susceptible to predation in the water, for example by killer whales or Pacific sleeper sharks. Killer whales are highly adaptable and mobile, so a reduced sea-ice scenario might facilitate greater access to spotted seals in the spring and early summer. One uncertainty is the amount of time that might elapse before killer whales extend their typical foraging range northward in response to a long-term reduction in ice extent or in response to changing prey availability elsewhere. The topics of how mammal-eating killer whales switch among favored prey, and the ecological consequences, are currently under active investigation and debate. (Springer et al. 2003, DeMaster et al. 2006, Mizroch and Rice 2006, Trites et al. 2007, Wade et al. 2007, Springer et al. 2008).

4.2.4 Inadequacy of Existing Regulatory Mechanisms

Spotted seals are currently protected under U.S. law, specifically by the Marine Mammal Protection Act (16 U.S.C. 1361 et seq.) (MMPA). However, at this time, there are no known regulatory mechanisms that effectively address reductions in spotted seals' sea-ice habitat, or other effects of global climate change.

Commercial hunting of marine mammals is prohibited in U.S. territorial waters by the MMPA and is not considered a threat to the species in this part of its range. The BRT is not aware of any laws that provide a similar level of protection to marine mammals in Russian or Japanese waters; however, government-issued permits are required for killing marine mammals in Russia for any purpose (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, May 1, 2009, pers. comm.). Sealing has been prohibited in China since 1983 (Wang 1998).

Large-scale commercial harvesting of spotted seals from Russian vessels ended in 1994, though small-scale commercial harvests from land and small boats occurs along the Russian Far East coast (Lowry and Burkanov 2008). Between the mid-1950s and mid-1970s, the combined annual catch from ship- and shore-based harvests in the Sea of Okhotsk and Bering Sea did not exceed 10,000-15,000 spotted seals per year (Popov 1976). This level of exploitation was not thought to have affected the species' stocks. During 2002-2005 the Russian Federation set high allowable catches ranging between 11,300 and 14,800 spotted seals per year (Marine Mammal Council 2008). These high commercial quotas represent a potential risk for spotted seals. If the allowed harvest were realized, the loss of seals in the Sea of Okhotsk and western Bering Sea could potentially approach unsustainable levels. Consequently, large-scale commercial harvests would need to be closely monitored to ensure they remain at sustainable levels. Currently, harvest levels remain very low, likely ranging in the tens to few hundreds of spotted seals per year (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, August 20, 2008, pers. comm.). If economic conditions were to change in Russia so that commercial sealing was once again profitable, high levels of harvest could adversely affect the species. Regulations which govern commercial harvest of ice seals in Russia are over 20 years old and are artifacts of the former Soviet Union (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, September 15, 2008, pers. comm.). Therefore, it is unclear what mechanisms are currently in place in Russia to ensure that potential commercial harvests remain within sustainable levels. Overall, the high allowable harvest levels and growing interest in resuming commercial sealing in Russia provide the potential for future overexploitation of the spotted seal.

Poaching is also a threat in portions of the spotted seals' habitat (Wang et al. 2003). In Liaodong Bay in China, the spotted seal population declined in the 20th century due to overhunting and destruction of coastal habitat (Won and Yoo 2004). The spotted seal population in the Bohai Sea was estimated at around 8,000 individuals in the early 1940s, but declined markedly due to high hunting pressure, to a low of 2,300 seals in the 1980s before increasing to 4,500 seals in 1990 (Won and Yoo 2004), likely due to the ban on hunting in the 1980s (Burns 2002). According to local residents near Bak-ryoung Island off western South Korea, seal numbers in the region have declined since the 1970s (Won and Yoo 2004). Spotted seal mortalities continue in this region from bycatch in fisheries, direct killing of seals by commercial fishers, and poaching (Won and Yoo 2004).

Due to overhunting, the spotted seal population in Peter the Great Bay declined from several thousand individuals at end of 19th century to perhaps 1,000 individuals in the 1980s (Trukhin and Mizuno 2002). The population likely rebounded somewhat due to protection of island and coastal haul-out sites by the establishment of the Far Eastern Marine Reserve in 1978 (Trukhin and Mizuno 2002). The establishment of the Far Eastern Marine Reserve prohibited hunting of spotted seals in parts of Peter the Great Bay, but it is unknown what level of hunting (if any) occurs outside of the reserve's boundaries. The spotted seal population was again estimated at 1,000 individuals in 1996, reflecting no population growth despite the prohibitions on hunting, protection of breeding and pupping areas, and favorable environmental conditions (Trukhin and Mizuno 2002). The lack of population growth was likely due to high mortality rates of spotted seals from bycatch in the saffron cod trap net fishery in Peter the Great Bay (Trukhin and Mizuno 2002).

A full discussion of commercial, subsistence, and illegal harvesting of spotted seals can be found in Section 4.2.2.1 .

4.2.4.1 Existing Conservation Efforts

4.2.4.1.1 International Agreements

Several conservation efforts have been undertaken by foreign nations specifically to protect spotted seals. In 1978, Russia established the Far Eastern Marine Reserve in Russia's Peter the Great Bay. The islands of the reserve provide both protection from human disturbance and suitable haul-out sites for spotted seals. The vast majority of this spotted seal population uses the reserve during the spring, particularly for breeding and molting (Trukhin 2005, Nesterenko and Katin 2008, Nesterenko and Katin 2009). Protection of breeding and pupping areas resulting from the establishment of the reserve may have resulted in some growth of the spotted seal population (Trukhin and Mizuno 2002). This population is still vulnerable to other threats outside of the reserve, such as set fishing nets.

In 1983, China's Liaoning provincial government banned the hunting of spotted seals (Won and Yoo 2004). In the 1990s, two national protected areas were established for the protection of spotted seals in the Liaodong Bay area of China, including the Dalian National Spotted Seal Nature Reserve. However, in 2006, the boundaries of the Dalian Nature Reserve were adjusted to accommodate industrial development (Bo 2006).

Spotted seals are listed in the Second Category (II) of the *State Key Protected Wildlife List* in China and listed as Vulnerable (V) in the *China Red Data Book of Endangered Animals* (Wang 1998). Won and Yoo (2004, citing Wang 1998) stated that spotted seals are categorized as Critically Endangered in the Yellow Sea, but this may be a misinterpretation (see Wang 1998). The spotted seal is designated a vulnerable species under the Wildlife Conservation Act of China (Wang 1998). However, as of 2004, no “conservation action, public awareness or education programmes have been carried out for the species in this region” (Won and Yoo 2004).

In 2000, spotted seals were afforded protected status under the Wildlife Conservation Act of South Korea. Despite this protection, the Liaodong Bay population, shared between China and Korea, continued to decline (J. B. Han, unpubl. data, cited in Han et al. *In press*).

4.2.4.1.1.1 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 regulates international trade in animals and plants by listing species in one of its three appendices. The level of monitoring and control to which an animal or plant species is subject depends on which appendix the species is listed in. Appendix I includes species threatened with extinction which are or may be affected by trade. 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 utilization incompatible with their survival. 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 that species. Spotted seals have no special status under CITES.

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

The IUCN Red List identifies and documents those species most in need of conservation attention if global extinction rates are to be reduced, and is widely recognized as the most comprehensive, apolitical global approach for evaluating the conservation status of plant and animal species. 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 standardized approach to determine species’ risks of extinction. The most recent Red List assessment suggested that reductions of the spotted seal population could exceed 30% in the next 30 years due to predicted reductions in its sea-ice habitat, meeting the IUCN threshold for “Vulnerable” under one criterion (Lowry and Burkanov 2008). None of the other ten criteria met the thresholds for Vulnerable or more urgent categories. Because current abundance and population trends are unknown, the spotted seal is currently classified as “Data Deficient” on the IUCN Red List.

4.2.4.1.1.3 Mechanisms to Limit Sea-ice Reduction and Ocean Acidification by Regulation of GHG

There are no known regulatory mechanisms that effectively address changes to spotted seal habitat from reduction in sea-ice or ocean acidification. The primary international regulatory mechanisms addressing GHG emissions and global warming are the United Nations Framework Convention on Climate Change and the Kyoto Protocol. However, the Kyoto Protocol’s first commitment period only sets targets for action through 2012. There is no regulatory mechanism governing GHG emissions in the years beyond 2012. The United States is a signatory to the Kyoto Protocol but has not ratified it; therefore, the Kyoto Protocol is non-binding on the United States.

4.2.4.1.2 Domestic Regulatory Mechanisms

4.2.4.1.2.1 Marine Mammal Protection Act of 1972, as Amended (MMPA)

Spotted seals are protected in U.S. waters and on the high seas by the MMPA (16 U.S.C. 1361 et seq.). 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 population stocks from diminishing to the point where they are no longer a significant functioning element of the ecosystems.

The MMPA places an emphasis on habitat and ecosystem protection. The habitat and ecosystem goals set forth include: (1) management of marine mammals to ensure they do not cease to be a significant element of the ecosystem to which they are a part; (2) protection of essential habitats, including rookeries, mating grounds, and areas of similar significance ``from the adverse effects of man's action''; (3) recognition that marine mammals ``affect the balance of marine ecosystems in a manner that is important to other animals and animal products'' and that marine mammals and their habitats should therefore be protected and conserved; and (4) directing that the primary objective of marine mammal management is to maintain ``the health and stability of the marine ecosystem.'' Congressional intent to protect marine mammal habitat is also reflected in the 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, for purpose of public display, subsistence use by Alaska Natives, and unintentional incidental take coincident with conducting 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 Department of Commerce, through NOAA, has authority with respect to whales, porpoises, seals, and sea lions. The remaining marine mammals, including polar bears, walruses, and sea otters, are managed by the Department of the Interior through the USFWS. Both agencies are responsible for the promulgation of regulations, the issuance of permits, the conduct of scientific research, and enforcement as necessary to carry out the purposes of the MMPA.

U.S. citizens who engage in a specified activity other than commercial fishing (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 unmitigable 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 and their habitat, 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.

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 unmitigable 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.

Certain exceptions from the prohibitions on taking are provided. The MMPA exempts Alaska Natives from the prohibitions on the taking of marine mammals, including spotted seals. Sections 101(b)(3) and 103 of the MMPA provide for subsistence harvest regulations for marine mammal stocks designated as depleted under that Act, after notice and administrative hearings as prescribed by the MMPA. Section 119 of the MMPA allows the Secretary of Commerce to enter into cooperative agreements with Alaska Native organizations to conserve marine mammals and provide co-management of subsistence uses.

4.2.4.1.2.2 National Environmental Policy Act (NEPA)

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

4.2.4.1.2.3 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 of the state boundaries (3-mile limit) in order to expedite exploration and development of oil and gas resources on the OCS. Implementation of OCSLA is delegated to the Minerals Management Service (MMS) of the Department of the Interior. Outer continental shelf 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. The OCSLA does not itself regulate the take of spotted seals, although through consistency determinations it helps to ensure that OCS projects do not adversely impact spotted seals or their habitats.

4.2.4.1.2.4 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 the 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 spotted seal habitats of Alaska, though the CZMA does not itself regulate the take of spotted seals.

4.2.4.1.2.5 Marine Protection, Research and Sanctuaries Act (MPRSA)

The 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 does not itself regulate the take of spotted seals, although it operates to protect the quality of marine habitats that spotted seals rely upon.

4.2.4.1.2.6 Mechanisms to Limit Sea-ice Reduction and Ocean Acidification by Regulation of GHG Emissions

There are currently no legal mechanisms regulating GHGs in the United States. GHG emissions have not been effectively regulated under the U.S. Clean Air Act (CAA). In 2003, the EPA rejected a petition urging it to regulate GHG emissions from automobiles under the 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 (Supreme Court of the United States 2007). 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 identified six GHGs that pose a potential threat. However, the proposed finding does not include any proposed regulations. Before taking any steps to reduce GHGs under the CAA, the EPA must conduct an appropriate process and consider public comment on the proposed finding (U.S. Environmental Protection Agency 2009).

The BRT did not attempt to separate the risk posed by the lack of a regulatory mechanism for GHG emissions from the risks posed by the effects of those emissions. In Section 4.2.1, the risks posed by increased GHG emissions, via potential destruction or modification of spotted seal habitat, were assessed by evaluating the best available projections of future conditions under scenarios of no regulation of GHGs (the projections were based on "non-mitigated" scenarios for future emissions). Therefore, the implications of the current lack of regulations are already included in the evaluation of risks to spotted seal habitat in the three DPSs. In other words, while there are no regulatory mechanisms that effectively address reductions in sea ice habitat or ocean acidification, we do not expect this

shortcoming to result in population-level impacts beyond those already identified in the section on present or threatened destruction of habitat.
Inadequacy or lack of stringency of mechanisms to regulate oil and gas activities in the Yellow Sea and Sea of Okhotsk could contribute to the cumulative risk faced by the Southern and Okhotsk DPSs.

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

4.2.5.1 Pollution and contaminants

Pollutants such as organochlorine compounds and heavy metals have been found in high concentrations in some Arctic phocids (reviewed in Quakenbush 1988, Becker 2000, Dehn et al. 2005). Relative to other ice-associated seals, spotted seals have low renal and hepatic levels of cadmium and total mercury (Dehn et al. 2005). Quakenbush et al. (2009) reported that liver tissue of spotted seals collected from 2003-2006 contained levels of metals similar to those found in other studies of spotted seals in Alaska. Although Dehn (2005) and Quakenbush (2009) reported low levels of total mercury in spotted seals, they also determined that spotted seals had the highest mean percentage of methyl mercury (a toxic form of mercury that composes part of total mercury) relative to ringed and bearded seals. Dehn et al. (2005) suggested that the high methyl mercury levels could be reflective of the spotted seals' piscivorous diet, potentially overwhelming the physiological demethylation process with continuous exposure.

Butyltin (BT) compounds are used as antifouling agents in ship bottom paints. They are retained in all tissues and largely in the liver rather than the blubber where polychlorinated biphenyls (PCBs) and dichloro-diphenyl-trichloroethane (DDT) accumulate. BTs have been found in spotted seals and some studies suggest marine mammals may have difficulty metabolizing these compounds (Iwata et al. 1997, Tanabe et al. 1998). Hepatic tissues in one spotted seal off the coast of Hokkaido, Japan had levels lower than other pinnipeds and cetaceans sampled (Tanabe et al. 1998). BT compounds may affect immune function in pinnipeds. One study showed suppression of spotted seal cell proliferation when lymphocytes were exposed to BT compounds (Nakata et al. 2002).

Research has also found persistent organochlorine pollutants (POPs), including flame retardant compounds like PBDEs (polybrominated diphenyl ethers; Quakenbush 2007), as well as DDTs, PCBs (Quakenbush and Sheffield 2007) and PFCs (perfluorinated contaminants; Quakenbush and Citta 2008) in spotted seals. Neale et al. (2007) found relatively low levels (< 1 ppb) of POPs in spotted seal blood samples collected from seven individuals in 2000-2001. Levels of CB-153 (hexachlorobiphenyl) and DDE (dichloro-diphenyl-dichloroethylene) were considerably lower than in harbor seals that were sampled from the same location. This may be explained by the fact that spotted seals generally forage at a lower trophic level than harbor seals, and spend more time in pelagic waters – near the pack ice edge – which may be less contaminated than coastal waters where harbor seals spend most of their time (Neale et al. 2007). Quakenbush et al. (2009) reported that blubber and liver tissues from spotted seals sampled during 2003-2006, finding that ribbon seals had higher levels of ΣCHL, ΣDDT, and ΣPCB in blubber tissue, but spotted seals had higher levels of ΣHCH. In pinnipeds specifically, DDT and PCB exposure have been linked to endocrine disruption, reproductive disorders, and reproductive failure (reviewed by Gregory and Cyr 2003) in addition to suppressed immune function at levels lower than those detected in wild marine mammal populations (de Swart et al. 1996, Ross et al. 1996). High levels of PCBs and DDTs have been detected in spotted seals off the coast of Hokkaido, Japan; with PCB levels up to one order of magnitude greater than levels detected in their prey (Chiba et al. 2002). PCB levels have also been negatively correlated with plasma thyroid hormone levels in spotted seals (Chiba et al. 2001).

Less is known about the toxicity of flame retardants, but they are widely used in carpets, upholstery, and plastics. PBDEs are ubiquitous in the environment. They are found in air, water, fish, birds, marine mammals and humans and detected levels have increased exponentially over the past 30 years (reviewed in Hites 2004). Studies have shown that they adversely affect thyroid function and neurodevelopment in mammals (Darnerud 2003, Viberg et al. 2004). Sources of PBDEs in the Arctic include Western Europe, eastern North America, highly populated local areas, and southern regions through long-range atmospheric transport (de Wit et al. 2006).

Cytochrome P450s, a class of hemoproteins induced by exposure to contaminants and pharmaceuticals, are used as biomarkers for exposure to certain contaminants, including organochlorines. Cytochrome P450 1A (CYP1A) has been identified in the spotted seal (Teramitsu et al. 2000) and its induction has been demonstrated in harbor seals after exposure to an organochlorine compound (Miller et al. 2005). Future research is likely to utilize this approach to evaluate effects of contaminant exposure in ice-associated seals.

The spatial distribution of organochlorines in pinnipeds appears to be consistent with levels found in the environment described by de Wit et al. (2006). Organochlorine levels are not expected to be affecting ice seal populations at this time and should be used as a baseline for future research (Quakenbush and Sheffield 2007, Quakenbush 2007, Quakenbush and Citta 2008) as concentrations in surrounding Arctic regions continue to rise (de Wit et al. 2006). Climate change has the potential to increase the transport of pollutants from lower latitudes to the Arctic (Tynan and DeMaster 1997), highlighting the importance of continuing to monitor spotted seal contaminant levels.

Most spotted seal contaminant research has been conducted in the Bering Sea and coastal areas around Hokkaido, Japan. Information about pollutants in waters and sediments of other parts of the species' range, such as the Yellow Sea, Peter the Great Bay, and the Sea of Okhotsk, can be used for inference about potential risk from contaminants in those areas. Pollution sources in those areas include oil fields, industrial effluent, fisheries, sewage, and rivers carrying contaminants from agricultural sources. Wan et al. (2008) reported decreasing metal contamination in the waters of the Yellow Sea from 2001 to 2005, though some areas exceed China's Water Quality Standard for Fisheries. Heavy metals have also been found in Peter the Great Bay where evidence of detrimental changes in benthic community structure have been documented including a "dead zone" (Vashchenko 2000). There is some evidence of recent DDT input in Qinhuangdao, Liaodong Bay, and Bohai Bay despite its ban in the 1980s (Ma et al. 2001, Liu et al. 2006). Although higher levels of DDT were found in sediment samples and fishes from the Yellow Sea and Sea of Japan than the Bering Sea (de Brito et al. 2002, Oh et al. 2005), the opposite is true of DDT metabolites such as DDE (de Brito et al. 2002). Based on sediment samples, PCB levels in the Yellow

Sea are similar to those found in the Bering Sea (Oh et al. 2005). Due to low water exchange and continued exposure to pollution, it is likely that high levels of contaminants would be found in seals of the Yellow Sea. It is also likely that this area will continue to be a source of pollution for the Arctic ecosystem due to atmospheric transport of DDT metabolites. The pollution levels impacting the Yellow Sea has led to reductions in biomass, diversity and habitat which may affect the entire marine ecosystem.

4.2.5.2 Oil and gas exploration, development, and production

4.2.5.2.1 United States

In 2001, President Bush issued Executive Order 13212 which directed U.S. departments to take appropriate actions to expedite projects that increase the production, transmission, and conservation of energy. In June 2007, Secretary of the Interior Kempthorne approved the 2007-2012 Offshore Oil and Gas Leasing Program. According to this program, lease sales are planned in the Chukchi Sea in 2010 and 2012, in the Beaufort Sea in 2010 and 2011, and in the North Aleutian Basin in the southeastern Bering Sea in 2011 (Minerals Management Service 2007b).

On January 16, 2009, the MMS announced the release of its 5-year Draft Proposed Program (DPP) for offshore oil and gas lease sales for 2010-2015. Secretary of the Interior Salazar announced on February 10, 2009 that he was extending the comment period on the DPP by 180 days to provide additional time for states, stakeholders, and affected communities to provide input on the plan (Minerals Management Service 2009).

4.2.5.2.1.1 Beaufort and Chukchi Seas

Despite 30 years of leasing in the Alaska OCS, there are no commercial oil or gas facilities located on Federal OCS lands in Alaska. Three existing projects are located offshore in the State waters of the Beaufort Sea (Endicott, Northstar, and Oooguruk). Northstar, covered by both State and Federal OCS leases, has been in operation since October 2001. Endicott is a State field (2 miles offshore) that began production in 1987. Oooguruk is a production facility located 3 miles offshore adjacent to the Colville Delta that began production in June 2008. Development of the OCS Liberty field will use ultraextended-reach wells drilled from the existing Endicott satellite drilling facility.

On February 6, 2008, the MMS completed the first Chukchi Sea lease sale (193) since 1991 (Minerals Management Service 2008b). The 193 lease sale was the most successful in Alaska's history based on the number of bids received and the number of tracts receiving bids. The 193 sale area is located offshore Alaska from north of Point Barrow to northwest of Cape Lisburne (Figure 19), and contains more than 29 million acres. The sale area extends from about 25 to 50 miles from shore out to 200 miles offshore. Tracts receiving bids are spread throughout the Chukchi Sea, with the closest to land being approximately 54 miles offshore.

Two previous sales have been held in the Chukchi Sea Planning Area. Sale 109 was held in 1988 with 351 leases issued, and Sale 126 was held in 1991 with 28 leases issued. Five exploration wells have been drilled, though all of the leases from those prior sales have either been relinquished or have expired.

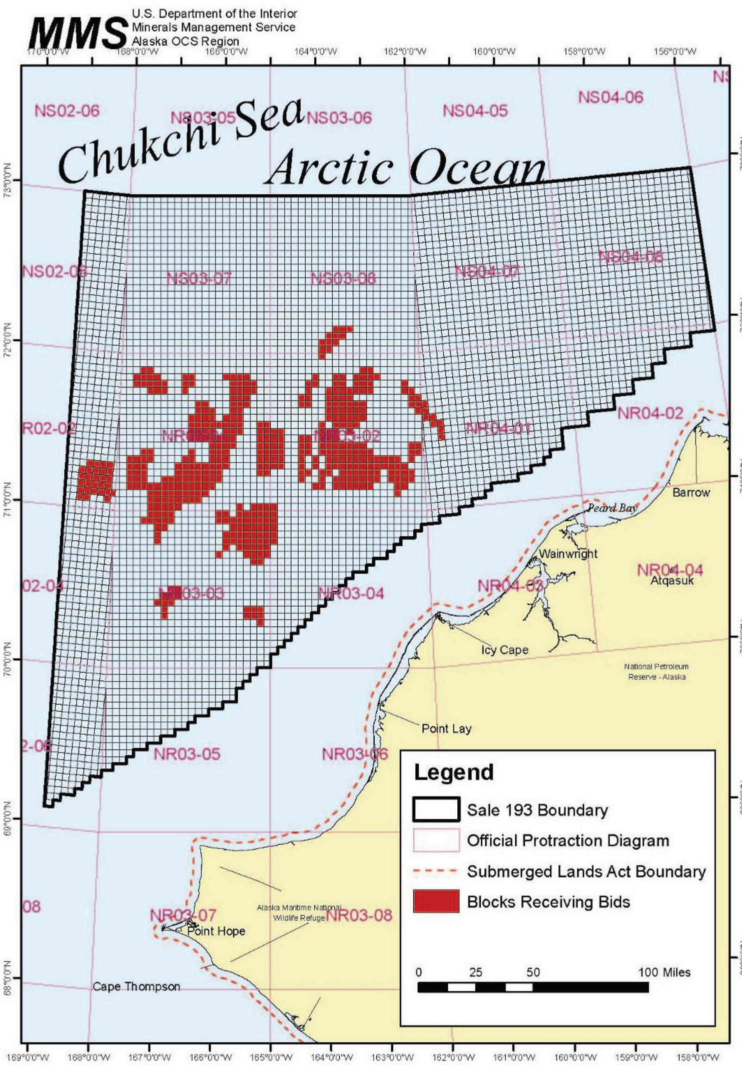

Figure 19. -- Sale 193 Lease Blocks in relation to the Alaska coastline.

4.2.5.2.1.2 North Aleutian Basin

On April 8, 2008, the MMS issued a Call for Information and a Notice of Intent to prepare an environmental impact statement for Lease Sale 214 in the North Aleutian Basin Planning Area, proposed for 2011 (Minerals Management Service 2008a). This is the first step in the potential leasing of the area and the NEPA evaluation processes. The North Aleutian Basin Planning Area is believed to be gas-prone and is located offshore of Alaska in the southeastern Bering Sea, and covers approximately 5.6 million acres (Figure 20).

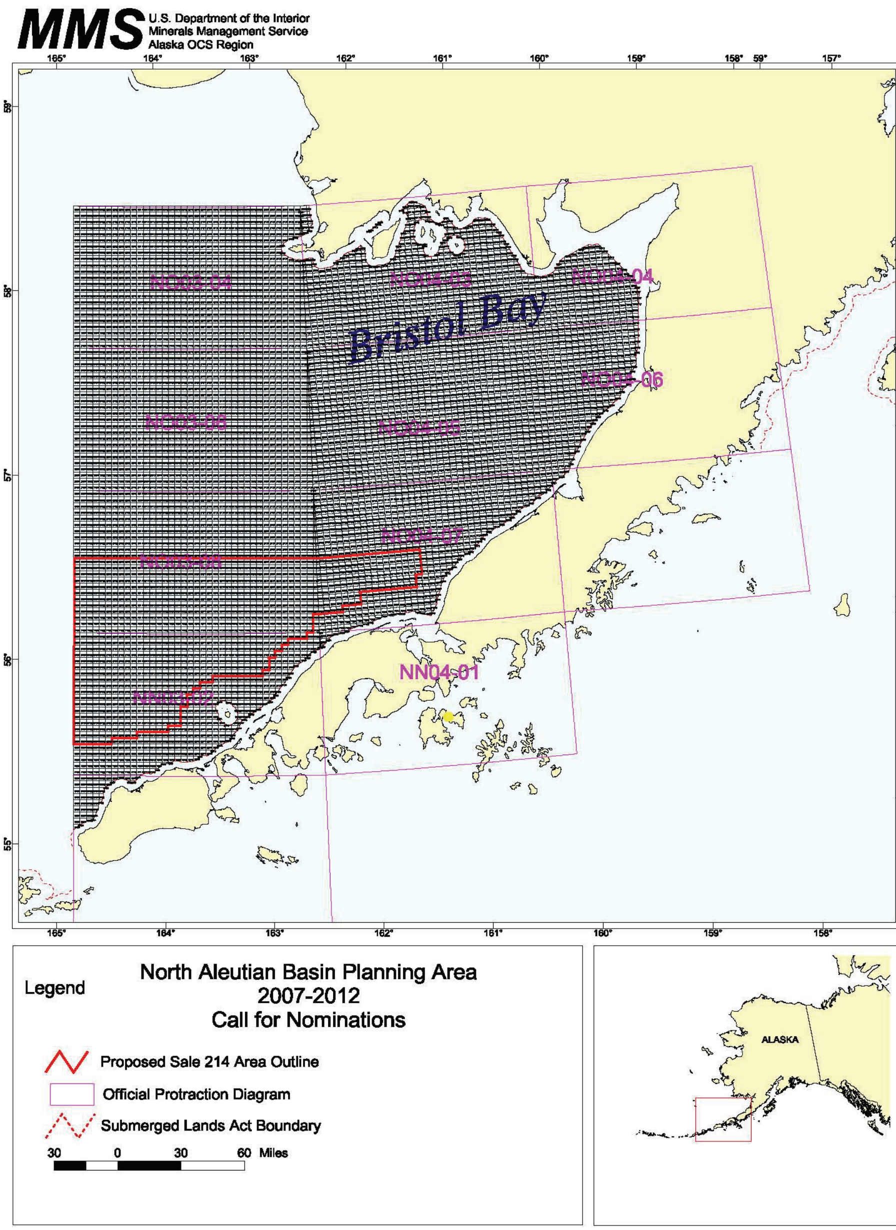

Figure 20. -- North Aleutian Basin Planning Area.

4.2.5.2.2 Russia

In the Sea of Okhotsk, at least six oil operations are active off the northeastern coast of Sakhalin Island. Oil extraction from these projects has already started, with associated construction of a platform, a terminal for oil shipment, and a floating oil tank with a capacity of one million barrels (Lapko and Radchenko 2000). In the Magadan region in the northern Sea of Okhotsk, an oil and gas project is also planned for development (Chernenko 2007). The western side of the Kamchatka shelf is considered a prospective area for oil development as well, with oil and gas extraction planned to begin there by 2015 (Chernenko 2007). Oil and gas development in the Sea of Okhotsk resulted in an oil spill in 1999, which released about 3.5 tons of oil (Lapko and Radchenko 2000). In the Chukotka region, the oil and gas industry is targeting regions of the Bering and Chukchi Seas, including the Gulf of Anadyr.

4.2.5.2.3 China/Korea

China plans to increase oil production in the Bohai Sea and to make it the country's second-largest oil producing field within 3 years. The number of producing oil fields in Bohai Bay is likely to jump from its current 28 over the next few years (Winning 2007). According to one source, Bohai Bay may hold oil reserves equivalent to 146 billion barrels (Anonymous 2007).

Korea hopes to find at least 100 million barrels of crude oil and natural gas reserves off its shores in the next decade to boost its energy security. The country has drilled 43 wells offshore since 1970 and 12 were found to contain gas and one oil. The government has developed 4 of the 12 gas wells, and plans are under way to develop the rest. Korea plans to intensify its offshore oil exploration efforts (Anonymous 2009).

4.2.5.2.4 Effects from offshore oil and gas exploration and development

Based on the paucity of information available on spotted seal ecology, specifically on habitat use patterns, and based on the lack of specific information regarding the nature and location of future oil and gas developments in the OCS regions of Alaska, China, Korea, and Russia, it is difficult to determine at this time what impacts will or will not occur to spotted seals as a result of oil and gas activities. Nevertheless, based on the available literature, we can reach some general conclusions about potential effects.

Oil and gas exploration and development activities may include, but are not limited to, artificial-island construction, drilling operations, pipeline construction, seismic surveys, and vessel and aircraft operations. The main issues for evaluating the impacts of exploration and development activities on spotted seals are the effects of noise and potential oil spills produced from these activities. Unfortunately, it is not possible to predict the type and magnitude of spotted seal responses to the variety of disturbances caused by oil and gas operations and industrial developments. Because the majority of marine waters that spotted seals inhabit have seen only limited and sporadic industrial activity, it is likely that there have been no serious effects or accumulation of effects to date on spotted seals from industrial activities throughout most of their range. There is little information available on impacts that oil and gas activities may have had on spotted seals in the waters of China and Korea.

4.2.5.2.4.1 Noise and disturbance

The 'noisiest' period of offshore oil and gas operations occurs during exploration and site establishment (Richardson et al*.* 1995). Conversely, production activities generally are quieter and require fewer support operations. With varying degrees, drilling operations produce low-frequency sounds with strong tonal components. Drilling occurs after a lease has been obtained for oil and gas development and may continue through the life of the lease.

Moulton et al. (2005) reported that during spring surveys, there was no evidence that construction, drilling, and production activities at BP's Northstar oil development in the Beaufort Sea affected local ringed seal distribution and abundance during the spring. Drilling and production sounds from Northstar likely were audible to ringed seals, at least intermittently, out to about 1.5 km in water and 5 km in air (Blackwell et al. 2004). Underwater sounds from construction, drilling, and production reached background values at 2-4 km (Richardson and Williams 2004), while underwater sound from vessels often were detectable as far as 30 km offshore. Likewise, Richardson and Williams (2004) concluded that there was little effect from the low to moderate level, low-frequency industrial sounds emanating from the Northstar facility on ringed seals during the open-water period, and that the overall effects of the construction and operation of the facility were minor, short-term, and localized, with no consequences to seal populations as a whole. These results suggest that any negative effects on spotted seals from individual oil and gas developments are also likely to be minor and localized. Because the Northstar facility is on a manmade island, it is not known whether these results are applicable to other types of drilling and production facilities.

The effects of sporadic air and vessel traffic on spotted seals are expected to be local and transient in nature. Some groups of spotted seals may be disturbed from their haulouts and enter the water, although most such responses will likely be relatively minor, highly variable, and brief in nature. However, repetitive disturbance events could be detrimental to spotted seals. As discussed in Section 2.3, spotted seals are one of the most cautious phocid species and are easily disturbed from their haul-out sites on land or sea ice (Krylov et al. 1964, Tikhomirov 1964, Heptner et al. 1976a, Wang 1986). Spotted seals will often haul out again in the same place from which they were disturbed when they feel safe again (Heptner et al. 1976a, Bigg 1981, Wang 1986), even though constant or repetitive disturbances may cause pups or haul-out sites to be abandoned (Lowry 1985).

4.2.5.2.4.2 Seismic surveys

Pinnipeds use the acoustic properties of sea water to aid in navigation, social communication, and possibly predator avoidance. There is considerable variability in the vocalizations of seals, and many of the ice-associated species vocalize underwater in association with territorial and mating behaviors. Most phocid seals spend greater than 80% of their time submerged in the water (Gordon et al. 2003); consequently they will be exposed to sounds from seismic surveys that occur in their vicinity. Few studies of the reactions of pinnipeds to noise from open-water seismic exploration have been published. Temporary threshold shift values for pinnipeds exposed to brief pulses (either single or multiple) of underwater sound have not been measured.

Phocids have good low-frequency hearing; thus, it is expected that they will be more susceptible to masking of biologically significant signals by low frequency sounds, such as those from seismic surveys (Gordon et al. 2003). Masking of biologically significant sounds by anthropogenic noise is equivalent to a temporary loss of hearing acuity. Brief, small-scale masking episodes might, in themselves, have few long-term consequences for individuals or groups of spotted seals. The consequences might be more serious in areas where many surveys are occurring simultaneously. Underwater audiograms for phocids suggest that they have very little hearing sensitivity below 1 kHz, though they can hear underwater sounds at frequencies up to 60 kHz and make calls between 90 Hz and 16 kHz (Richardson et al. 1995). A more recent review suggests that the auditory bandwidth for pinnipeds in water should be considered to be 75 Hz to 75 kHz (Southall et al. 2007). While seismic surveys can contain energy up to 1 kHz, most of the emitted energy is less than 200 Hz. Seismic surveys in the Beaufort and Chukchi Seas are unlikely to have impacts (e.g., masking) on vocalizations associated with breeding activity since spotted seals are not known to breed in those areas (Figure 3). Potential impacts are more likely in the southern portions of their range since the longer ice-free periods in these regions make it possible that seismic surveys could occur during the spotted seal's breeding season (Figure 4).

Reported seal responses to seismic surveys have been variable and often contradictory, although they do suggest that pinnipeds frequently do not avoid the area within a few hundred meters of operating airgun arrays (Brueggeman et al. 1991, Harris et al. 2001, Miller and Davis 2002). Telemetry work by Thompson et al. (1998) indicated that some harbor seals and grey seals exhibit strong avoidance behavior of small seismic airgun arrays, including swimming rapidly away from seismic sources, ceasing feeding activities, and hauling out, possibly to avoid underwater noise. The behavior of most of the seals reportedly returned to normal within 2 hours of the seismic array falling silent. The authors suggested that responses to more powerful commercial arrays might be more dramatic and occur at greater ranges.

There is no specific evidence that exposure to pulses of airgun sound can cause permanent threshold shifts (PTS) to the hearing of any marine mammal, even with large arrays of airguns. Nevertheless, direct impacts causing injury from seismic surveys would likely occur only if animals entered the zone immediately surrounding the sound source. Southall et al. (2007) proposed that auditory injury would occur to a pinniped in the water at a sound level of 218 db re: 1 micropascal. Although it is unlikely that airgun operations during most seismic surveys would cause PTS in spotted seals, caution is warranted given the limited knowledge about noise-induced hearing damage in this species. With appropriate protective measures in place (e.g., marine mammal observers and shutdown procedures), the probability of seismic-survey-generated injuries to spotted seals may be mitigated, although detecting seals in the water from a distance is often difficult, particularly at night.

In summary, there is little evidence that seismic surveys would cause significant individual or population level effects to spotted seals in the proposed oil and gas development areas.

4.2.5.2.4.3 Oil spills

The threat posed to spotted seals by oil spills increases as offshore oil and gas development and shipping activities increase across their range. The greatest impacts would likely result from an oil spill during the pupping season or if the spill affected a large area (St. Aubin 1990). Spotted seals could be affected by oil spills in several ways. Freshly spilled oil contains high levels of toxic aromatic compounds that, if inhaled, could cause serious health effects or death in spotted seals, as occurred with an estimated 300 harbor seals following the *Exxon Valdez* oil spill in Prince William Sound, Alaska (Frost et al. 1994a, Frost et al. 1994b, 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 crude-oil-covered water (Geraci and Smith 1976), harbor seals following the *Exxon Valdez* oil spill, as well as in 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). Some pinnipeds 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 still may (e.g., depending on temperature and whether the oil becomes frozen into ice) have high levels of toxic aromatic 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, 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).

Although spotted seals live in a cold environment that is energetically demanding, contact with spilled oil is unlikely to affect their thermoregulation to the extent that it would for fur seals or sea otters, which depend upon air trapped in the pelage for insulation (St. Aubin 1990). Phocid hair traps little or no air (Ling 1970); instead, their main insulation is a layer of blubber under the integument.

Oil spill clean-up in the broken-ice and open-water conditions that characterize the spotted seal's habitat is problematic. The MMS has noted that there are difficulties in effective oil-spill response in broken-ice conditions (Minerals Management Service 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".*

Currently, there are no active offshore oil and gas developments in the U.S. Bering or Chukchi Seas. Therefore, the current risk for spotted seals to be impacted by an oil spill in U.S. waters is very low. 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% (Minerals Management Service 2007a).

As far as is known, spotted seals have not been affected by oil spilled as a result of industrial activities even though such spills have occurred in spotted seal habitat. Oil and gas development in the Sea of Okhotsk resulted in an oil spill in 1999, which released about 3.5 tons of oil (Lapko and Radchenko 2000). Also, in December 2007 approximately 2.8 million gallons (10,500 tons) of crude oil spilled into the Yellow Sea offshore of South Korea's Taean Peninsula from a tanker. The size of the oil spill was about one-fourth that of the *Exxon Valdez* spill in 1989, and was the largest in Korean history (Sang-Hun 2007). It is unknown how many seals may have been affected by this spill. Incidences of oil spills are expected to increase with the ongoing increase in oil and natural gas exploration/development activities in the Bohai and Yellow Seas. Accompanying growth in tanker and shipping traffic could further add to the oil spill potential. According to experts in China, the threat of future oil spills remains high (Yu et al. 2001).

Though the probability of an oil spill affecting a significant portion of the spotted seal population in the foreseeable future is low, the potential impacts from such a spill could be significant, particularly if subsequent clean-up efforts were ineffective. The potential impacts would be greatest when spotted seals are relatively aggregated. For example, spotted seals in the Sea of Okhotsk move to coastal haul-out sites after the sea ice melts in July (Fedoseev 2000). Fedoseev (2000) reported 10,000 individuals along the Sakhalin Island coast, 30,000 individuals along the continental coast of Sea of Okhotsk, and 20,000 individuals on the western Kamchatka coast. Therefore, an oil spill along these coasts could have significant effects on local spotted seal populations. Such an event in the Bohai Sea could be particularly devastating to the Southern DPS of spotted seals.

It is important to evaluate the effects of anthropogenic perturbations, such as oil spills, in the context of historical data. Without historical data on distribution and abundance, it is not possible to measure the impacts of an oil spill on spotted seals. Population monitoring studies need to be implemented in areas where significant industrial activities are likely to occur, so that it will be possible to compare future impacts with historical patterns and thus determine the magnitude of potential effects (Frost et al. 2004).

In summary, the threats to spotted seals from oil and gas activities are greatest where these activities converge with coastal aggregations of the species. In particular, the spotted seals in the Bohai Sea and the Sea of Okhotsk are most vulnerable to oil and gas activities, primarily due to potential oil spill impacts.

4.2.5.3 Commercial fisheries interactions and bycatch

4.2.5.3.1 Bering DPS

Commercial fisheries may impact spotted seals through direct interactions (i.e., incidental take or bycatch) and indirectly through competition for prey resources (Lowry et al. 1996). During 1990-1999, three commercial fisheries operating within the range of spotted seals in U.S. waters were monitored for incidental take by NMFS observers, of which only the Bering Sea/Aleutian Islands groundfish fishery reported incidental take of spotted seals. Three mortalities were reported in 1996, which resulted in an estimated take of 5 spotted seals during that year and an average of 1 mortality per year (CV = 1.0) during 1995-1999 (Angliss and Lodge 2002). During 2000-2003, NMFS expanded their monitoring program to include an additional 3 commercial fisheries – bringing the total to 6 – which were delineated into 22 fisheries in 2004 to provide managers with better information on the component of each fishery that is responsible for bycatch of marine mammals. In 2004, the Bering Sea/Aleutian Islands flatfish trawl fishery reported 3 mortalities of spotted seals, which resulted in an estimated take of 4.4 spotted seals for that year and an average of 0.88 seals per year (CV = 0.33) during 2000-2004 (Angliss and Allen 2009). Logbook reports (available during 1989-1994) and self-reports (after 1995) maintained by fishing vessel operators have also been used as an additional sources of bycatch information; however, these reports are likely negatively biased or incomplete and only represent minimum mortality estimates (e.g., 1.5 spotted seals per year during 1990-1993 by the Bristol Bay salmon drift gillnet fishery; Angliss and Lodge 2002). Angliss et al. (2002) identified potential misidentification between harbor and spotted seals and the lack of observer data from the Bristol Bay drift gillnet fishery (which is known to interact with spotted seals) as factors contributing to the unreliability of the bycatch estimates. The authors also suggested that the current abundance of spotted seals in U.S. waters is high enough to sustain a level of annual mortality much higher than the estimated bycatch rates, implying that the threat due to bycatch is likely insignificant (Angliss and Lodge 2002).

For indirect interactions, it is important to note that commercial fisheries target a number of known spotted seal prey species, such as walleye pollock, Pacific cod, herring, and capelin. These fisheries may affect spotted seals indirectly through reductions in prey biomass. The U.S. fisheries in the North Pacific are managed to prevent overfishing of individual stocks. As such, strict limits on catch and bycatch are placed on all groundfish species or species groups. However, even well-managed fisheries will result in reduced levels of biomass relative to theoretical mean unfished levels. The extent that the lower abundance levels of these individual stocks affect the viability of spotted seal populations is unknown. In the U.S. Exclusive Economic Zone (EEZ), overall biomass levels of all groundfish species have remained relatively stable between 15 and 20 million metric tons of biomass after showing substantial increases since the 1970s (Mueter and Megrey 2006). Comparing the western and eastern Bering Sea, Aydin et al. (2002) found that the broad eastern Bering Sea shelf has a benthic community that is more diverse, whereas the narrower western Bering Sea shelf tends to have more productive pelagic layers (per unit volume) which propagates through to a productive pelagic phytoplankton and zooplankton community. These regional differences may impact foraging opportunities for spotted seals. In a conceptual assessment of marine mammal-fishery interactions in the Bering Sea, Lowry and Frost (1985) ranked spotted seals as a species with moderately-high probability for significant indirect fisheries interactions based on their feeding moderately and opportunistically on commercial species, high and stable population size relative to carrying capacity (i.e., historic levels), and the moderate importance of the Bering Sea as a feeding area.

Another potential effect of fishing on prey species is the tendency to reduce the average size and age of the populations relative to unfished conditions. A reduction in the average size of prey species could reduce the per capita energy content and may increase the foraging effort exerted by spotted seals. Conversely, older fish may be more cryptic, harder to catch, and less numerous. Groundfish stocks are known to have a high degree of interannual variability in recruitment (e.g., Mertz and Myers 1996), and it is likely that such fluctuations occurred prior to fishing. As such, spotted seals dependence on different size composition for groundfish species would seem to be fairly adaptable.

Some fisheries may be expected to expand or shift northward in response to an increased length of the ice-free, open-water season in the future. The North Pacific Fishery Management Council has established an Arctic Fisheries Management Plan that would place a moratorium on development of fisheries in federally managed waters in the U.S. EEZ north of Bering Strait (North Pacific Fishery Management Council 2008). Several Russian companies recently sent longline vessels to explore fishing prospects in the Chukchi Sea, with unknown results, and the fishing season in the western Bering Sea has reportedly been increasing due to reduced sea-ice conditions (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, September 19, 2008, pers. comm.).

4.2.5.3.2 Okhotsk and Southern DPSs

Information on commercial fisheries interactions with spotted seals specific to Sea of Okhotsk, Sea of Japan, and Yellow Sea was difficult to find; many of the general indirect effects described for the Bering DPS apply similarly to these regions. This species is also directly impacted by commercial fisheries in the Okhotsk and Southern DPSs. Spotted seals are reportedly killed by fishermen in many parts of the Russian Far East in order to stop them from stealing fish from salmon traps or nets. Although there are no accurate records of this illegal take, it might be “quite high” and could pose a “major threat” to spotted seals (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, May 1, 2009, pers. comm.). Based on a combination of interviews with locals and an examination of records from museums, zoos, and aquariums, Mizuno et al. (2001) reported a total of 113 incidental harvests by fishermen (primarily in salmon trap nets) and 153 “damage control kills” around Hokkaido, Japan during 1971-1998, for an average of about 10 seals per year. The authors considered this to be only a small portion of the actual take since there is no legal obligation to report harvests and no science-based regulations regarding the taking of seals in Japan (Mizuno et al. 2001). In Peter the Great Bay, Trukhin and Mizuno (2002) estimated that about 100-150 spotted seals may have been killed in trap nets set under the ice during the winter of 1996-1997. This level of mortality would be unsustainable for such a small population, and may have contributed to its limited growth during the 1990s (Trukhin and Mizuno 2002). Won and Yoo (2004) reported that bycatch of spotted seals in fishing nets occurs around Bak-ryoung Island in the Yellow Sea but is not monitored. They also reported that local residents and fishermen frequently stated that the number of seals in the region declined since the 1970s due to habitat disturbance and persecution by humans, partly due to conflict with commercial fishing, and recommended that commercial fishing be restricted in certain seasons and areas to mitigate its impacts (Won and Yoo 2004).

4.2.5.4 Shipping and transportation

4.2.5.4.1 Bering DPS

The extraordinary reduction in Arctic sea ice that has occurred in recent years has renewed interest in using the Arctic Ocean as a waterway for maritime commerce, including both regional and trans-Arctic shipping and transportation (Brigham and Ellis 2004). Declines in sea-ice extent and thickness have provided greater access to marine navigation routes, especially along the margins of the Arctic Basin, which historically have been ice-covered for most or all of the year (ACIA 2005). Climate models predict that the warming trend in the Arctic will accelerate, causing the sea ice to begin melting earlier in the spring, retreat farther away from most Arctic landmasses and get thinner during the summer, and resume freezing later in the fall, resulting in an expansion of potential shipping routes and lengthening the potential navigation season each year (ACIA 2005). This reduction in sea ice "is very likely to increase marine transport and access to resources" in the Arctic during this century (ACIA 2005).

The two most likely trans-Arctic navigation routes connecting the Atlantic and Pacific Oceans are the Northwest Passage (NWP) and the Northern Sea Route (NSR). The NSR traverses the Russian Arctic along the northern coast of Eurasia from the Barents Sea in the west to the Bering Sea in the east. For ships travelling between northern Europe and northeastern Asia, the NSR represents a savings of up to 40% in distance when compared to the normal shipping routes through the Suez or Panama Canals (ACIA 2005). This seasonally ice-covered route has been open to international marine traffic since 1991 and has been maintained year-round in its western region by Russian icebreakers since 1979 (ACIA 2005). The annual number of days with navigable conditions for the NSR is projected to increase from about 35 days to 75 days for non-ice-reinforced ships (<50% ice concentration) and from about 80 days to 125 days for ice-reinforced ships (<75% ice concentration) by mid-century (ACIA 2005).

The NWP traverses the Arctic along the northern coast of North America from the Labrador Sea in the east, through the Canadian Archipelago, to the Bering Sea in the west. This perennially ice-choked passage was ice-free for the first time in recorded history during the summer of 2007 (National Snow and Ice Data Center 2007). Studies by the Canadian Ice Service indicate that sea-ice conditions in this region during the past three decades have been characterized by high year-to-year variability, making prospects for regular marine transportation less predictable (ACIA 2005). Additional studies by Canada's Institute of Ocean Sciences suggest that increasing amounts of multi-year sea-ice and glacial ice bergs could be flushed through the channels and straits of the NWP more frequently as continued melting weakens the perennial blockages or "ice bridges" that have controlled ice movements in the past (ACIA 2005). These larger, denser ice features could present serious navigational hazards along this route.

The NWP and NSR pass through the range of the spotted seal in the East Siberian, Beaufort, Chukchi, and Bering Seas; therefore, increases in marine traffic along these routes present potential threats to this species, including increased risks of oil spills and other pollution hazards related to shipping accidents, increased effects of noise and disturbance, and increased GHG emissions, particularly black carbon, which may further accelerate local warming in the Arctic (Arctic Council and PAME 2009). The possible effects of oil spills and noise pollution on spotted seals and the biological effects of global climate change on spotted seals have already been discussed in this report (see Sections 4.2.5.2.4 and 4.2.1.2 , respectively), so it will not be discussed further here. The potential threat to spotted seals by the presence and movements of ships is the focus for the remainder of this section.

The main risk to spotted seals posed by ship traffic is the potential disruption of their nursing, resting, and molting behaviors while they are hauled out on sea ice. No studies have been conducted on the effects of ship traffic on spotted seals, but this species is known to be relatively wary, especially during their molting period (Krylov et al. 1964), so close approaches by ships would likely cause disturbance on some level. A study on the effects of cruise ship traffic on harbor seals (a close relative of spotted seals) in an Alaskan glacial fjord indicated that young, pre-weaned pups may be at risk from thermal stress if they are forced to spend more than 50% of their time in icy water (Jansen et al. *In review*). During their first few weeks of life, spotted seal pups may have an even lower energetic threshold given that they are considerably less aquatic than their harbor seal counterparts (Bigg 1981, Burns 2002) and would likely be entering colder water. Spending extra time in the water may also delay or disrupt the physiological process of molting, which is facilitated by higher skin temperatures (Feltz and Fay 1966), and may also affect seals' ability to get sufficient rest. It is currently unknown how these potential effects may impact an individual's fitness.

While these threats could potentially be significant to individuals, the likelihood that large numbers of spotted seals would be impacted is probably low. Future increases in Arctic shipping are expected to be greatest during the ice-free or low ice summer months (ACIA 2005, Hovelsrud et al. 2008, Arctic Council and PAME 2009) when spotted seals spend much of their time hauled out at coastal sites where they are less likely to be impacted by ship traffic. Ice-reinforced ships could potentially begin operating during the spring when spotted seals are still utilizing sea ice for reproduction and molting; however, the seals are typically spread out in such low densities (Burns et al. 1972, Moreland et al. 2008) and over such vast expanses of sea ice that ships would be unlikely to encounter them in large numbers. The potential disturbance of large numbers of spotted seals may increase in the future if the seals are concentrated in a reduced ice field, especially in the Bering Strait region where encounters with ships would likely be higher due to geographic constriction (Arctic Council and PAME 2009). In a preliminary assessment of future threats to Arctic marine mammals, Huntington (2009) considered shipping to be a low level threat with modest impacts that should be amenable to effective regulation.

4.2.5.4.2 Okhotsk and Southern DPSs

Very little information on current and future shipping trends specific to the Sea of Okhotsk, Peter the Great Bay, and Bohai Sea could be found, making the assessment of potential threats in these regions uncertain. Peter the Great Bay and the Bohai Sea are both relatively small bodies of water with large port cities that likely receive a high level of shipping traffic. Spotted seals in these areas may be at risk from an increased likelihood of oil spills and pollution as a result of shipping accidents, as well as disturbance of hauling out behaviors (discussed in the previous section) in these geographically confined areas. More information is needed in order to adequately assess these risks.

4.3 Analysis of Demographic Risks

Threats to a species' long-term persistence, such as those evaluated in Section 4.2, are manifested demographically as risks to its abundance; productivity; spatial structure and connectivity; and genetic and ecological diversity. These demographic risks thus provide the most direct indices or proxies of extinction risk. In this section, the current status of each of these risks is assessed in turn by responding to a set of questions adapted from McElhany et al. (2000) and incorporated into a draft NMFS interim protocol for conducting ESA status reviews (Nammack et al*.* 2007). Although the interim protocol itself has not yet been officially adopted as a whole, these questions are based on general conservation biology principles applicable to a wide variety of species.

4.3.1 Abundance

4.3.1.1 Is the species' abundance so low that it is at imminent risk of extinction due to environmental variation or anthropogenic perturbations (of the patterns and magnitudes observed in the past and expected in the foreseeable future)?

Bering and Okhotsk DPSs: Current and accurate abundance estimates for spotted seals throughout their ranges in the Bering and Okhotsk DPSs are unavailable. However, the most recent estimates suggest that the populations of each DPS are at least 100,000 individuals (Appendix 1; Fedoseev 2000), and perhaps considerably more. As such, in these two DPSs, spotted seals are not at risk from typical year-to-year variation nor to natural episodic perturbations such as El Niño and related oceanographic shifts that have no doubt occurred numerous times in the species' past. Thus, leaving aside low-frequency (i.e., long-term trend) variation such as climate change, the answer to this question for the Bering and Okhotsk DPSs is no, their abundance is not so low that they are at imminent risk of extinction.

The magnitudes and patterns of environmental variation and anthropogenic perturbations that are expected in the foreseeable future were addressed under Section 4.2. The anticipated pattern is one of high interannual variability superimposed on a long-term (anthropogenic) trend toward warmer, lower-pH seas with less ice cover. The degree of risk posed by the long-term threats is extremely uncertain due to a complete lack of information linking environmental conditions to spotted seal vital rates, and a lack of information about how resilient spotted seals will be to these changes. The BRT members were collectively about 70-80% certain in their belief that both DPSs would experience a decline due to cumulative effects of all the threats considered. Whether such a decline would put either DPS at risk of extinction within the foreseeable future is unknown, but the risk seems to be greater for the Okhotsk DPS than for the Bering DPS, primarily because the Bering Strait would provide the opportunity for spotted seals to adjust their breeding locales northward in response to a long-term decline in ice extent, whereas the spotted seals in the Sea of Okhotsk would have no similar opportunity.

Southern DPS: The Southern DPS of spotted seals has been significantly reduced by overharvesting, mortality incidental to fisheries, and possibly other, unquantified impacts from industrial activities in close proximity to the seals' habitat. Recent estimates of the two main breeding areas, Peter the Great Bay and Liaodong Bay, are 2,500 (Nesterenko and Katin 2008, Nesterenko and Katin 2009) and 800 (J. B. Han, unpubl. data, cited in Han et al. *In press*), respectively. Though these estimates apparently do not account for the proportion of seals in the water during the abundance surveys, both populations are considered to be historically low and/or declining despite recent protection efforts. Thus, the answer to this question for the Southern DPS is yes, the abundance is low enough that environmental variation or anthropogenic perturbations are a significant concern for the viability of the species.

4.3.1.2 Is the species' abundance so low, or variability in abundance so high, that it is at imminent risk of extinction due to depensatory processes?

Depensatory processes, in which per-capita growth rate declines with decreasing abundance (opposite of density dependence), are associated with very low abundance levels and include breakdown of social structures or mating systems, failure to muster foraging groups, and failure of group defenses against predators.

The current abundance of spotted seals in the Bering and Okhotsk DPSs is too high for concern about depensation. The variability in abundance is not well understood, but the life history characteristics of long life and slow reproduction coupled with a large population indicate that these seals are not subject to extreme fluctuations leading to risk of depensation.

Concern about the Southern DPS should be higher by virtue of its small population size, but the threshold for depensation in spotted seals, if there is one, is unknown. There is no prior experience with spotted seals or any similar species on which to base an estimate of the minimum number required to avert depensatory processes.

4.3.1.3 Is the species' abundance so low that its genetic diversity is at imminent risk due to inbreeding depression, loss of genetic variants, or fixation of deleterious mutations?

Genetic diversity in ice-associated seal species tends to be high (Davis et al*.* 2008, O'Corry-Crowe 2008) and initial results suggest the same is true for the Bering and Okhotsk DPSs of spotted seals (Mizuno et al. 2003, O'Corry-Crowe and Bonin 2009). Diversity is apparently much lower in at least the Liaodong Bay portion of the Southern DPS, perhaps indicating that the population already experienced a "bottle-neck" of low population size. This group may be at imminent risk from inbreeding, genetic drift or fixation of deleterious alleles, risks typically associated with very small populations of tens to hundreds of individuals (e.g., studies reviewed by Frankham 2005).

4.3.1.4 Is the species' abundance so low that it is at imminent risk of extinction due to its inability to provide important ecological functions throughout its lifecycle?

This situation would normally be a concern for a species that depends on critical numbers or density for modification of its or another organism's physical or biological environment. No aspect of the spotted seal's life cycle is known to depend on this type of relationship.

4.3.1.5 Is the species' abundance so low that it is at imminent risk due to demographic stochasticity?

Demographic stochasticity refers to changes in vital rates that arise due to chance in the "sampling" that occurs when nature acts on individuals with variable traits. For example, a badly skewed sex ratio, and consequent poor reproduction, could result if most of the remaining females in a small population succumb by chance, even though the overall rate of mortality, averaged over both sexes, is normal. The key factor in risk of demographic stochasticity is small populations. For a large, long-lived mammal such as the spotted seal, demographic stochasticity would be unlikely to be a concern for populations with greater than several tens of individuals. For the both the Bering and Okhotsk DPSs of spotted seals, each currently comprising at least 100,000 thousand of individuals, demographic stochasticity is highly unlikely to be an imminent risk. For the Southern DPS, with a population in the low thousands including perhaps only hundreds in the Yellow Sea, the population is still probably not currently at risk of demographic stochasticity but could become so if further reduced, for example, by a disease outbreak or oil spill.

4.3.2 Productivity

4.3.2.1 Is the species' average productivity below replacement and such that it is at imminent risk of satisfying the abundance conditions described above?

The current net productivity (population trend) of the Bering and Okhotsk DPSs of spotted seals is unknown due to the imprecision of available abundance estimates. Hypothetically, if the current population size of each of these DPSs is 100,000 individuals, these populations could sustain about 90 years of a moderately severe decline of say 5% per year before dropping into the realm (say <1,000 individuals) in which most of the abundance conditions above become a concern, though of course it would be prudent to try to intervene long before such a dire status were attained.

The trend of the Southern DPS is also unknown, but is likely to be negative, or stable at best. Therefore, with a total population likely in the low thousands and declining, the above concerns about abundance could materialize or become severe in the near future.

4.3.2.2 Is the species' average productivity below replacement and such that it is unable to exploit requisite habitats/niches/etc. or at imminent risk due to depensatory processes during any life-history stage?

For the Bering and Okhotsk DPSs, the average productivity is not known to be below replacement, and the species are thought to occupy all of their historically observed ranges and habitats. Depensatory risks were considered in Section 4.3.1.2 . As noted above, the productivity of the Southern DPS may be below replacement. There is currently no evidence that it is unable to exploit requisite habitats or niches as a result of its decline or reduced population size.

4.3.2.3 Does the species exhibit trends or shifts in demographic or reproductive traits that portend declines in per capita growth rate which pose imminent risk of satisfying any of the preceding conditions?

The limited amount of information on the demography or reproductive traits of spotted seals throughout their ranges precludes identification of any shifts or trends in per capita growth rate.

4.3.2.4 Species status evaluations should take into account uncertainty in estimates of growth rate and productivity-related parameters.

The great uncertainty about spotted seal population trends restricts the overall confidence in assessing the species' long-term risks. Unfortunately, an accurate trend estimate for spotted seals is not likely to be attainable in the near future simply because of the difficulty of surveying and estimating the population with sufficient precision to reveal trends. Nevertheless, a high priority should be placed on range-wide surveys to improve the timeliness and precision of abundance estimates. Another high priority for monitoring is the biological sampling of the Alaska Native subsistence harvest for estimates of productivity-related parameters.

4.3.3 Spatial Structure

4.3.3.1 Are habitat patches being destroyed faster than they are naturally created such that the species is at imminent risk of extinction due to environmental and anthropogenic perturbations or catastrophic events?

The diminishing quantity and quality of sea ice, as described in Section 4.2.1, represent a significant change in the habitats available to spotted seals. Changes that are both direct (e.g., sea ice as a platform for pupping, molting, resting) and indirect (e.g., shifts in sea-ice ecosystem food webs) will impact spotted seal habitat. Recent and projected future habitat changes do not appear to place seals in the Bering and Okhotsk DPSs at imminent risk of extinction; such ice-related changes and their associated impacts are likely to be more severe for the southern DPS.

4.3.3.2 Are natural rates of dispersal among populations, metapopulations, or habitat patches so low that the species is at imminent risk of extinction due to insufficient genetic exchange among populations, or an inability to find or exploit available resource patches?

Although dispersal rates are currently unknown, there is no reason to believe that they are low within the Bering and Okhotsk DPSs, given the relative absence of physical barriers within these marine environments (compared with terrestrial or river systems) and spotted seals' proven ability to move long distances, as shown by satellite-tracked individuals (Lowry et al. 1998). The Southern DPS was distinguished primarily on the basis of its genetic composition, particularly the Yellow Sea portion which appears to possess less genetic diversity than seals in the remainder of the range (Han et al. *In press*). The Yellow Sea portion also carries a characteristic genetic insertion, possibly indicating low dispersal around the Korean Peninsula between the Yellow Sea and Peter the Great Bay breeding groups. Further sampling and analysis of the genetic population structure within and between the DPSs is a high priority for future research.

4.3.3.3 Is the species at imminent risk of extinction due to the loss of critical source populations, subpopulations, or habitat patches?

To date, no populations, subpopulations, or habitat patches for spotted seals are known to have been lost. Concern about future loss of habitat was the primary motivation for the petition to list spotted seals and for this status review; this risk is considered explicitly in Section 4.2.1.

4.3.3.4 Analyses of species' spatial processes should take uncertainty into account.

The distribution of spotted seal breeding areas in the past few decades is relatively well known, though it has probably been portrayed as more discrete and more static than it is in reality. Also, it is not known whether there have been recent changes, owing to lack of recent surveys with sufficient coverage. Recent satellite-tracking studies have produced substantial new spatial data on movements and habitat use, particularly in the Bering DPS. High priority should be given to analysis and publication of these results for improving spotted seal assessments.

4.3.4 Diversity

4.3.4.1 Is the species at risk due to a substantial change or loss of variation in life-history traits, population demography, morphology, behavior, or genetic characteristics?

There are no known specific risks for the Bering and Okhotsk DPSs related to such changes or losses. In the Yellow Sea portion of the Southern DPS, signs of low genetic diversity have been reported from both mitochondrial and nuclear DNA, possibly reflecting a severe population reduction or "bottle-neck" (Han et al. *In press*). It is not currently known whether low diversity in these (assumed to be) neutral markers correlates with low diversity in the adaptive traits that would be required to cope with future changes and variability (Kellermann et al. 2009, Merilä 2009).

4.3.4.2 Is the species at risk because natural processes of dispersal and gene flow among populations have been significantly altered?

It is not known whether rates of dispersal and gene flow have been altered, for example, by more northerly breeding distributions that might produce greater physical isolation by the Korean Peninsula between the Yellow Sea and Sea of Japan or the Kamchatka Peninsula between the Sea of Okhotsk and the Bering Sea.

4.3.4.3 Is the species at risk because natural processes that cause ecological variation have been significantly altered?

Spotted seals – as wide-ranging inhabitants of temperate, sub-Arctic, and Arctic ecosystems – continue to be exposed to substantial ecological variation at a broad range of spatial and temporal scales. In the Bering and Okhotsk DPSs, the dominant mode of variability is the annual formation and retreat of the sea ice, which will continue to happen for the foreseeable future. The interannual variation in this feature is projected to remain high, as well. These modes of variability likely propagate through the marine ecosystem to produce variability in other important factors such as predators and prey of spotted seals. From the standpoint of concern about lack of ecological variation leading to lack of genetic diversity, this should not be a threat for spotted seals in these DPSs.

In the Southern DPS, the prospect for complete loss of sea ice in many or most years by the end of this century portends a scenario with significantly reduced ecological variation. The report by Trukhin (2005) that spotted seals breeding on shore in Peter the Great Bay have an extended whelping and nursing season – possibly due to a relaxation of constraints formerly imposed by the timing of ice availability – may be an early sign of the types of changes that could occur in response to reduced ecological variation. The seasonal timing of breeding is one factor that distinguishes harbor seals from spotted seals, perhaps important in maintaining their discreteness as species. Introgression with harbor seals may not be a current threat to the diversity or viability of spotted seals in Peter the Great Bay (not within the current range of harbor seals), but change of this general nature could significantly alter the diversity of or increase the isolation of the Southern DPS from the other DPSs.

4.3.4.4 Species status evaluations should take uncertainty about requisite levels of diversity into account.

Although there is no standard measure for how much (and what type) of genetic diversity is required for secure conservation status, there are no examples of problems stemming from diversity in other mammal species with similar levels of mtDNA and micro-satellite heterogeneity and similarly large populations to those in the Bering and Okhotsk DPSs. Thus, it is also unknown whether the reduced genetic diversity reported from the Yellow Sea poses a significant risk on its own. The BRT has tried to convey throughout this review the importance of uncertainty about diversity, as well as all other factors thought to be important to the species status, so that the uncertainty can be taken into account in the decision process.

4.3.5 Relevant Modifying or Mitigating Factors

4.3.5.1 Life-history characteristics

Spotted seals are long-lived, with overlapping generations and single offspring produced annually, all traits of a “K-strategist” life history that is suited to an environment with high year-to-year variability. This may be viewed as a mitigating factor for episodic threats or threats that increase environmental variability. On the other hand, these traits also are typically associated with relatively slow population growth rates, possibly a disadvantage for spotted seals if sudden large declines were to occur, especially in the small populations of the Southern DPS.

Ultimately, the question of whether spotted seals as a species can survive a major shift to a warmer climate hinges on their capability to adapt to the altered physical and biological conditions. Short-term adaptations are already a part of spotted seals’ normal response to living in the sub-Arctic and Arctic, regions characterized by extreme interannual variability.

The now-widespread concern about climate change has prompted numerous attempts to assess the potential effects on marine mammals (e.g., Learmonth et al. 2006, Simmonds and Isaac 2007), and specifically on Arctic marine mammals (e.g., Tynan and DeMaster 1997, Kovacs and Lydersen 2008, Laidre et al. 2008, Moore and Huntington 2008). Most studies have recognized that factors such as geographic distribution, migratory capabilities, diet diversity, and relation to sea ice during key life history events should play a role in a species' sensitivity to climate change. Still, the task of predicting demographic responses to environmental change is largely impossible because of our lack of understanding of resilience, or the capacity to adjust to the change (Moore and Huntington 2008).

The scope for longer-term, physiological or genetic adaptation is also uncertain. Widely distributed, temperate or high-latitude species may have greater genetic scope for adapting to climate change than narrowly distributed tropical species, at least among ectotherms (Kellermann et al. 2009). Given that the current genetic diversity in spotted seals appears to be high – except perhaps in the Yellow Sea – the species likely retains genetic raw materials for adaptation to conditions reflected in its evolutionary history. Paleoclimate reconstructions indicate that spotted seals have experienced many large deviations from current climatic conditions during the past ~1.1 million years since diverging from harbor seals.

Global cycles of glaciation have occurred over the past several million years and are particularly well documented over the past 430 thousand years (kyr) by ice cores. During that period, the cycles consisted of very large climate shifts approximately 100 kyr in duration with only about 10 to 30 kyr spent in each interglacial warm phase (Jansen et al. 2007). During the Last Interglacial, the climate was warmer than present, the Greenland and Antarctic ice sheets were reduced, and there was much less sea ice in the Arctic and surrounding Alaska (CAPE Last Interglacial Project Members 2006, Nørgaard-Pedersen et al. 2007). Thus, spotted seals have survived and adapted to many large climate shifts encompassing periods of both warmer and much colder conditions than the present, indicating that the species has tended to retain the genetic plasticity to adapt to both types of climatic extremes. For many of the shifts in the paleoclimate, however, either the data resolution are too low to adequately judge the rates of change in conditions, or the rates of change are known to have been much slower than the warming now anticipated and already observed in response to anthropogenic increases in GHGs. So, a great deal of uncertainty remains about how quickly spotted seals might be able to adapt to the present warming and predicted changes in sea-ice habitat.

Paleoclimatic records have revealed many abrupt climate changes with hemispheric to global impacts (National Research Council 2002). One of the most well-known examples is the warming shift out of the Younger Dryas interval (YD), about 11.5 kya, when temperatures rose by about 10^{o}C in 1-2 decades, and snow accumulation rates in Greenland doubled in about 3 years (Alley et al. 1993, Grachev and Severinghaus 2005). Other rapid warming events detected in Greenland ice cores include a rise of 9^{o}C over several decades about 15 kya (Severinghaus and Brook 1999). More than 20 so-called Dansgaard-Oeschger (D-O) oscillations have been documented in the Greenland ice core record of the past ~110,000 years, each with rapid warming to near inter-glacial temperatures over just a few decades (National Research Council 2002). The onset of the Last Interglacial, the most recent period when northern hemisphere climate was warmer than the present, occurred in approximately 100 years (Brauer et al. 2007). Although older northern hemisphere paleoclimate records lack the resolution to pinpoint such rapid shifts, they probably occurred in previous ice ages as well (National Research Council 2002).

The rapid and widespread shifts of the D-O oscillations, which are likely associated with changes in the North Atlantic thermohaline circulation regime, have many strongly correlated signals in biological records of the northern hemisphere such as terrestrial pollen, fossils, and marine plankton in sediments (National Research Council 2002). These events certainly modified both the physical and biological environments for spotted seals. Although there is, of course, great uncertainty about the nature of the changes, at least some of them must have been very dramatic; no climatic event since the YD has matched its magnitude or rapidity (Alley 2000). Thus, there is ample evidence that spotted seals have adapted successfully many times to both large and rapid ecological changes. This paleoclimatic history is not on its own an assurance that spotted seals can adapt to the changes projected for the foreseeable future. However, the present-day life history of the species reflects many of the traits that must have been required to persist through the past million years.

The present-day life history of spotted seals has several characteristics that others have recognized as providing resilience (Learmonth et al. 2006, Moore and Huntington 2008) to threats that we have considered:

- Spotted seals are highly mobile and migratory, providing the potential for adjusting to changes in conditions by moving to more suitable habitat patches.
- Spotted seals are known to have a diet that is ecologically and trophically diverse, which should enhance resilience to climate-related changes in prey communities.

Initial data from satellite tracking, and a lack of observations of large groups of spotted seals at sea, indicate that the seals tend to be highly dispersed and mostly solitary while at sea during the ice-free season. Although some of their concentrations ashore are large, these concentrations are widely dispersed in the Chukchi and Bering Seas and Sea of Okhotsk. These factors may provide a hedge against localized threats such as oil spills, concentrations of fishery activity, and interactions with shipping (though the Bering Strait is one area that may be an exception during migrations to and from the Chukchi Sea).

Spotted seals have demonstrated the capability to shift reproduction from sea ice to shore in several parts of their range, including the Bohai Sea (in the Yellow Sea), Peter the Great Bay, the South Kurile Islands, the Second Kurile Strait, Utashud Island, and the East coast of Kamchatka (Trukhin 2005). This shift may afford resilience to loss of sea ice but it is subject to a fundamental constraint of the phocid life history in which individuals are relatively slow and vulnerable out of the water and in which reproduction involves a period of maternal nurturing of relatively defenseless young. This aspect of spotted seals' life history requires reproductive habitat that is low in predation risk and free of frequent disturbance. Given a sufficient quantity of suitable habitat ashore, spotted seals could conceivably persist independent of sea ice. It is doubtful, however, that sufficient shore habitat exists within the

Southern DPS. In the Okhotsk DPS there are already very large coastal haul-out sites used in summer that might be suitable for reproduction if they are sufficiently free of predation or disturbance. An inventory of predators and disturbance factors at these sites has not been possible within the time frame of this status review. Two peer-reviewers of this document with expertise in spotted seal biology disagreed about the long-term prospects for success of shore-based reproduction in the Okhotsk DPS. In the Bering DPS, there may be suitable sites for reproduction ashore on the coasts of both Russia and Alaska, though spotted seals in the Bering DPS are likely to continue to have annual sea ice available.

4.3.5.2 Population characteristics

Within the Bering and Okhotsk DPSs the highly dispersed nature of spotted seals, both during the reproductive season when they are spread out in low-density family groups along the sea-ice front and during the ice-free season when they utilize widely dispersed haul-out sites and make extensive foraging trips at sea, should reduce demographic risks associated with localized threats, such as oil spills or a fishery with concentrations of gear that is prone to bycatch of seals. In the Southern DPS, the breeding areas are much smaller and more confined, and population sizes so low that the demographic risks from similar localized threats are much greater.

4.3.5.3 Habitat constraints or benefits

The marine habits of spotted seals and the capability of individuals to undertake large seasonal movements and shifts between near-shore and pack ice habitats may mitigate some anticipated impacts of anthropogenic climate change. For many species, especially terrestrial ones that have been threatened or endangered by human modification or destruction of habitat, the difficulty for survival is amplified by barriers to migration between remaining suitable, but fragmented habitat patches. This may typically be of less concern for wide-ranging marine mammals. Although many marine mammal populations have been threatened or endangered, the primary cause in nearly every case has been from overharvest or incidental takes in fisheries rather than destruction of habitat (exceptions are manatees, dugongs, and river dolphins, which inhabit easily fragmented or damaged coastal, estuarine, or river habitats). If sea-ice habitat within the Bering and Okhotsk DPSs is reduced by climate change, it is plausible that the populations will adjust by shifting their range to include new habitat made suitable by, for example, a northward shift of the typical spring ice edge. In the Bering DPS, this could eventually result in spotted seals shifting their breeding areas into the Chukchi Sea and Arctic Ocean. Such a northward shift would have its limits however in the Okhotsk DPS, which unlike in the Bering DPS, has a northern boundary of land beyond which the population could not shift. The Southern DPS has an even greater habitat constraint in that the current sea-ice patches are so small and confined that shifting of range is not a possibility. Indeed, any changes to the habitats of spotted seals may involve demographic impacts to populations, though the present level of quantitative understanding is insufficient to assess the magnitude of these impacts.

4.4 Conclusions of the Extinction Risk Assessment

4.4.1 Bering DPS

The primary threats faced by spotted seals in the Bering Sea are likely to be climate-related changes to the sea-ice habitat and to the prey community. Sea ice is expected to decline such that the average extent in May, during the latter half of the period for nursing, and initial independent development of pups, is limited to areas north of St. Lawrence Island by about the middle of the 21st century. There will, however, likely continue to be large interannual variations of nearly the same magnitude as in the past, so that some years will have very extensive ice and others will have very low ice extent. The low ice years, which will come more frequently than in the past, may have impacts on recruitment, primarily through pup survival. On the other hand, some aspects of reduced ice may be beneficial to spotted seals, mitigating the impacts of low ice years. This is possible because of the prospect that thinner and more broken ice is likely to occur over large areas of the northern Bering Sea and Chukchi Sea that are currently too densely covered to be suitable for spotted seal breeding. The impacts of ocean acidification, the other significant climate-related threat to spotted seals, are even less predictable than the impacts of sea-ice reduction. Spotted seals, like other ice-associated species, are adapted for coping with large ranges of variability in conditions. There is currently no quantitative basis for determining whether the climate-related habitat impacts will outweigh the mitigating factors.

No other threats were thought to pose significant demographic risks to the Bering DPS. A large population (at least 100,000) has persisted over the past several decades with no conspicuous extreme fluctuations. The suite of risks from overutilization, disease and predation, inadequacy of regulatory mechanisms, and other natural or human factors is not anticipated to change sufficiently to place the Bering DPS at risk of extinction within the foreseeable future.

4.4.2 Okhotsk DPS

The threats faced by spotted seals in the Sea of Okhotsk are the same as to those in the Bering Sea, but the projections of future climate-related habitat conditions are less certain. In consideration of observed climatology and projected air temperatures, much of the region may have ice-deteriorating conditions in April by the mid-21st century. This region is characterized by some differences from the Bering Sea that may be significant to the status of spotted seals. The ice-covered area is smaller in the Sea of Okhotsk and there is no marine connection to the Arctic Ocean, unlike in the Bering Sea. Over the very long term, spotted seals in the Sea of Okhotsk do not have the prospect of following a retreating ice front northward into the Arctic, as Bering Sea spotted seals would. There is currently no basis to judge whether ocean acidification will be any more severe or rapid in the Sea of Okhotsk than in other parts of the North Pacific, so the impact from that threat is no more predictable than for the other spotted seal DPSs.

Although most of the other risks are expected to be similarly low between the Bering and Okhotsk DPSs, the risks associated with petroleum exploration, development, and production are likely to be significantly greater in the Okhotsk DPS. Oil production and further development in the Sea of Okhotsk are well underway and likely to be less stringently regulated than similar activities that are as yet only proposed for the Bering and Chukchi Seas (at least in U.S. waters). Commercial fishery interactions, either direct or indirect, also may pose a significant risk in the Okhotsk DPS. Together, these risks and the climate-related risks summarized above could have substantial cumulative effects.

The demographic status of the Okhotsk DPS is less certain than the Bering DPS, but large numbers (as high as 268,000) of spotted seals were reported in the late-1960s to 1990. No conspicuous extreme changes are known to have occurred more recently. Even if the population was typically overestimated by a factor of 2, there would likely be approximately 100,000 spotted seals currently in the Okhotsk DPS, so that demographic and genetic risks from low abundance should not be a significant concern.

4.4.3 Southern DPS

Although there is great uncertainty in projecting sea-ice conditions for the Yellow Sea and Sea of Japan, sea-ice formation in the recent past has already been greatly reduced, and indirect evidence from air and sea surface temperature modeling suggests that seasonal ice will rarely form in these areas by about the middle of the 21st century. The species appears to have some capability to accomplish breeding and molting on shore when ice is not available. However, pinnipeds are generally not well protected from predation when they are constrained by the necessity of maintaining a mother-pup bond; that is, when escape to the water may disrupt the bond or poses thermoregulation problems for the pup. Therefore, suitable space for spotted seals to breed on land is likely limited to offshore rocks and small islands without human habitation, which are relatively scarce in the Southern DPS.

The dire status of spotted seals in the Southern DPS is likely to be maintained or worsened by the cumulative effects of: poaching for genitalia and culling by fisherman; loss of sea-ice habitat; breeding and molting in a non-preferred and possibly scarce habitat (ashore vs. on ice); reduced prey populations (e.g., pollock in the Sea of Japan and herring in the Yellow Sea); possible prey community disruption from ocean warming and acidification; and oil and gas development activities. The population sizes are already significantly reduced from historical levels, and if reduced further they may begin to be at significant risk from small-population threats such as demographic stochasticity and genetic problems. The small sizes of these populations, as well ecologically unique characteristics associated with life at the southern extremity of the species range, have been recognized by China, South Korea, and Russia through designation of special conservation status on the seals and portions of their habitat, though the effectiveness of these measures for preventing extinction is uncertain.

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7 APPENDIX 1: ESTIMATE OF CURRENT SPOTTED SEAL ABUNDANCE IN THE EASTERN AND CENTRAL BERING SEA

In the spring of 2007, researchers from NMML conducted aerial surveys for spotted and other ice-associated seals in the U.S. sector of the Bering Sea (Cameron and Boveng 2007). The surveys were conducted from a helicopter based aboard the U.S. Coast Guard icebreaker *Healy* during two cruises: April 10-May 12 and May 16-June 18, 2007. The cruises ranged throughout the pack ice of the eastern and central Bering Sea, providing access to areas not surveyed since the 1970s (Burns and Harbo 1977, Braham et al. 1984) and 1980s (Fedoseev et al*.* 1988).

7.1 Field Methods

Line transect surveys were conducted whenever the *Healy* was near ice and the weather conditions were conducive to flying between 09:00 and 15:00 (local apparent time), which corresponds to the timing of peak seal haul out. Each flight had 2-3 observers and was flown at a target altitude of 118 m (400 ft) and speeds of 80-95 knots. Only seals hauled out on ice were recorded. The distance from each seal to the helicopter's track line was calculated using a sighting bar mounted on each observer's window. In all, 1,567 seals, 778 of which were identified as spotted seals (Table A1) were observed during 48 hours and 55 minutes of survey effort covering 4,414 nautical miles of survey line on 44 flights (Figure A1).

Table A1. -- Counts of pinnipeds observed during aerial surveys in the eastern and central Bering Sea, 2007.

Species	Count
Bearded seal	320
Ribbon seal	217
Ringed seal	24
Spotted seal	778
Unk. Pinniped	228
Walrus	283
TOTAL	**1,850**

7.2 Analysis

The software package DISTANCE (Thomas et al*.* 2006) was used to calculate detection probabilities and densities for each species (Moreland et al*.* 2008). The extent of the area (i.e., sea-ice field) over which the seals were distributed changed dramatically throughout the survey as the ice shifted and melted. This change in habitat was assumed to affect the densities of seals hauled out on the ice. To compensate for the reduction in sea ice over the 69 days of the survey, the analysis was divided into three time periods: High ice coverage (April 12-May 4), medium ice coverage (May 5-May 28), and low ice coverage (May 29-June 11), and calculated average densities of 0.87 (SE = 0.13), 0.94 (SE = 0.36) and 1.8 (SE = 1.6) spotted seals hauled out/nmi^2, respectively (Moreland et al*.* 2008). The dates of the medium and low ice concentration survey periods coincided with rapid melting of the ice in the region and the seasonal transition to a more pelagic existence for some age classes (Boveng et al. 2007), complicating the choice of an effective survey area; therefore, the medium and low ice coverage periods were not included in the rest of the analyses.

Integrating the estimated density from the high-ice period over the entire survey area, calculated as the minimum convex polygon encompassing all survey tracks (64,500 nmi^2), produced an estimate of 56,115 spotted seals (with a variance of $0.13^2*64{,}500^2 = 70{,}308{,}225$), not including an adjustment for seals in the water at the time of our surveys.

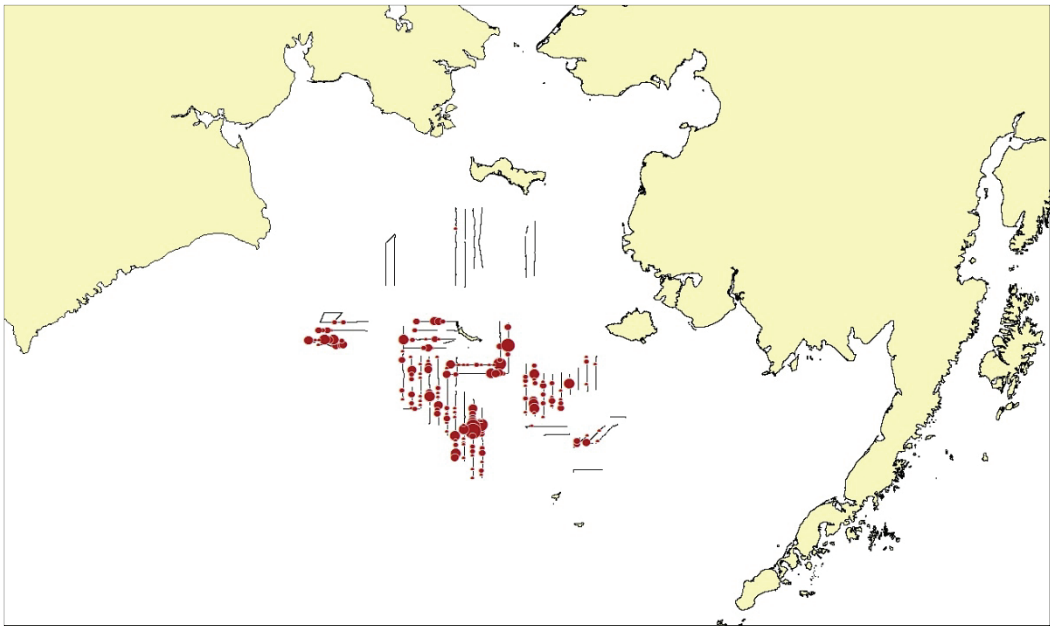

Figure A1. -- Map of the Bering Sea. The black lines show the locations of aerial surveys conducted during the high ice concentration period (April 12 to May 4, 2007). The red circles indicate locations where spotted seals were observed (larger circles indicate more spotted seals).

To adjust for seals that were missed because they were in the water, the estimate was divided by the average proportion of the population that was hauled out at the time of the survey period. This proportion was estimated from records of time spent in the water by seals carrying satellite-linked data recorders (SDRs). During the autumn of 2005 in Kotzebue Sound, and during the spring of 2006 and 2007 in the eastern Bering Sea, NMML researchers attached SDRs to spotted seals captured on the ice with hand-held hoop nets or in the water with tangle nets. For each day, these SDRs provided information on the percent of each hour that each seal was hauled out of the water.

We fitted a model for the proportion of seals hauled out, based on SDR data records from 18 seals following the methods detailed by (Ver Hoef et al. 2009) using hour of the day, month of the year, gender, and age of the seal as explanatory variables. Although there were no significant effects of gender or age, date and time of day had strong effects, with the greatest proportion of seals hauling out in springtime (with a peak in May) and during mid-day.

We integrated a correction factor surface (e.g., the inverse of the modeled proportion of seals hauled out) for times between 09:00 to 15:00 (local apparent time), and from April 12 to May 4. This average correction factor (1.810), multiplied by the on-ice abundance estimate (56,115), produced an overall abundance estimate of 101,568 seals. We obtained a standard error of 17,869 using the delta method (Dorfman 1938) for the integrated surface and then the formula on the variance of products (Goodman 1960).

The primary value of producing this estimate is for identifying potential gross failures of assumptions or gross changes in distribution or density. Unfortunately, earlier surveys did not report abundance estimates specifically for the central and/or eastern Bering Sea. However, Shustov (1972) , Fedoseev et al. (1988), and Fedoseev (2000) provided estimates ranging from 100,000 to 135,000 for the entire Bering Sea. Ours is not a range-wide estimate and, lacking details about the Russian survey methods, it would be inappropriate to use this estimate to infer population trends.

8 APPENDIX 2: GLOSSARY OF ABBREVIATIONS

Abbreviation	Description
ADFG	Alaska Department of Fish and Game
AOGCM	atmosphere-ocean general circulation models
AR4	IPCC Fourth Assessment Report
BRT	Biological Review Team
BT	butyltin
CAA	Clean Air Act
CBD	Center for Biological Diversity
CDV	canine distemper virus
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMIP3	Coupled Model Intercomparision Project Phase 3
CZMA	Coastal Zone Management Act
DDE	dichloro-diphenyl-dichloroethylene
DDT	dichloro-diphenyl-trichloroethane
D-O	Dansgaard-Oeschger
DPP	Draft Proposed Program
DPS	distinct population segment
EEZ	Exclusive Economic Zone
ESA	Endangered Species Act
GHG	greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature and Natural Resources
kya	thousand years ago
kyr	thousand years
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service
MPRSA	Marine Protection, Research, and Sanctuaries Act
mtDNA	mitochondrial DNA
mya	million years ago
NAO	North Atlantic Oscillation
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
nmi^2	square nautical mile
NMML	National Marine Mammal Laboratory, Alaska Fisheries Science Center
NOAA	National Oceanic and Atmospheric Administration
NSR	Northern Sea Route
NWP	Northwest Passage
OCS	outer continental shelf
OCSLA	Outer Continental Shelf Lands Act
PBDE	polybrominated diphenyl ether
PCB	polychlorinated biphenyl
PDO	Pacific Decadal Oscillation
PDV	phocine distemper virus
PFC	perfluorinated contaminant

Abbreviation	Description
PhHV	phocid herpesvirus
POP	persistent organochlorine pollutant
PTS	permanent threshold shift
SAT	surface air temperature
SDR	satellite-linked data recorder
SST	sea surface temperature
TAR	IPCC Third Assessment Report
TCV	Tillamook calicivirus
TINRO	Soviet Pacific Institute of Fisheries and Oceanography
USFWS	U.S. Fish and Wildlife Service
YD	Younger Dryas interval

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