NOAA Technical Memorandum NMFS-AFSC-255

Status Review of the Ribbon Seal (*Histriophoca fasciata*)

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center

June 2013

NOAA Technical Memorandum NMFS

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This document should be cited as follows:

Boveng, P. L., J. L. Bengtson, M. F. Cameron, S. P. Dahle, E. A. Logerwell, J. M. London, J. E. Overland, J. T. Sterling, D. E. Stevenson, B. L. Taylor, and H. L. Ziel. 2013. Status review of the ribbon seal. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-255, 174 p.

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June 2013

STATUS REVIEW OF THE RIBBON SEAL
(*Histriophoca fasciata*)

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June 2013

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EXECUTIVE SUMMARY

This status review is intended to be a compilation of the best available information concerning the status of ribbon seals (*Histriophoca fasciata*), including the past, present, and future threats to this species. It is an update to a previous review (Boveng et al. 2008) conducted in response to a petition filed by the Center for Biological Diversity to list the ribbon seal as threatened or endangered under the U.S. Endangered Species Act (ESA), primarily due to concern about threats to this species' habitat from climate warming and loss of sea ice. This update was compiled by a National Oceanic and Atmospheric Administration (NOAA) biological review team (BRT) under a settlement agreement with the Center for Biological Diversity on August 30, 2011, in which NMFS agreed to apply a modified approach to analyzing extinction risk in the "foreseeable future", and incorporate new information that has become available since the previous review.

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 to determine 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". The horizon of the foreseeable future was determined to be the year 2100 because a broad scientific consensus has developed around climate and sea-ice projections by the Intergovernmental Panel on Climate Change, and results of those projections are available through the end of the current century. Projections to the middle of the century are considerably more certain because past and current emissions of greenhouse gases have already largely set the course for changes in the atmosphere and climate until that time, so the BRT also considered potential outcomes from the present to the year 2050, as well.

Species Background: The ribbon seal is a strikingly-marked member of the family Phocidae that primarily inhabits the Sea of Okhotsk, and Bering and Chukchi Seas. This species is strongly associated with the sea ice during its whelping, mating, and pelage molt periods, from mid-March through June. Most of the rest of the year is spent at sea; the species is rarely observed on land. The rates of survival and reproduction are not well known, but ribbon seals can live 20 to 30 years. They become sexually mature at 1-5 years of age, probably depending on environmental conditions, and adult females usually give birth every year to a single pup which is nursed for 3-4 weeks and then abandoned to fend for itself.

Species Delineation: Although there are two main breeding areas for ribbon seals, one in the Sea of Okhotsk and one in the Bering Sea, there is currently no evidence of discrete subpopulations on which to base a separation into distinct population segments. The population composing the entire species is the subject of this review.

Extinction Risk Assessment: To assess the extinction risk, the BRT first evaluated specific threats faced by the species, grouped in categories, or factors, 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

Present or threatened destruction, modification, or curtailment of the species' habitat or range: The main concerns about the conservation status of the ribbon seal stem from the likelihood that its 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 reliable assessment of the future conservation status of ribbon seals requires a focus on projections of the specific regional conditions, especially sea ice, and changes that could impact vital rates.

In contrast to the Arctic Ocean, where sea ice is present year-round, the ice in the Bering Sea and Sea of Okhotsk is seasonal in nature. Despite the recent dramatic reductions in Arctic Ocean ice extent during summer, the sea ice in the northern Bering Sea and Sea of Okhotsk is expected to continue forming annually in winter for the foreseeable future. The sea ice regimes in these seas will continue to be subject to large interannual variations in extent and seasonal duration, as they have throughout recorded history. While there may be more frequent years in which ice coverage is reduced, the late March-April period in which ribbon seal reproduction occurs will continue to have substantial ice, particularly in the northern regions of the breeding range. In years of low ice it is likely that ribbon seals will adjust at least in part by shifting their breeding locations in response to the position of the ice edge as they have likely done in the past in response to interannual variability.

There will likely be impacts on ribbon seal survival and recruitment from more frequent years of reduced ice thickness and duration of seasonal ice coverage. Decreased availability of stable platforms for adults to complete their molt out of the water may lower survival, but it is not currently possible to quantify this impact or the extent to which ribbon seals may adapt by shifting locations for key life history events of breeding and molting. Weaned pups are likely dependent on sea ice for a 2-3 week period as they develop self-sufficiency in foraging. They enter the water regularly during this period, and therefore may not be particularly sensitive to modest reductions in coverage or quality, though they may be relatively limited in their capability to respond to rapidly deteriorating ice fields by relocating over large distances, a factor that could occur more frequently in the foreseeable future. Preliminary analysis of recent satellite tracking results corroborate natural history observations that ribbon seals prefer to forage at the continental shelf break or in deeper water beyond. This preference may result in reduced condition, survival, or reproduction if the future ice edge recedes far from the shelf break during periods when ribbon seals are tied to the ice by a need to reproduce or molt, though their feeding is likely reduced and perhaps not as important during the molt.

Ocean acidification, a result of increased carbon dioxide in the atmosphere, may impact ribbon seal survival and recruitment through disruption of trophic regimes that are dependent on a wide array of calcifying organisms, but also through more general impacts on physiology and energetics of a broader suite of fish and invertebrates. The nature and timing of such impacts are extremely uncertain. Because of ribbon seals' apparent dietary flexibility, the species may have greater resilience to these impacts, unless there are major trophic shifts that persist for periods of a ribbon seal generation or more.

Changes in ribbon seal prey, anticipated in response to ocean warming and loss of sea ice, also have the potential for negative impacts, but again 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 ribbon seals. For example, several fish species, including walleye pollock (*Theragra chalcogramma*), a common ribbon 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 ribbon seal foraging locations and habits may make these threats of lower concern than more direct impacts from changes in sea ice. However, the possibility of cumulative or multiplicative effects involving both loss of sea ice and changes in prey communities is important to consider.

Overutilization for commercial, subsistence, recreational, scientific, or educational purposes: Recreational, scientific, and educational utilization of ribbon seals is currently at very low levels and is not projected to increase to significant threat levels in the foreseeable future. Commercial harvests by Russian sealers have at times been high enough to cause significant reductions in abundance and catch-per-unit-effort. The population apparently rebounded from a period of high harvest in the 1960s. Substantial but lower numbers were harvested for a few years in the early 1990s. Although Russian government quotas were recently in place that would allow large harvests (~18,000 annually), the actual takes are low because of poor economic viability. There is some effort in Russia to develop new uses and markets for seal products, but unless these are successful, the harvest is unlikely to increase in the near future. Subsistence harvest levels have been low historically, but could potentially increase in the future if ribbon seals are forced to use a reduced and more northerly ice field, which could put them in closer proximity to Alaska Native communities near the Bering Strait.

Diseases, parasites, and predation: A variety of pathogens (or antibodies), diseases, helminthes, cestodes, and nematodes have been found in ribbon 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. A recent outbreak of disease in ice-associated pinnipeds including ribbon seals, in which no infectious agent has yet been identified, may be evidence of that risk. There is little or no direct evidence of significant predation on ribbon seals and they are not thought to be a primary prey of any predators. Polar bears and killer whales may be the most likely opportunistic predators in the current sea ice regime, but sharks may be underestimated as ribbon seal predators, and walruses could pose a potentially greater risk if reduced sea ice conditions force these pagophilic species into closer proximity in the future.

Inadequacy of existing regulatory mechanisms: There is little evidence that the inadequacy of existing regulatory mechanisms currently poses a threat to ribbon seals. However, there are no known regulatory mechanisms that effectively address reductions in sea ice habitat at this time. Also, it is unclear what regulatory mechanisms are in place to ensure that potential commercial harvests in Russia are conducted in a sustainable fashion.

Other natural or human factors affecting the species' continued existence: Although some pollutants are at elevated levels in ribbon seals, there is no conspicuous evidence of toxicity or other significant impacts to the species. Continued and expanded monitoring would be prudent, to document any trends in the contaminants of greatest concern.

Oil and gas exploration and development activities may include 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 ribbon seals are the effects of noise, disturbance, and potential oil spills produced from these activities. Any negative effects on ribbon seals from noise and disturbance associated with development activities are likely to be minor and localized. Ribbon seals are also highly dispersed during the summer, open-water season so the rate of interactions with seismic surveys would likely be low, and in any case seals have not been shown to be significantly impacted by seismic surveys for oil and gas. The threat posed to ribbon seals by oil spills will increase if offshore oil and gas development and shipping activities increase across their range as predicted. The potential impacts would be greatest during April-June when the seals are relatively aggregated and substantially lower during the remainder of the year when they are dispersed in the open water throughout the North Pacific Ocean, Sea of Okhotsk, and Bering and Chukchi Seas.

Estimates from observed by-catch in commercial fisheries imply that less than 200 ribbon seals per year are taken, though mortalities are certainly under-reported in some fisheries. Because there is little or no fishery activity near aggregations of ribbon seals when they are associated with ice, and they are highly dispersed in the remainder of the year, by-catch is unlikely to be a significant threat to ribbon seal populations. For the same reason, competition from fisheries that reduce local abundance of ribbon seal prey is unlikely to be significant. Broad-scale reduction in a commercially-fished, primary prey species could have a significant impact, but the large groundfish fisheries in Alaska waters, at least, are well-managed to prevent depletion of the stocks.

The extraordinary reduction in Arctic sea ice that has occurred in recent years has renewed interest in trans-Arctic navigation routes connecting the Atlantic and Pacific Oceans via the Northwest Passage and the Northern Sea Route. The Chukchi Sea and Bering Strait would be the most likely areas for increased exposure of pelagic ribbon seals to ship traffic, because of the geographic constriction and the seasonal migration of part of the ribbon seal population around the beginning and end of the ice-free season. However, there is currently little or no information on direct impacts from shipping on seals in open water. Ribbon seals hauled out on sea ice may also be at risk from increased ship traffic, but likely only during spring and early summer, and then only by ice-reinforced ships. Assessing risk from increases in shipping and transportation is difficult because projections about future shipping trends within the ribbon seal's range are currently unavailable.

Threats Assessment: A structured approach was used to elicit BRT members' expert judgment about the significance of threats facing ribbon seals. The threats were grouped by ESA Section 4(a)(1) factors (excluding Inadequacy of Existing Regulatory Mechanisms), and each individual threat was scored for its significance in two components: extent and likelihood. Extent was defined as the portion of the population that would experience reduced survival or reproductive success if the threat condition or event were to occur. Judging the extent of a threat required considerations such as the geographic scope, the age classes of ribbon seals affected, and the duration of that threat. Likelihood was defined as the probability that the threat will occur within a specified time period in the foreseeable future.

The extent and likelihood of each threat were scored on 5-level scales, separately for the Bering Sea and the Sea of Okhotsk, and in consideration of two time intervals: from now to the year 2050, and from now to the year 2100. The former interval was included to provide a sense of how some of the threats are anticipated to change, and to provide a reference similar to the time frame used in the previous assessment of ribbon seal status. The latter interval corresponds to the foreseeable future for the primary threats related to climate disruption by greenhouse gas emissions.

The extent and likelihood scores for the period from now to 2100 were combined as a product to yield a threat score that could range from low to extreme (numerically from 1-25). These individual threat scores were then considered in a judgment about the overall score, using the same scale, for all the threats included in each ESA Section 4(a)(1) factor. In assigning an overall factor score, BRT members considered that a factor score should typically be at least as high as the individual threat scores within that factor, and in some cases higher because multiple threats may have cumulative effects that amplify the overall significance of the factor.

For ribbon seals in both the Bering Sea and Sea of Okhotsk, the BRT judged the threats of destruction or modification of habitat to be of greater significance than the threats from the other factors. In the Bering Sea, loss of suitable ice for molting and pup maturation, and diminished prey from effects of ocean acidification were judged to be the greatest threats to habitat, although confidence about the score for the latter threat was low. In the Sea of Okhotsk, losses of ice suitable for whelping, nursing, mating, and molting were judged to pose the greatest threats. Threats of overutilization were judged to be of low significance and threats from disease, parasites, and predation were judged to be of moderate significance in both regions. Threats from other natural or man-made factors were judged to be of moderate significance in both regions. Across all four factors, the threats were judged to be more significant in the Sea of Okhotsk than the Bering Sea, reflecting greater concern about ice loss and regulation of petroleum development in the Sea of Okhotsk. There was substantial variability in the threat scores and factor scores among the BRT members, with strong consensus only in the factor comprising threats of overutilization in the Bering Sea.

Demographic risks: Threats to a species' long-term persistence are manifested demographically as risks from low abundance, poor productivity, disrupted spatial structure and connectivity, and reduced genetic and ecological diversity. These demographic risks thus provide the most direct indices or proxies of extinction risk. The current and foreseeable future status of each of these risks was assessed in turn by responding to a set of questions adapted from guidelines used to assess salmonid populations but based on general conservation biology principles applicable to a wide variety of species.

The BRT members' assessments of the significance of demographic risks to the persistence of ribbon seals were summarized in numerical scores. Scoring was modeled on similar approaches used in other ESA status reviews and was designed to elicit expert judgment about the likelihood that the known and potential threats will impact a species' persistence. Specifically, each BRT member considered the risk that the population may be placed in danger of extinction by demographic problems with abundance, productivity, spatial structure, or diversity, and then assigned a score to each of these demographic categories as follows: 1 = very low or zero risk, 2 = low risk, 3 = medium risk, 4 = high risk, and 5 = very high risk. To assess future risks of extinction, the BRT members scored the risks that problems associated with those demographic categories will—between now and 2050, and between now and 2100—place the species in danger of extinction.

For the period from now to 2050, demographic risks were judged to be low to very low (average of BRT members' scores ranging from 1.1 to 2.0). With a population likely comprising at least 200,000-300,000 individuals, ribbon seals are not currently at risk from the demographic issues of low abundance commonly associated with ESA listing decisions, such as demographic stochasticity, inbreeding, loss of genetic diversity, and depensatory effects. The current population trend is unknown, but observations by hunters and a recent estimate of 61,100 ribbon seals in the eastern and central Bering Sea are consistent enough with historical accounts to suggest that no major or catastrophic change has occurred in recent decades. The species is thought to occupy its entire historically-observed range; there are no portions of the range in which ribbon seals have been reported to have disappeared or become extinct.

For the longer time frame, from now to 2100, a recognition of the increasing significance of diminished sea ice and increased prevalence of ocean acidification was reflected in risk scores that ranged from low to medium (1.6 to 2.8). The greatest risks perceived by the BRT were in the category of spatial structure, stemming from loss of habitat patches and connectivity that is anticipated to become significant in the latter half of this century.

To express a single, summarized judgment about extinction risk, each BRT member was asked to allocate 10 likelihood points to various time intervals, indicating his or her judgment about the time until ribbon seals would reach a population level of 5,000 individuals, representing a hypothetical extinction threshold or minimum viable population. The time intervals were 'now to 2025', '2026 to 2050', '2051 to 2075', '2076 to 2100', and '>2100'. Averaged over the 11 BRT members, a likelihood of 0% was ascribed to the combined intervals from now to 2050, 4% was ascribed to the interval 2051 to 2075, 13% was ascribed to 2076 to 2100, and 83% was ascribed to the period beyond 2100. In other words, the BRT's collective judgment was that there is a 4% + 13% = 17% chance that the ribbon seal population will decline to 5,000 individuals before the end of the current century. The range among BRT members in this judgment was from 0% to 50%, reflecting the variation that results from sparse and uncertain information underlying this assessment.

1 INTRODUCTION

On December 20, 2007, 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 ribbon seal (*Histriophoca fasciata*) as a threatened or endangered species and to designate critical habitat for this species pursuant to the U.S. Endangered Species Act of 1973, as amended (ESA) (16 U.S.C. 1531 et seq.) (Center for Biological Diversity 2007).

On March 28, 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) and convened a biological review team (BRT) to conduct an ESA status review of the ribbon seal (Boveng et al. 2008). On December 30, 2008, NMFS published a 12-month finding stating that ribbon seal abundance was likely to decline gradually for the foreseeable future due to slight but chronic impacts on reproduction and survival caused by reduced frequency of years with suitable sea-ice extent, quality, and duration of persistence, but that listing of the ribbon seal was not warranted at that time (National Marine Fisheries Service 2008a). On September 3, 2009, CBD and Greenpeace, Inc. (collectively, "Center") filed a complaint in U.S. District Court challenging NMFS' 12-month finding. On December 21, 2010, after considering cross-motions for summary judgment, the Court denied the Center's motion for summary judgment and granted NMFS's cross-motion, upholding its 12-month finding. The Center filed a notice of appeal of this judgment to the Ninth Circuit Court of Appeals on January 18, 2011.

New information became available after the publication of the 12-month finding that could have implications for the status of the ribbon seal relative to the listing provisions of the ESA, including new data on ribbon seal movements and diving, as well as a modified approach to analyzing extinction risk in the "foreseeable future" (see Section 4.1). In consideration of this information, NMFS entered a settlement agreement with the Center on August 30, 2011, under which NMFS agreed to initiate a new status review of the ribbon seal and submit a 12-month finding to the Office of the Federal Register by December 10, 2012 (National Marine Fisheries Service 2011). On November 27, 2012, NMFS and the Center agreed to change this deadline to June 10, 2013. NMFS convened a new BRT to conduct this status review which was composed of 8 marine mammal biologists, 2 fishery biologists, and 1 climate scientist.

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 ribbon 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 to serve 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 make this assessment, 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 intended to be a compilation of the best available scientific and commercial data and a description of past, present, and likely future threats to the ribbon 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 result of the decision 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 ribbon seal is known by many names throughout its range. Alaska Eskimos call these seals *qasruliq* in central Yupik, *kukupak* in St. Lawrence Island Yupik, and *qaigullik* in northern Inupiaq (Burns 1994). In Russia, ribbon seals are called *ur* or *al'kha* by the Gilyaks, *il'yar* or *khilar* by the Eveny, *molodarka*, *peganka*, or *pegaya nerpa* by other people around the Sea of Okhotsk, *vaal'kkhleryn* by the Chukchi, and *krylatka* in other places (Krylov et al. 1964). Ribbon seals are also sometimes referred to as "striped seals" (Tikhomirov 1966) or "banded seals" (Riedman 1990).

Burns (1981) and Kelly (1988) recounted the history of the earliest scientific accounts and taxonomic classification of the ribbon seal. Allen (1880) was apparently the first to use the Latin binomial *Histriophoca fasciata*, adopting the genus proposed by Gill (1873) and the original Latin specific name, bestowed by Zimmermann (1783; original not seen). This name was widely accepted for many years (Mohr 1951, Chapskii 1955, Scheffer 1958, King 1964). Based on a comparison of skull morphology within the family Phocidae, Burns and Fay (1970) advised reassigning *Histriophoca* to sub-generic status under the genus *Phoca* (*sensu lato*), and the original binomial *Phoca fasciata* was revived (Burns 1981, King 1983, Lowry 1985, Kelly 1988). However, recent molecular phylogenetic analyses of the Phocidae, indicate that ribbon seals belong in a separate genus (Mouchaty et al. 1995, Higdon et al. 2007, Fulton and Strobeck 2010b), thus *Histriophoca fasciata* is the appropriate taxonomic name (Rice 1998).

The ancestors of ribbon seals and all other northern true seals (sub-family Phocinae) except the bearded seal (*Erignathus barbatus*) were adapted to breeding on ice from at least 11-12 million years ago (mya) as indicated by the common trait of a white lanugo coat (Árnason et al. 2006, Fulton and Strobeck 2010b, Fulton and Strobeck 2010a). A split within the tribe Phocini occurred about 4.5 mya, leading to the sub-tribe Histriophocina, and another divergence at about 3.4 mya led to the present-day genera of *Pagophilus* (harp seal) and *Histriophoca* (Fulton and Strobeck 2010a). The ribbon seal probably arose in the Arctic Basin and moved into the North Pacific after the Bering Strait opened (Árnason et al. 2006, Fulton and Strobeck 2010b, Fulton and Strobeck 2010a).

2.2 Species Description

Ribbon seals are among the most striking and easily recognizable seals in the world. This species gets its common and specific (*fasciata*) names from the distinctive band or "ribbon" pattern exhibited by mature individuals. This pattern typically consists of four light-colored ribbons on a background of darker pelage. One ribbon encircles the neck and nape, another encircles the trunk around the lumbar region and hips, and two lateral ovals encircle each foreflipper from the lower neck to the midsection. Naito and Oshima (1976) described the development of these ribbon patterns, which vary among individuals in shape and width and sometimes become fused, and suggested that they may be involved with mate identification and selection. Krylov et al. (1964) suggested that this pattern helps to break up the shape of the ribbon seal's body when seen from a distance, making it less discernible from the surrounding ice hummocks and shadows. Adult males exhibit the most striking patterns, having bright white ribbons on a dark brown to black pelage (Figure 1), while adult females exhibit less contrast between their ribbons and lighter brown to silvery-gray pelage (Figure 2).

Figure 1. -- Adult male ribbon seal.

Ribbon seal pups are born with a thick, wooly white lanugo coat (Figure 2) that is molted after 3-5 weeks. Their new pelage is counter-shaded dark gray dorsally and light gray ventrally, similar to that of young hooded seals (*Cystophora cristata*) (Burns 1981). The ribbons are very indistinct or absent at first and gradually develop over 3 years with each successive molt (Naito and Oshima 1976). Naito and Oshima (1976) also noted the appearance of small ringed or spotted patterns in 7.9% of the 316 pelages they examined, and suggested that this may show evidence of avatism, or an expression of ancestral traits, related to the harbor seal (*Phoca vitulina*) or ringed seal (*Phoca hispida*). The only other seal species with a banded pelage pattern is the harp seal (*Pagophilus groenlandicus*), which is the closest relative of the ribbon seal (Lowry 1985).

Figure 2. -- Adult female ribbon seal with pup in natal white (lanugo) coat.

Ribbon seals are medium-sized when compared with the other three species of ice-associated seals in the North Pacific, being larger than ringed seals, smaller than bearded seals, and similar in size to spotted seals (*Phoca largha*). Newborn pups are approximately 86 cm long (nose to tail) and weigh about 9.5 kg (Tikhomirov 1968, Burns 1981). Burns (1981) reported the "normal" weights and lengths for the first six age classes as the following: age 1, 33 kg and 106 cm; age 2, 50 kg and 130 cm; age 3, 59 kg and 139 cm; age 4, 61 kg and 144 cm; age 5, 65 kg and 148 cm; and age 6, 67 kg and 148 cm. The author noted great variation in both weight and length within all age classes, and considered this growth rate rapid when compared with ringed and bearded seals (Burns 1981). Tikhomirov (1968) reported larger sizes for his age-class data (about 13% greater on average) and Fedoseev (2002) stated that ribbon seals in the southern Sea of Okhotsk are bigger and heavier than those from the northwestern Sea of Okhotsk and Bering Sea. Ribbon seal adults typically attain lengths of approximately 150-175 cm and weights of about 70-90 kg (Burns 1981, Popov 1982, Fedoseev 2002), with males and females being approximately the same size (Fedoseev 1973). Heptner et al. (1976) reported the maximum weight of ribbon seals is 150 kg and maximum lengths of 192 and 198 cm for males and females, respectively. Of 48 adult ribbon seals examined in the Bering Sea mostly during May in 2007-2010, 9 exceeded 100 kg in mass, the largest male was 106 kg, and the largest female was 122 kg (unpubl. data, Peter Boveng, National Marine Mammal Laboratory (NMML), 7600 Sand Point Way NE, Seattle, WA 98115). Like many other pinnipeds, the weight of ribbon seals fluctuates annually with their seasonal feeding cycles. On average, they lose about 20-30% of their weight and 50-60% of their blubber thickness during the spring whelping, breeding, and molting season (Fedoseev 1973, Burns 1981).

2.3 Ecological Adaptations

Ribbon seals exhibit several anatomical features that make them well adapted for a seasonally pelagic, deep diving lifestyle. Individuals older than pups have larger eyes and a more streamlined body form when compared with other Bering Sea phocids (Burns 1971, Burns 1981). Ribbon seals also have a comparatively short, wide skull with a short rostrum and a small, wide palate which typically contains 34 small, widely spaced teeth (Burns and Fay 1970). This species' most unique anatomical feature lies within its respiratory anatomy. Attached to the lower end of the trachea, through a narrow slit in its membrane, is a thin-walled air sac (Sleptsov 1940). This air sac is most developed in adult males and can extend posteriorly across the ribs on the right side of the body to the level of the foreflipper (Burns 1981). It can be poorly developed or absent in adult females and young individuals of both sexes (Abe et al. 1977). The function of the air sac remains unknown, but it may provide additional buoyancy for resting at sea (Burns 1981) and may be involved with sound production (Sleptsov 1940).

The ribbon seal's physiology also suggests that it is well adapted for life in the open ocean. Fedoseev (2000) showed that the internal organs of ribbon seals were larger (as a proportion of total body weight) than those of other seals, and suggested that this was an adaptation for deep diving and fast swimming. Sokolov (1966, cited in Fedoseev 2002) showed that ribbon seals have the highest number and volume of erythrocytes and the highest blood hemoglobin of all seals, indicating a suitability for deep diving. Lenfant et al. (1970) showed that ribbon seals have a greater diving ability than harbor and spotted seals, having higher total oxygen storage capacity, hemoglobin concentrations, and hematocrit values.

Unlike ringed seals, which have strong foreclaws for scraping ice, ribbon seals are not well adapted for maintaining breathing holes in winter sea ice. In an unusual event documented by an Alaska Native in 1926, ribbon seals in Lopp Lagoon on the Seward Peninsula were isolated from open water by a rapid freeze-up (Bailey 1928). Many seals were found moving south over the peninsula, even miles inland and up in the mountains, apparently in an effort to return to open water.

Compared with most other seals, ribbon seals are rather specialized in their mode of locomotion when they are out of the water. They move across the ice very rapidly in a serpentine motion, using their front claws to dig into the ice and pulling with alternating foreflipper strokes while moving the head and hips in a side-to-side motion, similar to a crabeater seal (*Lobodon carcinophaga*). This type of movement is apparently not very effective on substrates other than ice and snow. A vagrant ribbon seal taken into captivity in California had difficulty moving across a concrete surface when its pool was drained (Roest 1964). Another vagrant, observed numerous times during winter and spring of 2012 in Washington State and British Columbia, Canada, exhibited severe erosion of the tips of its claws (photo by Neil Fisher Photography, Vancouver, B.C., Canada, in NMML files). This individual was seen hauled out only on surfaces such as docks and decks that afforded access by lunging up from the water below, much like ice floes in the species' natural habitat. The claw wear was presumably caused by an inability to get effective traction with the foreflippers on these surfaces because the seal's normal sliding motion was inhibited by greater friction of its coat on these surfaces than on ice or snow. The ribbon seal's unusual mode of locomotion out of water may be the primary reason that the species is so rarely seen hauled out on land, and may indicate poor prospects for adapting to diminished sea ice by making more frequent use of land for hauling out.

2.4 Behavior

Ribbon seals have evolved some unusual behaviors compared with other northern phocids. Unlike most other seals, they are relatively unwary of their surroundings while hauled out and can often be approached quite closely by boat before being disturbed. They typically haul out near the middle of ice floes and don't raise their heads to scan for danger as often as other Bering Sea phocids (Burns 1981). Mothers are also known to leave their pups unattended for long periods of time during the nursing season (Tikhomirov 1964, Burns 1981). These "unwary" behaviors suggest that ribbon seals have not experienced the same levels of predation (from bears, foxes, or humans) as other northern phocids.

When ribbon seals are disturbed on ice, they typically remain still (at least initially) and extend their long necks to investigate the disturbance. This scanning can last longer than seems appropriate, suggesting that ribbon seals may have poor eyesight in air, which also may account for the comparative ease with which they may be approached (Burns 1981). When captured live with a net on the ice, ribbon seals tend not to struggle as much as other pinnipeds (Lowry and Boveng 2008), often adopting a "play dead" strategy until they sense they are being released, whereupon they instantly resume a vigorous attempt to escape.

Little is known about the vocalizations of this species. Watkins and Ray (1977) recorded two kinds of underwater sounds from ribbon seals in the ice-covered waters near St. Lawrence Island during spring. One was described as "intense downward frequency sweeps" and the other as a "broadband puffing" sound. Based on the seasonal timing of these sounds and an analogy with sounds made by other seals, the authors speculated that these sounds are probably related to reproduction and/or territorial behavior (Watkins and Ray 1977). Ribbon seals calls were detected by passive acoustic recorders on the 70 m isobath in the southeastern and central Bering Sea (Miksis-Olds and Parks 2011). The calls were detected from January-June during periods of ice cover greater than 80%, with a peak in April-May. Ribbon seal calls were also detected by passive acoustic recording in the northern Chukchi Sea at 75°N during October-November (Moore et al. 2012), far outside the seasonal period normally associated with reproductive behaviors.

2.5 Distribution, Habitat Use, and Movements

The distribution of ribbon seals is restricted to the northern North Pacific Ocean and adjoining sub-Arctic and Arctic seas, where they occur most commonly in the Sea of Okhotsk and Bering Sea (Figure 3).

Habitat selection by ribbon seals is seasonally related to specific life history events that can be broadly divided into two periods: spring and early summer when whelping, nursing, breeding, and molting all take place in association with sea ice on which the seals haul out, and mid-summer through fall and winter when ribbon seals rarely haul out and are mostly not associated with ice.

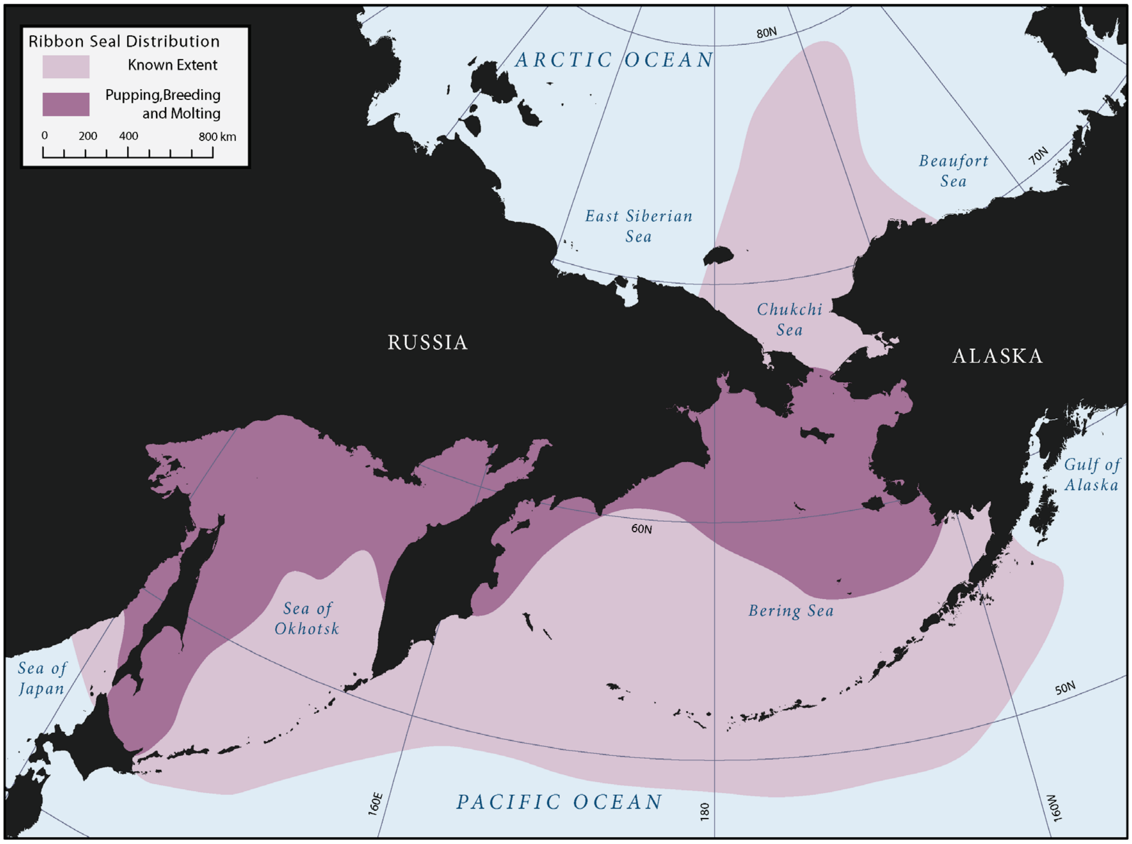

Figure 3. -- The approximate geographic distribution of ribbon seals, based on documented observations and satellite telemetry.

In spring and early summer (March-June), ribbon seal habitat is closely associated with the distribution and characteristics of seasonal sea ice (Shustov 1965a, Lowry 1985). Ribbon seals are strongly associated with sea ice during the breeding season and not known to breed on shore (Burns 1970, Burns 1981). During this time, ribbon seals are concentrated in the ice front or “edge-zone” of the seasonal pack ice, ranging up to 150 km north of the southern edge (Burns 1970, Fay 1974, Burns 1981, Braham et al. 1984, Lowry 1985, Kelly 1988). Shustov (1965a) observed that ribbon seals were most abundant in the northern part of the ice front and this north-south gradient has been observed in several other studies as well (Burns 1970, Naito and Konno 1979, Kelly 1988). The ice front is characterized by small ice floes, usually less than 20 m wide, separated by water or slush ice and subject to rapid movement by winds and ocean currents (Burns 1970, Fay 1974, Popov 1982). In most years, the Bering Sea pack ice expands to or near the southern edge of the continental shelf (Burns 1981, Braham et al. 1984, Lowry 1985, Mizuno et al. 2002). Most of this ice melts by early summer. However, Burns (1969) described a zone of sea ice that remains in the central Bering Sea until melting around mid-June. Satellite imagery has verified the presence and persistence of this zone of ice and has shown that it is located relatively close to the edge of the continental shelf (Burns 1981). Ribbon seals are numerous in this area, which is an extremely productive region that likely provides rich foraging grounds (Burns 1981). Prey availability could strongly influence whelping locations because females probably feed actively during the nursing period (Lowry 1985). In spring and early summer, ribbon seals are usually found in areas where water depth does not exceed 200 m, and they appear to prefer to haul out on ice that is near or over deeper water, indicating their preference for the continental shelf slope (Heptner et al. 1976).

A sample of adult and subadult ribbon seals monitored by satellite telemetry exhibited a seasonal dive-depth pattern consistent with a preference for feeding on the shelf slope (Figure 4). During June, when some ribbon seals have completed their molt and others are still molting, the tagged seals' dives were spread over all depths to 500 m, with the mode at 71-100 m. During July-October, when ribbon seals are not tied to the ice for reproductive and molting requirements, the dives were more evenly spread over the top 500 m, with a few dives exceeding 600 m. In November, when ribbon seals tend to return to the sea ice zone, the dives were nearly all to 100 m or shallower, consistent with sea ice that is limited to the shelf region. As sea ice advanced south during December-March, the dive depths increased, presumably as the tagged seals became able to reach the shelf slope during foraging trips from the ice edge. This pattern suggests that ribbon seals prefer to forage in deeper water when not constrained by the distribution of available ice being too far from the continental shelf slope.

Shustov (1965a) found that ribbon seal abundance increased only with ice concentration and was unaffected by ice type, shape, or form. This is in contrast to most studies which show that ribbon seals generally prefer new, stable, white, clean, hummocky ice floes, invariably with an even surface; it is rare to observe them on dirty or discolored floes, except when the ice begins to melt and haul-out options are more limited (Heptner et al. 1976, Burns 1981, Ray and Hufford 2006). Ribbon seals also seem to choose moderately thick ice floes (Burns 1970, Fay 1974, Burns 1981). These types of ice floes are often located at the inner zone of the ice front and rarely occur near shore (Burns 1981), which may explain why ribbon seals are typically found on ice floes far away from the coasts during the breeding season (Heptner et al. 1976).

During May and June, ribbon seals spend much of the day hauled out on ice floes while weaned pups develop self-sufficiency and adults complete their molt. As the ice melts, seals become more concentrated (Fay 1974, Lowry 1985) with at least part of the Bering Sea population moving towards the Bering Strait and the southern part of the Chukchi Sea (Fay 1974). This suggests that proximity to the shelf slope and its habitat characteristics (e.g., water depth, available prey) become less important, at least briefly around the molting period when feeding is likely reduced.

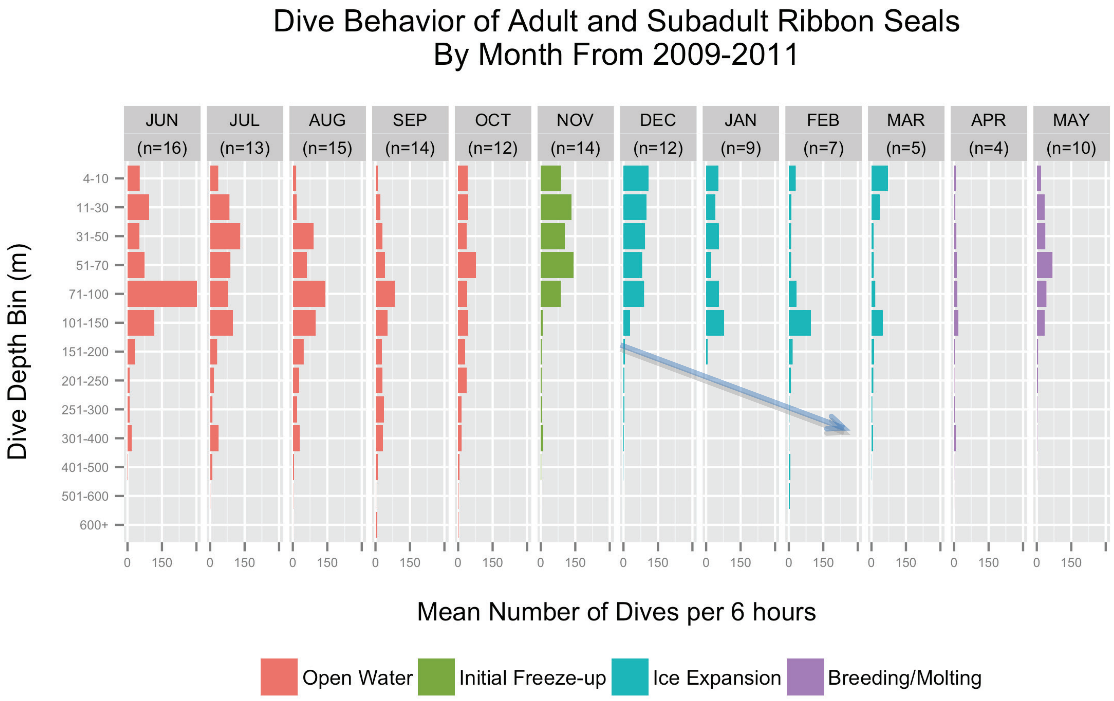

Figure 4. -- Seasonal changes in ribbon seal dive depths, in relation to advance and retreat of sea ice in the Bering Sea (unpubl. data, Peter Boveng, NMML, 7600 Sand Point Way NE, Seattle, WA). The arrow indicates the tendency for the dive depths to increase as the ice edge expands south, nearer to the continental shelf break.

Although ribbon seals are strongly associated with sea ice during the whelping, breeding, and molting periods, they do not remain so after molting is complete (Shustov 1965a, Burns 1981). During summer, the ice melts completely in the Sea of Okhotsk, and by the time the Bering Sea ice recedes north through the Bering Strait, there are usually only a small number of ribbon seals hauled out on the ice (Burns 1981). Significant numbers of ribbon seals are only seen again in winter when the sea ice reforms (Shustov 1965a, Heptner et al. 1976, Burns 1981).

Several authors (e.g., review by Kelly 1988) have speculated, based on the distribution and timing of sightings, about where ribbon seals go during the months when the Bering Sea and Sea of Okhotsk are free of ice. One possibility is that many of those breeding in the Bering Sea may migrate north into the Chukchi Sea (Tikhomirov 1964, Shustov 1965a), and that breeders from the Sea of Okhotsk may migrate into the Bering Sea (Tikhomirov 1961). Although ribbon seals have been observed regularly in small numbers around St. Lawrence Island in the fall, they are seldom seen by Eskimo hunters from villages along the southern Chukchi Sea coast in Alaska, and are rare in the northern Chukchi Sea (Burns 1981). Most studies have concluded that relatively few ribbon seals pass through the Bering Strait (Burns 1970, Burns 1981, Lowry 1985). They are rarely seen near the coasts of the Bering Sea during late summer and fall (Heptner et al. 1976, Burns 1981, Lowry 1985), though instances of ribbon seals hauled out on land have been reported from the Sea of Okhotsk (Burns 1981). Most sightings of ribbon seals during summer in the Bering Sea have been near the Pribilof Islands, which suggests they spend the summer months feeding in productive regions of the shelf and slope (Lowry 1985).

The presumption that ribbon seals are well adapted to a pelagic lifestyle and that they range throughout the Bering Sea have been corroborated by tracking with satellite-linked tags (unpubl. data, Peter Boveng, NMML, 7600 Sand Point Way NE, Seattle, WA). Ten ribbon seals tagged in the spring of 2005 near the eastern coast of Kamchatka spent the summer and fall throughout the Bering Sea and Aleutian Islands (Figure 5). However, of 72 ribbon seals tagged in the central Bering Sea during 2007-2010, 21 (29%) moved to the Bering Strait, Chukchi Sea, or Arctic Basin as the seasonal ice retreated northward. Approximately 9.5% of ribbon seals’ time budget during July-October was in those areas (Figure 6), based on 41 seals that carried tags of a type that provides locations at sea. The majority of the seals tagged in the central Bering Sea did not pass north of the Bering Strait (Figure 6). These seals and the seals tagged near Kamchatka in 2005 dispersed widely, occupying coastal areas as well as the interior of the Bering Sea, both on and off the continental shelf, diving to the seafloor when in shallow water and occasionally diving to depths of over 500 m while over the basin. Although there is still much to be learned about the movements and habitat selection of ribbon seals, these tracking records begin to give a sense of the relative and seasonal importance of different zones throughout the species’ range. Their widespread distribution and diving patterns suggest that they are able to exploit many different environments and can tolerate a wide range of habitat conditions in mid-summer through winter.

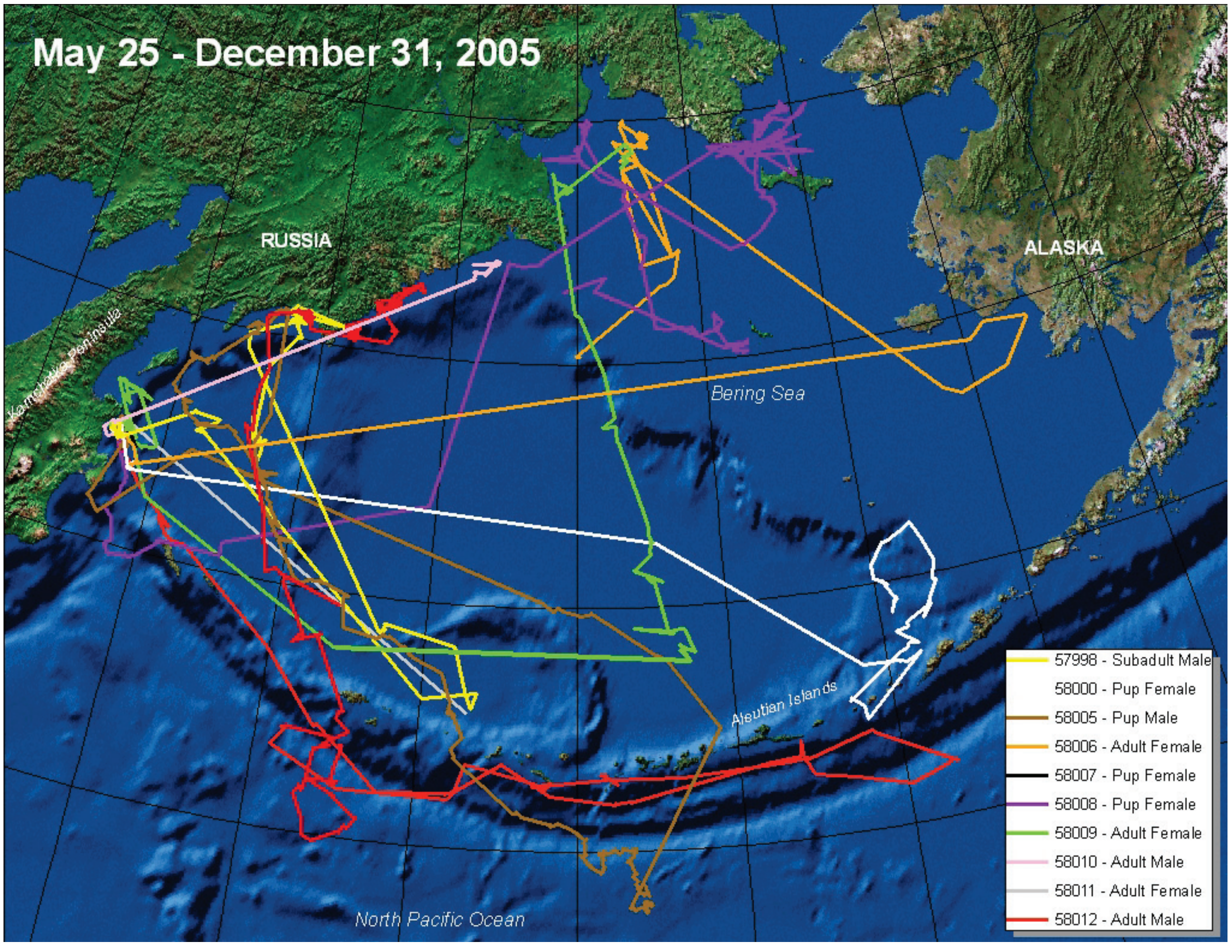

Figure 5. -- Movements of 10 satellite-tracked ribbon seals instrumented off the eastern coast of the Kamchatka Peninsula, Russia, in May 2005. The region was ice-free for much of the summer and fall, and all of the seals became pelagic, dispersing widely yet remaining in the Bering Sea and North Pacific Ocean during this time.

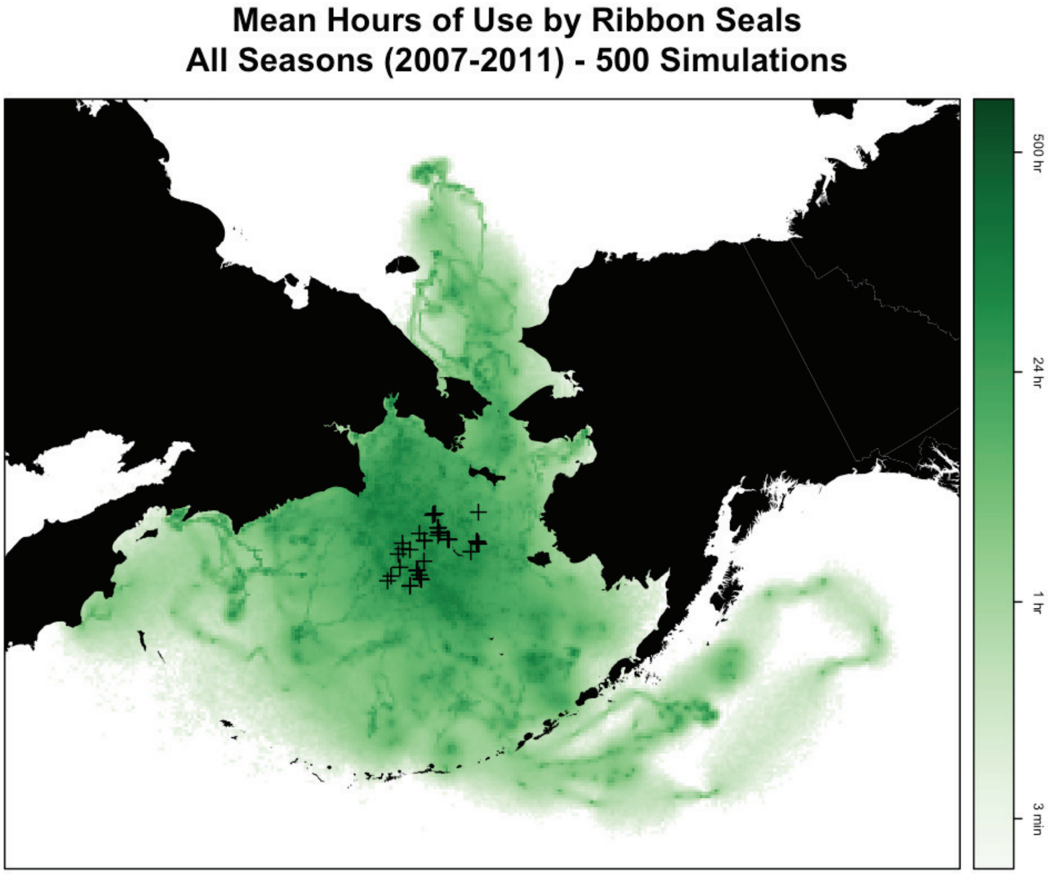

Figure 6. -- Estimated time budget for spatial use by ribbon seals breeding in the central Bering Sea, based on satellite telemetry of locations from 41 seals tagged in May and June of 2007-2010. The "+" symbols designate tagging locations.

2.5.1 Extralimital and Out-of-Habitat Occurrences

Individual ribbon seals are occasionally sighted along coasts of Asia and North America that are not considered to be a part of their normal range, or in unusual habitats within their range. A male ribbon seal, nearly hairless, came ashore near Morro Bay, California, in November, 1962, and was taken into captivity (Roest 1964). Observations of the seal's attempts to move across the concrete floor of a drained pool supported the notion that ribbon seals are poorly suited for motion on substrates that do not allow the hair on their bellies to slide freely.

An adult female ribbon seal stranded in a muddy field in northern Cook Inlet, Alaska, during October, 2007. The seal appeared to be molting (R. Andrews, Alaska SeaLife Center, October 9, 2007, pers. comm.).

A ribbon seal was observed and photographed hauled out on ice calved from a glacier in Tracy Arm, southeast Alaska, in July 2011 (L. Burback, Expeditions.com, July 27, 2011, pers. comm., via L. Jemison, Alaska Department of Fish and Game).

Several ribbon seals, mostly young and with hair loss or incomplete molt were observed in 2011-2012 along coasts of the main Japanese Island of Honshu, which is not normally frequented by the species (Y. Mitani, Hokkaido University, June 18, 2012, pers. comm.).

A young (~1 year old) ribbon seal with skin sores and no hair stranded alive at Yakutat, Alaska, in March 2012. Behavior and clinical symptoms, as well as necropsy findings after the seal was euthanized, were consistent with the case definitions of the Arctic Pinniped Unusual Mortality Event (UME) that was occurring at the time (NOAA and U.S. Fish and Wildlife Service 2012).

A young adult male ribbon seal was observed on several occasions between January and June 2012, hauled out on docks and decks in the inland waters (i.e., the Salish Sea) of Washington State and British Columbia, Canada, as well as the outer coast of Washington. This seal appeared to undergo a normal molt in about the same seasonal period as the molt of adult male ribbon seals in their natural habitat.

Ribbon seals are inconspicuous and seldom observed during most of their annual life history cycle, especially the pelagic phase when they tend to be far out at sea, not associated with sea ice, and presumably solitary. Because they do not haul out on shore as part of their normal behavior, the observations that are characterized as out-of-range or out-of-habitat are, not surprisingly, often of individuals that are ill or otherwise in poor condition. The observed symptoms frequently include pelage abnormalities that indicate a delayed or disrupted molt.

2.6 Life History

Female ribbon seals over the age of 4 or 5 typically give birth to a single pup each year (Tikhomirov 1964, Shustov 1965d, Burns 1981). Whelping in the Bering Sea and northern Sea of Okhotsk occurs over a period of about 5-6 weeks, ranging from late March to mid-May with a peak in early to mid-April (Tikhomirov 1964, Shustov 1965d, Burns 1981), perhaps with some annual variation related to weather and ice conditions (Burns 1981). The timing of whelping in the southern Sea of Okhotsk and Tartar Straight is not known, but may occur earlier, during March-April (Tikhomirov 1966). Pups are nursed for 3-4 weeks, during which time their weight may triple from about 9.5 to 28.5 kg (Tikhomirov 1968, Burns 1981). Mothers continue to feed during lactation, sometimes leaving their pups unattended on the ice while diving. Males are typically absent during this period as well. Most pups are weaned by mid-May, which occurs when the mother abandons the pup (Tikhomirov 1964). By that time, pups are obese and appear to be poor swimmers, having difficulty diving due to their high percent body fat (Burns 1981). During their initial 2-3 weeks of independence, pups survive off their fat reserves, losing about 10-20% of their body weight while gradually increasing their proficiency at diving and feeding (Tikhomirov 1968, Burns 1981). Pups appear to be proficient swimmers by the time the sea ice melts in mid-June in the Bering Sea (Burns 1981).

Breeding occurs shortly after weaning, typically peaking at the end of April to early May (Tikhomirov 1964, Shustov 1965d, Burns 1981). Ribbon seals in the southern Sea of Okhotsk may breed earlier (Tikhomirov 1966), and females that are breeding for the first time or that did not have a successful pregnancy the previous year may mate outside of this time range (Burns 1981). Little is known about the mating act, but males are presumed to be polygynous (Shustov 1965d). Nearly all females (90% or more) are sexually mature by age 3 (Shustov 1965d, Fedoseev 1973) or age 4 (Tikhomirov 1966, Burns 1981), while most males become sexually mature at age 4 (Shustov 1965d, Fedoseev 1973) or age 5 (Tikhomirov 1966, Burns 1981). Fedoseev (1973) reported that ribbon seals in the Sea of Okhotsk have a higher growth rate, and mature earlier than their Bering Sea counterparts, with 11% of females and 25% of males becoming sexually mature in their first and second years, respectively. Similar to other pinnipeds, ribbon seals delay implantation of the blastocyst for about 2.5 months after fertilization (Krylov et al. 1964). Gestation lasts another 8.5 months so the total pregnancy (from mating to birth) lasts about 11 months.

Ribbon seals molt their coat of hair each year between late March and July, with the timing of an individual’s molt depending upon its age and reproductive status (Burns 1981). Subadult seals (ages 1 to about 4) molt first, beginning in late March and finishing by mid-May (Tikhomirov 1964, Burns 1981). Newborn pups molt next, mostly during late April to early May, or about 3 to 5 weeks after birth (Tikhomirov 1964, Heptner et al. 1976, Burns 1981). Heptner et al. (1976) suggested that the duration of an individual pup’s molt lasts about 1 week; the molt duration for individuals of other age classes is unknown. Sexually mature seals begin molting around the time of mating, in late April to early May (Tikhomirov 1961, Krylov et al. 1964, Tikhomirov 1964, Heptner et al. 1976, Burns 1981), although some non-reproductive adult males may begin molting earlier (Tikhomirov 1964). Based on observations during one expedition to the Bering Sea in 1962, Tikhomirov (1964) judged that molting was most intensive for adult males between May 20 and June 10, while adult females had peak molting between June 1 and 20. The molt timing has not been confirmed to that level of detail in subsequent studies. The physiological process of molting and regrowing new hair is facilitated by elevated skin temperatures (Feltz and Fay 1966), so seals spend more time hauled out on the ice and perhaps reduce their feeding during this time, resulting in a loss of body weight. The completion of the adult molt, which may extend to mid-July (Tikhomirov 1961), normally coincides with the melting of sea ice in the Bering Sea (Burns 1981). Figure 7 summarizes the approximate annual timing of the ribbon seal’s ice-associated life history events, and the approximate duration of each event for an individual seal.

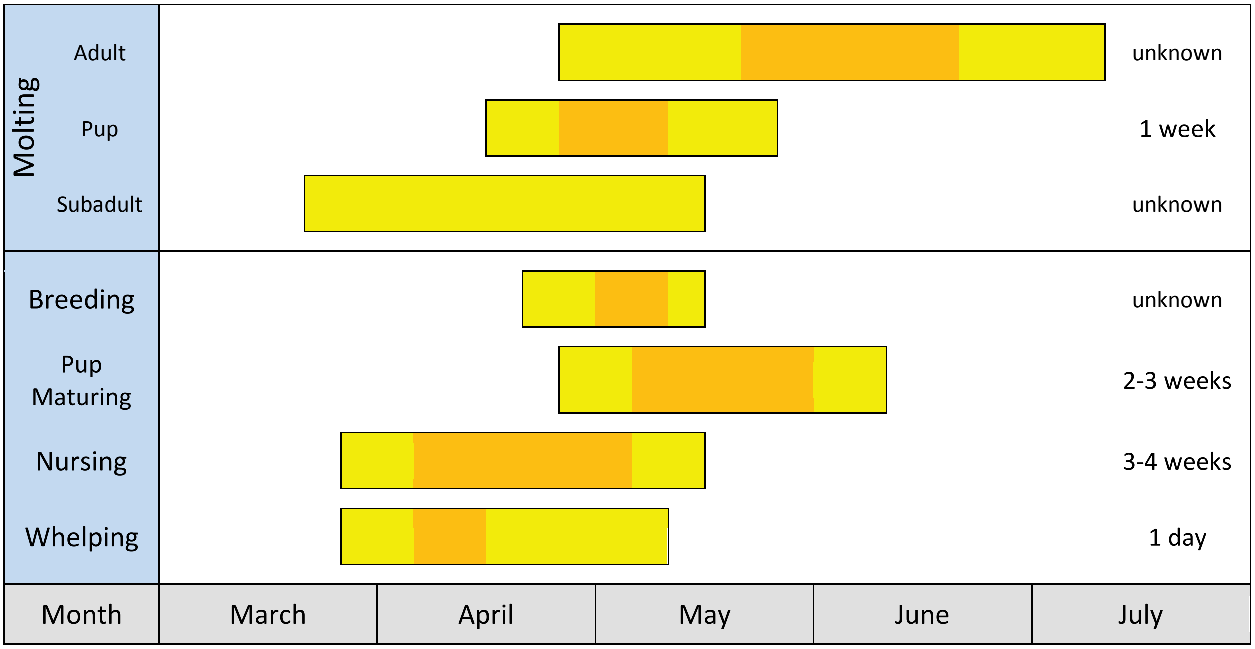

Figure 7. -- Approximate annual timing of ribbon seals' ice-associated life history events. Yellow bars indicate the range over which each event is reported to occur and orange bars indicate the reported peak timing of each event. "Pup Maturing" refers to the period when weaned pups may remain at least partially dependent on sea ice while they develop proficiency at diving and foraging for themselves. The approximate duration of each event for an individual ribbon seal is listed along the right side of the figure (Sources: Krylov et al. 1964, Tikhomirov 1964, Shustov 1965d, Tikhomirov 1966, Fedoseev 1973, Heptner et al. 1976, Burns 1981).

Recent studies of individual ribbon seal haul-out patterns by satellite telemetry have begun to support and add detail to the timeline reported in the literature, which has of necessity been derived primarily from natural history observations of a cross-section of the population. Haul-out records from 20 ribbon seals tagged with satellite-linked data recorders (SDRs) are shown in Figure 8. Although they are based on small samples within age classes, and must be interpreted with consideration for potential biases from the timing of the duty cycle and the type of tag (i.e., flipper-mounted SPOT5 tags vs. back- or head-mounted SPLASH tags), several patterns are apparent that may have implications for ribbon seals' relationship with sea ice. There was a period of nearly continuous haul out by adults that lasted about 2-3 weeks during mid-May to late June, seen most clearly in the center and right panels of Figure 8 where the records of seals carrying SPOT5 tags continued through a second and into a third molt season; this corresponds well to the reported peak of the adult molt (Figure 7). Although the sample size (n=2) is small for subadults in this figure, they seemed to complete their intensive haul-out bouts by early June. This is consistent with the reported patterns, at least with regard to subadults molting earlier than adults. Finally, for most seals, the intensive haul-out bouts that were presumably associated with molting ended rather abruptly. This may signify that these seals began their pelagic period in response to reaching some physiological threshold rather than in response to deterioration of the ice floe on which they were hauled out; deterioration of ice might produce a more gradual or interrupted decrease in haul-out time as seals sequentially seek new intact floes on which to haul out.

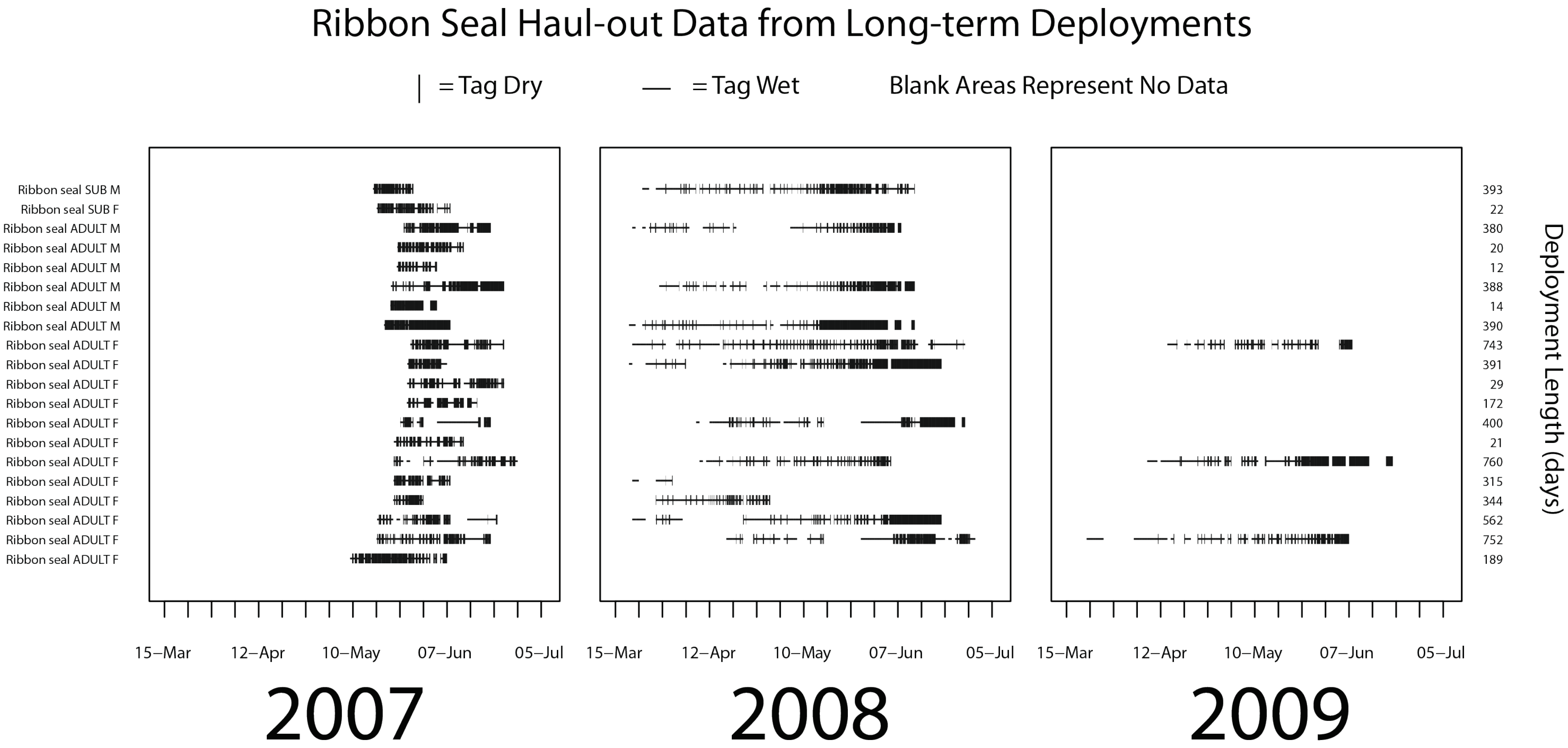

Figure 8. -- Haul-out records from 20 ribbon seals tagged with Argos satellite-linked data recorders in the central Bering Sea sea ice during spring 2007. Vertical hash marks denote haul-out (dry) time, thin horizontal lines denote time in the water, and the blank portions of each timeline indicate when no data were acquired. The age class (adult or subadult) at the time of tagging, and the sex of each seal is shown along the left edge of the figure.

2.7 Vital Parameters

Little information exists on the vital rates of ribbon seal populations. Most of the available data were collected by intensive Soviet commercial sealing operations during 1961-1965 and 1970-1971, which were supplemented by U.S. sampling efforts in 1967, and to a lesser extent, in the late 1970s (Lowry 1985). There are difficulties interpreting these data, however, due to the effects of potential age-biased sampling and possible effects of heavy exploitation on density-dependent parameters, such as productivity and mortality, which may have changed during the depletion and subsequent recovery of the stocks (Lowry 1985).

The sex ratio has been reported to be approximately 1:1 from birth throughout maturity (Shustov 1965d, Fedoseev 1973, Burns 1981). Based on samples from the western Bering Sea, Shustov (1969b) calculated natural mortality rates of about 40% for the first 2 years, 16.5% for ages 3-10, and 14.9% for ages 11-20. The author also reported that 28.5% of the sample were mature females, of which about 80% reproduce annually, resulting in a estimated gross annual production of about 23% (Shustov 1969b). Factoring in mortality rates, the cumulative mortality by age 4 was calculated to be 58.2%, which yields a net productivity of 9.5% (Kelly 1988). Believing that Shustov's analyses were biased, Fedoseev (1973) calculated his own estimates of mortality and productivity based on samples from the Sea of Okhotsk. Mortality was estimated to be about 45% for pups in their first year, which decreased to about 8-10% for adults annually, resulting in about 25% of the seals born surviving to sexual maturity at age 5 (Fedoseev 1973). Fedoseev's (1973) gross and net annual productivity estimates were 30% and 6%, respectively. The maximum net productivity for a pinniped with this type of life history is generally thought to be about 12% (Wade and Angliss 1997).

The normal lifespan of a ribbon seal is probably around 20 years, with a maximum of perhaps 30 years (Burns 1981). Of the approximately 2,500 seals aged by Shustov (1965d) and Burns (1969), less than 30 (1.2%) were older than 20 years (Burns 1981). The oldest seals in these samples were two 26-year-old females with pups; they showed no signs of old age and appeared to be well fed. Therefore, the author surmised that the maximum age of this species is somewhat higher than 26 years and that its capacity for reproduction does not diminish with age (Shustov 1965d).

Reproductive parameters, and particularly the age of maturation, may change in response to foraging conditions; good foraging leads to rapid growth and good body condition, which in turn is typically associated with more rapid maturation in mammals. Quakenbush and Citta (2008) found that female ribbon seals harvested in the 1960s, 1970s, and 2000s matured (i.e., first ovulated) at 1-5 years of age. The average age of 13 females that had ovulated once was 2.2 years, suggesting relatively rapid maturation. Quakenbush and Citta (2008) also found that ribbon seals harvested in the 1970s had longer age-specific body length (i.e., faster growth) than seals harvested in the 1960s and 2000s. Body condition assessed by a blubber volume index was suggestive of the same pattern, but condition in the 1970s was not significantly different than in the 2000s. Pregnancy rates were high in their samples, 95% on average. Overall, it appears that ribbon seals have had generally good conditions in the central Bering

Sea during the past several decades. The number of samples collected in the 2000s was relatively small, limiting the power to detect any recent changes that may have occurred.

2.8 Feeding Habits

The year-round food habits of ribbon seals are not well known, in part because almost all information about ribbon seal diet is from the months of February through July, and particularly March through June (Arsen'ev 1941, Wilke 1954, Shustov 1965c, Fedoseev and Bukhtiyarov 1972, Nikolaev and Skalkin 1975, Frost et al. 1977, Lowry et al. 1979, Frost and Lowry 1980, Burns 1981, Lowry 1985, Deguchi et al. 2004, Ziel et al. 2008). No diet samples have been collected for ribbon seals from either the Bering Sea or Sea of Okhotsk during the ice-free period (Shustov 1965c), and only two stomach samples have been collected during mid-winter (Burns 1981). Ribbon seals must feed intensively during the ice-free and winter months, and although there are very few data, Lowry (1985) suggests that diet during these months is based on the distribution of seals and their potential prey. Therefore, it is likely that pelagic and demersal species such as walleye pollock (*Theragra chalcogramma*), eelpouts (Zoarcidae), and cephalopods are major prey items at these times (Lowry 1985). These are also major prey items during the spring, so it is presumed they forage for similar prey during winter (Burns 1994). The two stomach samples collected from mid-winter contained walleye pollock and Arctic cod (*Boreogadus saida*) (Burns 1981).

Another reason for the lack of information is that in most diet studies of ribbon seals, the majority of stomachs collected were empty (Arsen'ev 1941, Shustov 1965c, Nikolaev and Skalkin 1975, Frost et al. 1977, Lowry et al. 1979, Frost and Lowry 1980, Deguchi et al. 2004, Dehn et al. 2007). At first it was thought that ribbon seals did not feed at all while on the ice in the late spring, but then many seals were collected with food remains in the intestines and fecal matter packed in the rectum (Heptner et al. 1976). However, feeding may be reduced during the spring months when seals are hauled out on the ice for whelping, breeding, and molting (Arsen'ev 1941, Shustov 1965c, Burns 1981, Lowry 1985) and most stomach samples have been collected during these times. One study found that seals taken later in the months of February-April had a higher frequency of empty stomachs than seals taken earlier (Deguchi et al. 2004). Ribbon seals increase the time spent on the ice when they begin whelping at the end of March to early April (Heptner et al. 1976, Burns 1981). In a study that collected seals from March through July, empty stomachs were found consistently throughout the 5 months (Shustov 1965c). Shustov (1965c) also found remains of prey more frequently in stomachs from seals killed in the water than in seals killed while on the ice.

Ribbon seals primarily consume pelagic and nektobenthic prey, including demersal fishes and cephalopods (Arsen'ev 1941, Shustov 1965c, Burns 1971, Ziel et al. 2008). Ribbon seals generally eat pelagic prey species, but they get them from great depths (Arsen'ev 1941). Shustov (1965c) suggested ribbon seals feed mostly on nektobenthic prey in areas between bearded and ringed seal foraging locations, claiming that ribbon seals are more agile than bearded seals, which feed on the ocean floor, but not as mobile as ringed seals so they cannot feed solely on pelagic forms of fish and crustaceans.

Deguchi et al. (2004) suggested that ribbon seals may have the ability to dive to greater depths than spotted seals and typically forage in deeper water, because spotted seal prey items more frequently included shallow water fishes from the continental shelf. The size of walleye pollock in stomachs of ribbon seals from Nemuro Strait indicated that the seals were likely foraging on spawning groups, which are found in the mid-level water layer (200-400 m) on the continental shelf, and the larger size of magistrate armhook squid in stomachs indicated they were at the bottom layer of the continental slope (Deguchi et al. 2004). These findings suggest that ribbon seals usually forage in deeper water, at the intermediate-bottom layer of the continental shelf (Deguchi et al. 2004). In another study, Dehn et al. (2007) measured $\delta^{13}C$ levels, which can indicate spatial habitat use and carbon sources. Mean $\delta^{13}C$ in ribbon seals was similar to ringed and spotted seals that feed pelagically, and was significantly lower than in bearded seals which are benthic feeders. This supports the suggestion of Burns (1970) that ribbon seals become pelagic during ice-free months and that they feed in the pelagic and demersal zones.

Table 1 contains a complete list of prey items that have been found in ribbon seals or their scats (feces). Walleye pollock is a primary prey item, at least during spring, in both the Bering Sea (Frost et al. 1977, Lowry et al. 1979, Frost and Lowry 1980, Ziel et al. 2008) and the Sea of Okhotsk (Arsen'ev 1941, Wilke 1954, Shustov 1965c, Fedoseev and Bukhtiyarov 1972, Bukhtiyarov 1990, Deguchi et al. 2004). Other fish prey species found in multiple studies were Arctic cod, Pacific cod (*Gadus macrocephalus*), saffron cod (*Eleginus gracilis*), Pacific sand lance (*Ammodytes hexapterus*), smooth lumpsucker (*Aptocyclus ventricosus*), eelpouts, capelin (*Mallotus villosus*), and flatfish species (Arsen'ev 1941, Shustov 1965c, Frost et al. 1977, Lowry et al. 1979, Frost and Lowry 1980, Burns 1981, Bukhtiyarov 1990, Deguchi et al. 2004, Dehn et al. 2007). Cephalopods are also important prey for ribbon seals throughout their range; several species of both squid and octopus make up a significant part of ribbon seal diets (Arsen'ev 1941, Wilke 1954, Shustov 1965c, Fedoseev and Bukhtiyarov 1972, Frost et al. 1977, Lowry et al. 1979, Frost and Lowry 1980, Bukhtiyarov 1990, Deguchi et al. 2004). Deguchi et al. (2004) determined that walleye pollock and magistrate armhook squid were the first and second most important prey items, respectively, for ribbon seals in Nemuro Strait. They also examined diet differences among three developmental classes of seals (young: ages 1-2, subadult: ages 3-6, and adult: ages 7+). Walleye pollock and magistrate armhook squid were the two most important prey items among all three age classes, but subadults and adults consumed more walleye pollock and less squid than young seals (Deguchi et al. 2004). However, Deguchi et al. (2004) also suggested that the importance of some fishes, such as lanternfishes (Myctophidae) and northern smoothtongue (*Leuroglossus schmidti*), may be underestimated because they have smaller, more delicate otoliths that are more likely to erode and become unidentifiable than walleye pollock otoliths, which resist erosion well. Lowry et al. (1979) found that stomachs were mostly empty, but suggested that crustacean remains could have been digested and excreted prior to examination because the few stomach contents they did find mainly consisted of hard parts (otoliths, bones, beaks). Other studies have found that crustaceans are an important part of the ribbon seal’s diet (Arsen'ev 1941, Wilke 1954, Shustov 1965c, Fedoseev and Bukhtiyarov 1972, Frost and Lowry 1980, Burns 1981, Bukhtiyarov 1990, Dehn et al. 2007).

Table 1. -- Prey species found in ribbon seal stomachs or feces.

Species	Common Name	Source(s)[a]
FISHES		
Clupeidae		
Clupea pallasii	Pacific herring	3, 12
Bathylagidae		
Leuroglossus schmidti	northern smooth-tongue	10
Lipolagus ochotensis	popeye blacksmelt	10
Osmeridae		
Mallotus villosus	capelin	1, 3, 6, 7
Osmerus mordax	rainbow smelt	3, 9
Notosudidae		
Scopelosaurus harryi	scaly waryfish	10
Myctophidae		
Lampanyctus jordani	brokenline lanternfish	10
Nannobrachium regale	pinpoint lanternfish	10
Gadidae		
Boreogadus saida	Arctic cod	3, 7, 8, 11, 12
Eleginus gracilis	saffron cod	3, 4, 7, 9, 10
Gadus macrocephalus	Pacific cod	1, 3, 10, 12
Theragra chalcogramma	walleye pollock	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12
unidentified spp.	unknown gadid	12
Cottidae		
unidentified spp.	sculpin	7
Agonidae		
unidentified spp.	poacher	7
Cyclopteridae		
Aptocyclus ventricosus	smooth lumpsucker	1, 3
Liparidae		
unidentified spp.	snailfish	7
Zoarcidae		
Bothrocarina microcephala	silvery eelpout	10
Lycodes sp.	eelpout	5, 6, 7, 12
Stichaeidae		
Anisarchus medius	stout eelblenny	3

Table 1. -- Continued.

Species	**Common Name**	**Source(s)**[a]
unidentified spp.	prickleback	7
Pholidae		
Pholis sp.	gunnel	8
Ammodytidae		
Ammodytes hexapterus	Pacific sand lance	3, 9
Pleuronectidae		
Reinhardtius hippoglossoides	Greenland halibut	7
Hippoglossoides robustus	Bering flounder	12
unidentified spp.	flatfish	6, 9
Bothidae		
unidentified spp.	flatfish	6
Unknown family		
unidentified spp.	unknown fish	9
CEPHALOPODS		
Onychoteuthidae		
Onychoteuthis borealijaponica	boreal chubhook squid	10
Gonatidae		
Berryteuthis magister	magistrate armhook squid	1, 10
Gonatus berryi	berry armhook squid	10
Gonatus middendorffi	gonatid squid	10
Gonatus pyros	photogenic gonate squid	10
Gonatus sp.	gonatid squid	9
Ommastrephidae		
Ommastrephes sp.[b]	unknown squid	1
Octopodidae		
Octopus sp.	unknown octopus	4, 5, 6, 7, 9
Unknown family		
unidentified spp.	unknown cephalopod	1, 2, 3
CRUSTACEANS		
Mysidacea		
Stilomysis grandis	mysid	3
Euphausiacea		
Thysanoessa raschii	Arctic euphausiid	9

Table 1. -- Continued.

Species	Common Name	Source(s)[a]
unidentified spp.	unknown euphausiid	12
Amphipoda		
Themisto sp.	hyperiid amphipod	3
Decapoda		
Pandalidae		
Pandalus borealis	northern shrimp	3
Pandalus goniurus	humpy shrimp	1, 3, 9
Pandalus tridens	yellowleg pandalid	11
Pandalus sp.	pandalid shrimp	8, 9
Pandalopsis sp.	pandalid shrimp	3
Hippolytidae		
Eualus gaimardii	circumpolar eualid	3
Spirontocaris murdochi	murdoch blade shrimp	3
Lebbeus sp.	hippolytid shrimp	3
Crangonidae		
Crangon dalli	ridged crangon	1, 3
Neocrangon communis	twospine crangon	11
Sclerocrangon sp.	crangonid shrimp	8
Nectocrangon lar	crangonid shrimp	3
Oregoniidae		
Hyas coarctatus	Arctic lyre crab	9
Unknown family		
unidentified spp.	unknown decapod	9
unidentified spp.	unknown crustacean	4, 7
OTHER		
Nuculana sp.[c]	small clams	7

[a] Sources: (1) Arsen'ev 1941, (2) Wilke 1954, (3) Shustov 1965c, (4) Fedoseev and Bukhtiyarov 1972, (5) Frost et al. 1977, (6) Lowry et al. 1979, (7) Frost and Lowry 1980, (8) Burns 1981, (9) Bukhtiyarov 1990, (10) Deguchi et al. 2004, (11) Dehn et al. 2007, (12) Ziel et al. 2008.

[b] Unlikely, do not occur in the Bering Sea (B. Walker, NMML, December 6, 2007, pers. comm.).

[c] Probably not directly eaten by ribbon seals but were present in eelpouts which the seals consumed.

Frost and Lowry (1980) found that ribbon seal food habits varied by geographic location in the Bering Sea. They examined food habits in the south-central, central, and northern Bering Sea by collecting and examining stomach samples from the different locations. They used number of fish and estimated weights of prey to determine importance of prey items. Based on both number of fish and estimated fish weight, walleye pollock were the major prey in the south-central Bering Sea. In the central Bering Sea, walleye pollock were the major prey based on numbers found; however, based on estimated weight, eelpouts were the major prey in the central Bering Sea. In the northern Bering Sea, based on both number and estimated weight, Arctic cod were the major prey. Walleye pollock were also consumed by ribbon seals in the northern Bering Sea but were not the major prey. Most prey species identified in this study were found in more than one location, but only walleye pollock occurred in stomachs from all three locations. Cephalopod beaks were also present in many samples, but Frost and Lowry (1980) believed cephalopods may have been underrepresented in stomach samples examined. Also, they did not estimate the importance of soft-bodied invertebrates in the diet because prey remains in the stomach and intestines were mostly composed of hard parts, reflecting rapid digestion of certain tissues and prey species.

Several studies have indicated that young ribbon seals primarily consume small crustaceans (Popov 1982, Lowry 1985). Fedoseev (2002) stated that first year ribbon seals eat mostly euphausiids and one- to two-year-olds mainly eat shrimp. Arsen'ev (1941) suggested that young seals may eat crustaceans after they are weaned and begin to feed independently; then as they mature, they switch to prey items characteristic of adults. He found two stomachs that only contained pandalid shrimp, and one of these seals was young. Shustov (1965c) determined that, in the Bering Sea, stomachs from young seals (up to age 1) contained mysids, tiny crabs, and small shrimps. He also noted this trend in the Sea of Okhotsk and suggested that younger animals cannot dive as deep as adults. Bukhtiyarov (1990) collected samples from the Sea of Okhotsk and found that pups only had Arctic krill (*Thysanoessa raschii*) in their stomachs. He concluded that between age 1 and 2, ribbon seals preferred *Pandalus* shrimp, young saffron cod, and young walleye pollock; whereas, older seals mostly consumed saffron cod, walleye pollock, and squid (Bukhtiyarov 1990). Dehn et al. (2007) used both stomach contents and stable isotope analysis to examine food habits in ribbon seals. Only 2 of the 37 ribbon seals they collected contained stomach contents. They found that $\delta^{15}N$ was positively correlated with age in ribbon seals, which indicates that trophic level of prey species increases with increasing age. This result supports previous studies, based on stomach contents analysis, which concluded pups and juveniles mainly feed on small crustaceans and adults primarily consume fish and nektobenthos, like walleye pollock and cephalopods (Heptner et al. 1976, Lowry 1985, Bukhtiyarov 1990, Fedoseev 2002, Deguchi et al. 2004).

2.9 Historic and Current Abundance and Trends

Ribbon seal abundance estimates have been based on catch data from sealing vessels, aerial surveys (Table 2), and shipboard observations when seals are hauled out on the ice to whelp and molt. Russian estimates of Bering Sea abundance and trends were determined in the early 1960s from commercial catch data (Shustov 1965a). Aerial survey data were often inappropriately extrapolated to the entire area based on densities and ice concentration estimates without behavioral research to determine factors affecting habitat selection. Very few details of the aerial survey methods or data have been published, so it is difficult to judge the reliability of the reported numbers. No suitable behavior data have been available to correct for the proportion of seals in the water at the time of surveys. Recent research and monitoring efforts are just beginning to address these limitations.

Table 2. -- Ribbon seal abundance estimates (in thousands) from aerial surveys.

Year	Bering Sea	Sea of Okhotsk	Total	Sources
1963-64	80-90			Fedoseev 2000 (citing Shustov 1969a)
1968		116		Fedoseev 2000
1969	60-70	208	268-278	Fedoseev 2000, Fedoseev 2002
1969-70	60	140	200	Burns 1981 (citing Shustov 1972)
1974	95*	173	268	Fedoseev 2000
mid-70s	90-100			Burns 1981
1976	84*	201	285	Fedoseev 2000
1979	134*	449	583	Fedoseev 2000
1981		410		Fedoseev 2000
1986		508		Fedoseev 2000
1987	139*			Fedoseev 2000
1988		630		Fedoseev 2000
1989		445		Fedoseev 2000
1990		562		Fedoseev 2000

*western Bering Sea

The Soviet Union began ship-based commercial sealing efforts in the Sea of Okhotsk in the 1930s with no reported impact until the fleet was increased in the 1950s, and the catch increased to approximately 20,000 ribbon seals annually during the 1960s (Heptner et al. 1976). Following more than a decade of intensive harvesting, ribbon seal numbers in the Sea of Okhotsk were estimated to be 116,000 in 1968 (Fedoseev 2000). Sealing restrictions initiated in 1969 apparently had a positive effect on ribbon seal abundance as estimates in the Sea of Okhotsk were reported to have increased rapidly during the late 1970s and 1980s, peaking in 1988 at 630,000 seals (Fedoseev 2000) (Table 2). However, under the Soviet system there was likely little or no peer review of these surveys, there were only crude methods available for survey navigation and estimation of ice coverage, and therefore the results should be considered in the context of these uncertainties (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, October 3, 2008, pers. comm.).

The Soviet Union expanded commercial sealing to the Bering and Chukchi Seas in 1961 (Heptner et al. 1976, Burns 1981). Shustov (1975, cited in Fedoseev 2000), using a “bio-statistical method”, estimated the abundance of ribbon seals in the Bering Sea to be about 115,000-120,000 prior to the initiation of hunting. The number of Bering Sea ribbon seals declined noticeably throughout the decade due to overharvest by Soviet hunting (Burns 1981), dropping from an estimated 80,000-90,000 in 1963-1964 (Shustov 1969a, cited in Fedoseev 2000) to about 60,000-70,000 in 1969 (Fedoseev 2002). Following the initiation of sealing restrictions in 1969, ribbon seal abundance in the Bering Sea increased to about 90,000-100,000 by the mid-1970s (Burns 1981) and the only survey conducted during the 1980s put the abundance at about 140,000 in 1987 (Fedoseev 2000).

Off the coast of Hokkaido, Japan, ribbon seal numbers in early Japanese harvests were unremarkable, composing less than 1% of seals harvested in 1948 (Wilke 1954). More recent aerial surveys conducted in 2000 estimated between 2,000-3,000 ribbon seals in the southern Sea of Okhotsk off the coast of Hokkaido (Mizuno et al. 2002).

Aerial surveys were conducted in portions or all of the ice-covered Bering Sea east of the international date line by NMML in 2003 (Simpkins et al. 2003), 2007 (Cameron and Boveng 2007, Moreland et al. 2008, Ver Hoef et al. 2013), 2008 (Cameron et al. 2008), 2012 (Moreland et al. 2012), and 2013. The data from these surveys are currently being analyzed to construct estimates of abundance for the eastern and central Bering Sea from frequencies of sightings, ice distribution, and the timings of seal haul-out behavior. A provisional population estimate of 61,100 ribbon seals (95% credible interval 35,200-189,300) was derived from the surveys conducted in 2007 (Ver Hoef et al. 2013). Using restrictive assumptions, this number was scaled according to distributions of ribbon seal breeding areas in 1987, described by Fedoseev et al. (1988), to produce total Bering Sea estimates ranging from 121,000 to 235,000 (Appendix 1). Similar scaling based on a range-wide distribution presented by Fedoseev (1973) produced estimates of 143,000 for the Bering Sea, 124,000 for the Sea of Okhotsk, and 267,000 for the total-range (Appendix 1). If the 95% credible interval from our eastern and central Bering Sea estimate is carried through the area-scaling process, the total range-wide estimate could be as low as 154,000 or as high as 827,000.

Aerial surveys of the Bering Sea and Sea of Okhotsk were conducted by NMML and partner institutions from the Russian Federation during spring of 2012 and 2013. The surveys included many sightings of ribbon seals, and preliminary analyses suggest that the abundance estimates will likely be higher than those obtained in the more limited survey reported by Ver Hoef et al. (2013).

Within our range-wide estimate of 267,000, the Sea of Okhotsk component of about 124,000 is lower than all but one of the previous estimates for that region (Table 2), and dramatically lower than the most recent estimates from Russian surveys during 1979-1990, which ranged from 410,000 to 630,000 (Fedoseev 2000). This difference is more likely to reflect errors in the estimates than a population decline. Our estimate for the Sea of Okhotsk was derived from a recent density estimate in the Bering Sea, scaled by a very generalized distribution from the 1960s of seals in the Sea of Okhotsk. Our density estimate may simply not be applicable to the distribution, and vice versa. The relatively high Russian abundance estimates lack details about how they were obtained, and the Soviet-era system of monitoring commercially harvested species is widely acknowledged to have included strong positive biases. Lacking any data from the Sea of Okhotsk more recent than 1990, the BRT opted to use the smaller number.

The current population trend of ribbon seals cannot be determined from the time series of imprecise and potentially inaccurate abundance estimates. Other information that might support inference about trends includes observations by Alaska Native hunters and life history parameters estimated by sampling harvested ribbon seals.

Quakenbush and Sheffield (2007) interviewed 70 subsistence hunters from five Alaska Native villages about their traditional knowledge regarding seal ecology and hunting. When asked about trends in ribbon seal abundance, 24 respondents (34%) said that numbers had stayed the same since they began hunting, 12 respondents (17%) said that numbers had decreased, and 6 respondents (9%) said that numbers had increased. The remaining 28 respondents (40%) apparently did not offer an opinion. When asked about trends in ribbon seal distribution, the majority of the respondents (65%) said that they found ribbon seals in the same areas over the past several years. And when asked about the timing of the hunting season, the vast majority of the respondents (84%) said that they hunt ribbon seals at the same time of the year as they did in the past, which occurred during May-June in four villages and during October-November in two villages (Table 9 and Appendix B in Quakenbush and Sheffield 2007).

Quakenbush and Citta (2008) found evidence from ages and measurements of harvested ribbon seals that physical growth rates were higher in the 1970s than in the 1960s and since 2000. Body condition was also better in the 1970s than the 1960s, but not significantly different between either period, compared with the small samples obtained since 2000. There was also a tendency toward greater proportions of older seals in the harvests after 2000. Taken together, these patterns could reflect conditions that were conducive for population growth in the 1970s, perhaps because densities had been reduced by high Soviet harvest rates (Quakenbush and Citta 2008). The recent increase in the proportion of older adults could reflect increased adult survival rates or a decline in abundance driven by reduced reproduction. The reproductive parameters measured by Quakenbush and Citta (2008) did not favor either of these possible scenarios.

Considering all of the information available for assessing trends, the BRT concluded that the current trend cannot be determined, but that strong trends in the recent past seem unlikely. High rates of ribbon seal sightings in recent surveys, and reports from hunters that indicate stable or rising numbers, suggest that there has not been a recent dramatic decline.

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”.

Although the appropriate name and taxonomic placement of the ribbon seal genus has been debated (2.1), it is a monospecific genus and there have been no sub-species structure proposed in the scientific literature. Therefore, the species *Histriophoca fasciata* and any distinct population segments of it that may exist are listable species under the ESA.

3.1 Consideration of Distinct Population Segments

Under the ESA, a species division smaller than a subspecies may be afforded protection if it is a “distinct population segment.” The term “distinct population segment” (DPS) 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 ribbon seals merited delineation into DPSs. This analysis is described in the following sections.

3.2 Evaluation of Discreteness

Ribbon seals breed in two sub-Arctic seas: the Bering Sea and the Sea of Okhotsk[1]. Although Tikhomirov (1961) reported that no ribbon seals are seen in the Sea of Okhotsk after mid-July, and speculated that

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[1] We include amongst the ribbon seals of the Sea of Okhotsk, a small portion of the species that may breed in the contiguous waters of the northeast Sea of Japan and Tatar Strait (Figure 3).

they migrate to the Bering Sea during summer, it remains unclear whether mixing occurs between seals from the Sea of Okhotsk and Bering Sea breeding regions (Kelly 1988). Shustov (1965a) speculated that the Bering Sea and Sea of Okhotsk harbored separate populations of ribbon seals, based on the large distance from the southern margin of the Bering Sea ice and the Kurile Straits, where he thought that any mixing would be possible. This view was investigated by Shustov (1970) but Fedoseev (1973) indicated that craniometric differences found by Shustov between seals from the Bering Sea and Sea of Okhotsk could be explained by age differences in the samples, and there were no significant differences in other meristic characters between the two populations. Within the Bering Sea, samples from a central and an eastern breeding area were found not to differ in a suite of non-metrical skull characteristics (Fedoseev 1984), and the putative central and western Bering Sea breeding groups were not observed in the mostly continuous distribution of sightings reported by Braham et al. (1984). Within the Sea of Okhotsk, Fedoseev (1973) noted that no ribbon seals in a sample of 80 from the northern region were infected with any of the 11 species of helminthes found in seals farther south, along Sakhalin Island. Given the complexity of helminth life cycles and the limited scope of these data, it is not possible to infer enough about dispersal rates between these groups for defining population structure. In summary, no compelling evidence has been presented for demographically significant population structure within the ribbon seal breeding distribution. The topic would best be addressed by studies of genetic differentiation between samples collected during the breeding season. Only a small number of ribbon seals have been tested for genetic evidence of population structure, and none of the samples tested thus far is known to be associated with breeding areas in the Sea of Okhotsk. A high priority should be placed on obtaining an inventory of relevant samples available in existing collections, and facilitating a genetic analysis.

Lacking direct evidence such as genetic data on discreteness of ribbon seal populations, comparison of ribbon seal traits with those of related species may indicate the likelihood for population structure. In a study of Arctic and Antarctic seal species (that did not include ribbon seals), Davis et al. (2008) considered breeding habitat stability (fast ice vs. pack ice) and several life-history characteristics that might influence or reflect the geographic structure within a species: degree of natal site fidelity, geographically variable vocalizations, female gregariousness in breeding, and ability of males to limit access to females. They found no significant population structure among pack ice breeders (though fast ice also was not found to be a requisite for population structure). The degree of natal philopatry (fidelity to natal sites during breeding) is unknown for most ice-associated seals, including ribbon seals, but it seems obvious that it is a requirement for maintenance of geographic structure. Ribbon seals, at least the males, are vocal and have a moderate repertoire of stereotyped, narrowband calls, as do bearded, leopard (*Hydrurga leptonyx*), and Ross seals (*Ommatophoca rossii*) (Rogers 2003). Within this group, only bearded seals have been shown to have genetic population structure. Ribbon seals do not form dense breeding aggregations and females are solitary rather than gregarious. By the same token, their dispersed, low-density breeding distribution in shifting pack ice would seem to preclude males from limiting access to females, and would be expected to confound any tendency toward natal site fidelity (Davis et al. 2008). In summary, although the population structure of ribbon seals has not been evaluated by the most effective tools (genetic analysis), the life history characteristics of the species are not those typically associated with geographically structured populations.

Spotted seals, like ribbon seals, have major breeding grounds in both the Bering Sea and Sea of Okhotsk. NMFS designated those as separate DPSs in a recent status review and ESA listing determination (Boveng et al. 2009, National Marine Fisheries Service 2010). The two population segments were presumed to be discrete on the basis of an expectation that the Kamchatka Peninsula is an effective barrier between Bering Sea and Sea of Okhotsk breeding concentrations of spotted seals. The effectiveness of this geographical barrier was assumed to derive from spotted seals' affinity for ice during winter and spring, and from the fact that the seasonal ice does not extend south to the tip of the peninsula. Spotted seals that have been tracked by satellite have not moved far out of the ice field or off of the continental shelf, which would be necessary for substantial interchange between the two populations. Ribbon seals, in contrast, routinely move in deeper waters off the continental shelf and make very extensive forays throughout the Aleutian Basin and into the North Pacific Ocean. Ribbon seals tagged on the east coast of the Kamchatka Peninsula moved to the central Bering Sea and the west coast of Alaska, and ribbon seals tagged in the central Bering Sea made the reciprocal movement to the east coast of Kamchatka (Figure 5 and Figure 6). These extensive movements, including long forays away from the continental shelves, suggest that for ribbon seals, the effectiveness of the Kamchatka Peninsula as a geographical barrier to dispersal between the Bering Sea and Sea of Okhotsk is likely to be lower than it is for spotted seals.

Discreteness of a DPS may also be justified on grounds of international 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. Ribbon seals occur throughout a vast area of international waters and waters under the jurisdiction of the U.S., the Russian Federation, and the State of Alaska. The primary breeding locations are in the territorial seas and exclusive economic zones of the U.S. and the Russian Federation.

As detailed in Sections 4.2.2.1 and 4.2.4.3 , and 4.2.5.2.1.1.2, Russian Federation measures to assure protection from overexploitation and conservation of habitat for ribbon seals may be substantially different than those in the U.S. Although no significant commercial harvest of ribbon seals in Russia has been documented in recent years, likely due to poor commercial viability, the Russian Federation continued to set quotas for commercial harvests through 2009 and one member of the Russian Fisheries Agency proposed that a substantial new harvest could be viable for production of various substances that have not traditionally been obtained from seal harvests (Grachev 2006). Also, petroleum resources in the Sea of Okhotsk have been actively explored and developed recently, in much closer proximity to ribbon seal breeding habitat than current U.S. petroleum activities. The effectiveness of environmental laws and regulations for oil spill prevention and habitat restoration in the Sea of Okhotsk was not assessed by the BRT, but was assumed to be less effective than analogous laws and regulations in the U.S.

In summary, the BRT noted that the evidence in support of considering the Sea of Okhotsk and Bering Sea breeding populations of ribbon seals as discrete, is sparse and based primarily on delimitation 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. A delineation along international boundaries would divide the eastern and central Bering Sea (i.e., U.S.) portion of the ribbon seal range from the western Bering Sea and Sea of Okhotsk (i.e., Russian) portion; this would place the division within the Bering Sea, where the distribution of ribbon seal breeding areas appears to be continuous, and where ribbon seals move routinely without regard to the boundary. Scientific evidence for actual biological discreteness of the two populations is weak or equivocal.

3.3 Evaluation of Significance

3.3.1 Persistence in an Unusual or Unique Ecological Setting?

The ecological settings of ribbon seals in the Sea of Okhotsk and Bering Sea are similar to one another, with no conspicuous aspects of uniqueness, at least during the period for reproduction and molting. In both seas, ribbon seals overlap with bearded, ringed, and spotted seals, and the ribbon seal niche is not known to be appreciably different between the Sea of Okhotsk and Bering Sea, relative to the niches of the other three seal species. When the seasonal ice recedes, Bering Sea breeders disperse to the Gulf of Alaska, the North Pacific, the Chukchi Sea, and the Arctic Ocean. The summer-autumn distribution of Sea of Okhotsk breeders has not been adequately determined, but may include the Sea of Japan, North Pacific Ocean, and Bering Sea. Thus, during the non-ice-associated summer and autumn period, ribbon seals from the two sea basins may face different ecological settings, but it has not been determined whether there is any appreciable difference between them.

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

Loss of either the Okhotsk or Bering segment of the ribbon seal population would result in a significant reduction in the range of the species. This reduction would not constitute a “gap” *per se*, as the breeding range does not currently extend to the east of the Sea of Okhotsk nor to the west of the Bering Sea.

3.3.3 Population Segment is the Only Surviving Natural Occurrence?

Neither of the two segments under consideration for designation as DPSs could be considered to be the sole surviving naturally occurring unit of the population. Both segments are naturally occurring and the species is thought to inhabit its entire historic range.

3.3.4 Segment Differs Markedly in Genetic Composition?

The genetic compositions of the ribbon seals in the Sea of Okhotsk and Bering Sea have not been determined. As detailed in 3.2, the reproductive habits and seasonal movements of ribbon seals are mostly not of a type that would be expected to be associated with strong genetic population structure.

3.4 Determination of Distinct Population Segments

Although there are differences between the United States and the Russian Federation in the control of exploitation, management of habitat, and regulatory mechanisms that influence conservation status, the BRT recommends not considering the Sea of Okhotsk and Bering Sea segments to be DPSs under the ESA on the basis of these differences. Delimitation by international boundaries is a weaker basis of population discreteness than one based in demography of the species. The two segments are not, or are not known to be ecologically unique or unusual. Loss of one segment or the other would not cause a gap in the range of the species, though it would constitute loss of a portion of the range that contributes substantially to the species' viability. The BRT has considered the Sea of Okhotsk and Bering Sea segments to compose a single "species" of ribbon seals for the assessment of extinction risk. However, in assessing extinction risk, the BRT considered whether any of the threats set forth below pose a risk to the species throughout all of its range or throughout any portions of the range that are considered important to the species' continued viability.

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 ribbon 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 the foreseeability of both the threats to the species and its 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, or a threat from petroleum development activities that may or may not take place, depending on many unpredictable economic and policy factors.

4.1.1 Factors in the Foreseeability of Threats to Ribbon Seals

The petition by the CBD to list ribbon seals cited global warming as the foremost concern, and others have speculated similarly that ribbon 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 ribbon 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 ribbon 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 IPCC 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, extent of 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 (SAT) 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, by the year 2100 depends strongly on the assumed scenario for emissions of CO_2 and other greenhouse gasses. 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) than are longer-term projections to the end of the century. Though low-frequency (i.e., decadal and multidecadal) natural variability is a factor, 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. 2007):

“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 original decision not to propose any listing for the ribbon seal (National Marine Fisheries Service 2008a).

In its review of the spotted seal, the NMFS recognized that the physical basis for some of the primary threats faced by the species had 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. Although there is considerable variation among scenarios in the GHG emissions and concentrations in the latter half of the 21st century, all six marker scenarios project substantial warming through the year 2100 (Figure 9). Therefore, the NMFS used the end of the 21st century as the time horizon when deciding to list the Southern DPS (i.e., Yellow Sea and Sea of Japan populations) of spotted seals as threatened (National Marine Fisheries Service 2009). In the risk assessment for ribbon seals that follows, the BRT similarly 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, while a few may make assumptions of reduced future emissions levels (e.g., resulting from a transition to cleaner fuels), 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 ribbon 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 ribbon seals under the ESA.

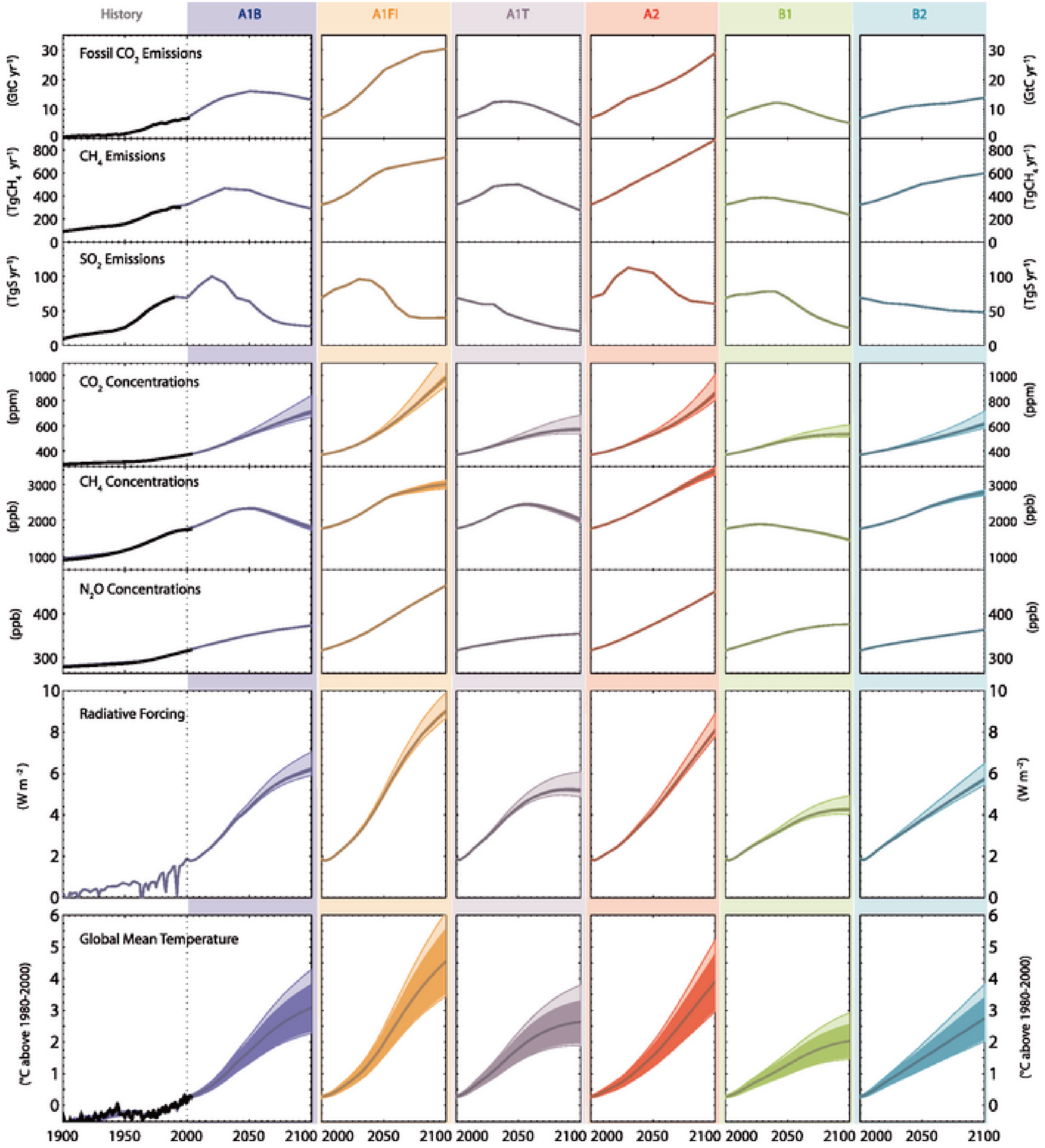

Figure 9. -- Greenhouse gas emissions, corresponding concentrations, radiative forcing, and global mean temperature projections for six illustrative emission scenarios. Source: Figure SPM.5 in IPCC (2007b).

4.1.2 Factors in the Foreseeability of Ribbon 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 ribbon seals to threats from a warming climate are in most cases 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, and vital rates) and uncertainty about the species' habitat requirements and resilience to the effects of climate change. As discussed in more detail in Sections 2.9 and 4.2.1.1.4, the data on size and trends of the populations are very imprecise, and there is very little information available to quantitatively link projected environmental conditions to ribbon seal vital rates of survival and reproduction. In our limited understanding of ribbon seal biology, there is no analog to the relatively well understood processes that link GHG emissions to warming. Projecting ribbon 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 ribbon seal population size is bounded above by the maximum growth rate that is feasible for the species' life history. 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 ribbon seals are likely to reach some threshold conservation status within a particular period of time. We must therefore rely upon the judgment of experts familiar with the natural history of the species and its evolutionary origins.

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 ribbon 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. Not all potential threats to ribbon seals are climate related, and therefore not all can be regarded as foreseeable through the 21st century. For example, 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 ribbon seals, but the time frame of forseeability of an inherently episodic and novel threat is difficult or impossible to establish. Similarly, factors that influence the magnitude and foreseeability of threats from oil and gas industry activities are inherently difficult or impractical to predict. These are only two examples of many potential threats without clear horizons of foreseeability. Therefore, although it is intuitive that foreseeability varies among threats facing ribbon seals, it is impractical to explicitly specify separate horizons of foreseeability for some of them (that is, there is no consensus among BRT members, let alone a broader community of scientists).

Faced with the challenge of applying the "foreseeable future" terminology of the ESA to a comprehensive scientific assessment of extinction risk, the BRT opted to evaluate threats and demographic risks on two time frames within the period defined by the horizon of foreseeability for the threats of primary concern, namely those stemming from greenhouse gas emissions: the period from now to mid-century, corresponding to the time over which the IPCC considers climate warming to be essentially determined by past and near-furture emissions, and the period from now to the end of the century, a period in which sustained warming is anticipated under all plausible scenarios, but the magnitude of that warming is more uncertain in the latter 50 years. Use of these two time frames was intended to provide a sense of how the BRT's judgment of all the threats and the level of certainty about those threats may vary over the period of foreseeability for climate-related threats.

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

Section 4(a)(1) 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

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. 2007; 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).

Our focus in this section is to assess the observed and projected changes with significant potential to impact the ribbon 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 ribbon seal prey species.

4.2.1.1.1 Effects of climate change on annual formation of ribbon seals' sea-ice habitat

Sea-ice extent at the end of summer (September) 2012 in the central Arctic Ocean was a record low, more than 50% below the long-term climatology and another 20% reduction from the previous record set in 2007 (a monthly mean ice extent of 3.41 vs. 4.3 million km^2 (Overland and Wang 2013)). Most of this loss was on the Pacific side of the Arctic. Arctic Ocean ice extent in the summer of 2007 was the second lowest on record. 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).

The Sea of Okhotsk and 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 ribbon 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 ribbon 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 the material for the first two parts is taken from Stabeno et al. (2012a).

4.2.1.1.1.1 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 mid-November 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.

4.2.1.1.1.2 Warm year analogs for future conditions

4.2.1.1.1.2.1 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 et al. 2012a). In contrast, sea-ice coverage in the Arctic and Bering Sea *can be* decoupled as occurred in fall 2007 through spring 2008.

In 2007, following a record minimum sea ice extent in the Arctic Ocean, the Chukchi Sea did not freeze until early December and the Bering Sea remained largely ice-free until the middle of December (Figure 10, 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 10, 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 10, 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. A similar example occurred in 2012, when the winter sea ice reached a record maximum extent in the Bering Sea that was followed by a new record minimum summer Arctic Ocean ice extent later in the same year.

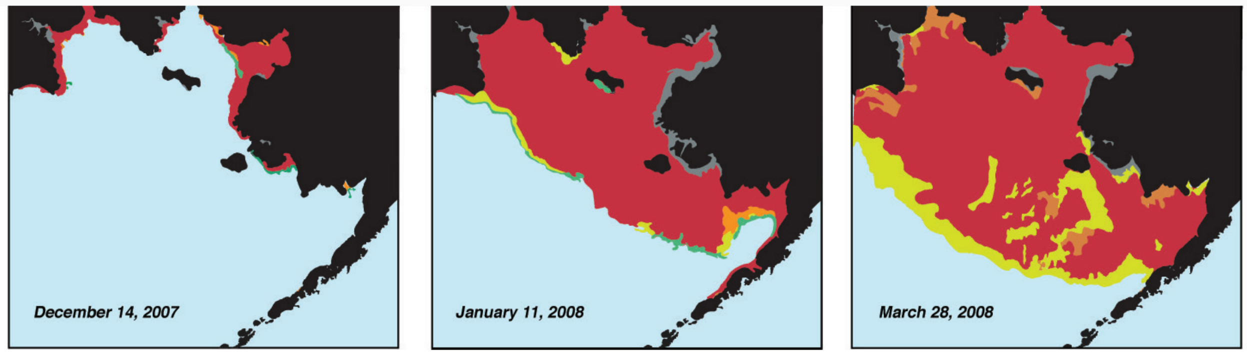

Figure 10. -- Sea ice extent in the Bering Sea on December 14, 2007; January 11, 2008; and March 28, 2008.

4.2.1.1.1.2.2 Sea ice in the northern Bering Sea in other years

Figure 11 shows the ice coverage, averaged within each year from December through May, in the southern (56.5-57.5°N), central (59.5-60.5°N), and northern (61.7-62.7°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 (red 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 (dark blue line), with variation mostly limited to a range of about 50-75% coverage.

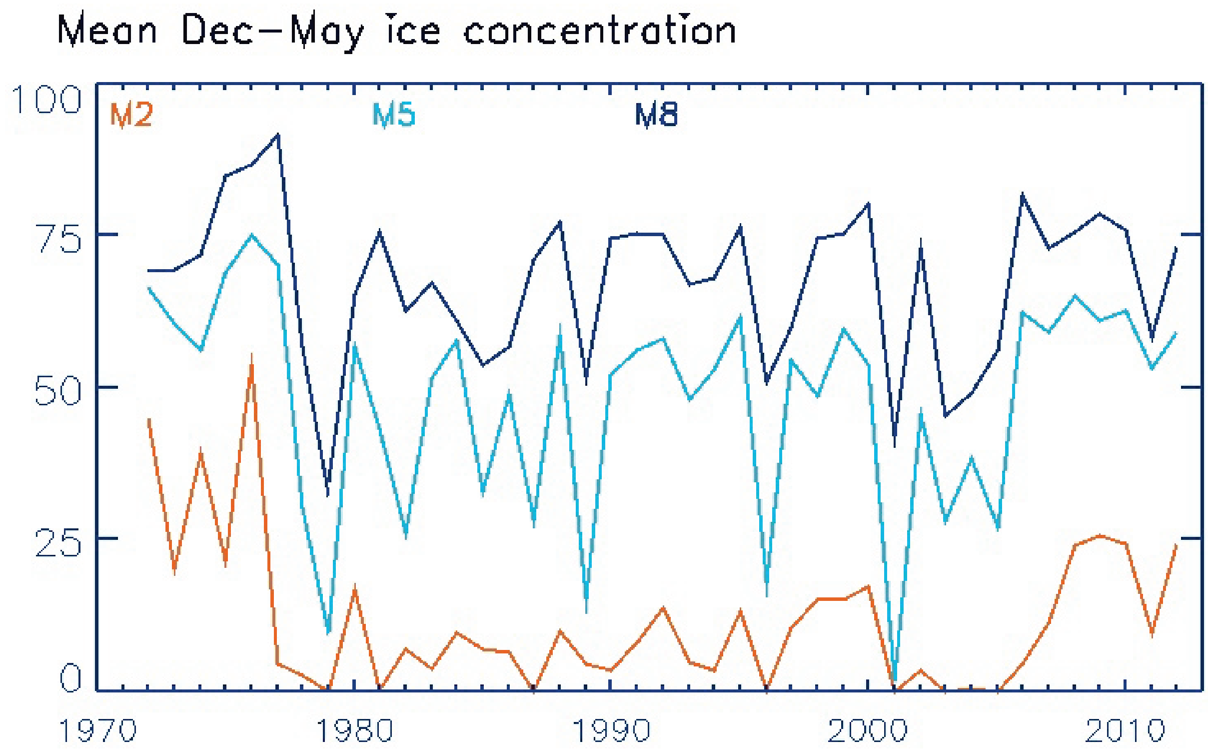

Figure 11. -- Percentage of ice coverage, averaged within each year from December through May, in the southern (red), central (light blue), and northern (dark blue) regions of the Bering Sea. Each region is a 100 km box around oceanographic moorings M2 (56.5-57.5°N, 165-163°W), M5 (59.5-60.5°N, 173-171°W), and M8 (61.7-62.7°N, 176-174°W) (Stabeno et al. 2012a). Compiled from a combination of weekly sea ice concentrations prior to 1979 (National Ice Center), and satellite observations from 1979 onward (SSMI; http://nsidc.org). Courtesy of S. Salo, NOAA Pacific Marine Environmental Laboratory, Seattle, WA.

4.2.1.1.1.3 IPCC model projections

Comprehensive Atmosphere-Ocean General Circulation Models (AOGCMs) are the major objective tools that scientists use to understand the complex interaction of processes that determine future climate change. The IPCC used the simulations from about two dozen AOGCMs developed by 17 international modeling centers as the basis for its *Fourth Assessment Report* (AR4) (IPCC 2007a). Regional projections from these models are also being used by management agencies to assess and plan for future ecological and societal impacts (e.g., Scenarios Network for Alaska Planning: http://www.snap.uaf.edu/home). The AOGCM results are archived as part of the Coupled Model Intercomparison Project-Phase 3 (CMIP3) at the Program for Climate Model Diagnosis and Intercomparison (PCMDI) at the Lawrence Livermore National Laboratory.

Since the publication of IPCC AR4, the modeling community has carried out more climate projection experiments, which constitute the Coupled Model Intercomparison Project-Phase 5 (CMIP5) in preparation for the upcoming *Fifth Assessment Report* (AR5) to be published by the IPCC in 2014. The outputs from those models are archived at the PCMDI as well. Although many more model runs were available to the community from CMIP5, a study by Knutti and Sedláček (2012) found that projected global temperature change from the new models is remarkably similar to that from the models used in

IPCC AR4 after accounting for the different underlying scenarios. The spatial patterns of temperature and precipitation change are also very consistent. The AR5 is not yet available as the summary evaluation and guidance for interpretation of the CMIP5 model outputs. Therefore, we used the modeling results from IPCC's AR4 in this report.

The IPCC's AR4 emphasizes that current generation AOGCMs provide credible quantitative estimates of future climate change at continental scales and above (IPCC 2007a). The CMIP3 models are improved over the models used for the *Third Assessment Report* (Randall et al. 2007, Reichler and Kim 2008). Climate researchers are also making use of the AR4 AOGCM simulations on regional scales (e.g., Walsh et al. 2008). The PCMDI shows over 1,100 projects and over 500 publications using CMIP3, most based on regional studies. The CMIP3 AOGCMs provide reliable projections, because they are built on well-known dynamical and physical principles, and they simulate quite well many large-scale aspects of present-day climate (Randall et al. 2007, Knutti et al. 2008). Further, some biases in simulated climate by different models can be unsystematic (Räisänen 2007, Jun et al. 2008). The coarse resolution of most current climate models certainly dictates careful application on small scales in heterogeneous regions such as along coastlines or regions of rugged topography. Our experience and that of other groups conducting model evaluations indicates the importance of multiple, complementary approaches.

There are three main contributors to the divergence in AOGCM climate projections: large natural variations, the range in emissions scenarios, and across-model differences (Hawkins and Sutton 2009). First, it is known that if climate models are run several times with slightly different initial conditions, the trajectory of day-to-day and indeed year-to-year evolution will have different timing of events, even though the underlying statistical-spectral character of the model climate tends to be similar for each run. This variability is a feature of the real climate system, and consumers of climate projections must recognize its importance. Natural variability is a source of ambiguity in the comparison of models with each other and with observational data. This variability can affect decadal or even longer term means, so it is relevant to the use of model-derived climate projections. The variability can be incorporated by averaging the projections over decades or, preferably, by forming ensemble averages from several runs of the same model.

A second source of variation in projections arises from the range in plausible emissions scenarios. Emissions scenarios have been developed based on assumptions for future development of humankind (Nakicenovic and Swart 2000); they are converted into greenhouse gases and aerosol concentrations, which are then used to drive the AOGCMs in the form of radiative forcing specified in the CMIP3 models, and summarized in the IPCC AR4. For this study, we used emission scenario A1B, a middle range case, which is also the closest to the CO_2 concentrations observed in the last decade, and A2, a high emissions scenario (IPCC 2000). Because of the residence time of carbon in the atmosphere and the thermal inertia of the climate system, climate projections are relatively insensitive to the choice of which future emissions scenarios are used over the next few decades. The impacts of the scenarios are rather similar before mid-21st century (Hawkins and Sutton 2009). For the second half of the 21st century, however, and especially by 2100, the choice of the emission scenario becomes the major source of variability among climate projections and dominates over natural variability and model-to-model differences (IPCC

2007a). If 2030-2050 is a timescale of interest, we will often use the A1B scenario—or A1B and A2 together—to increase the number of potential ensemble members as their CO_2 trajectories are similar before 2050.

The third source of variability is termed across-model uncertainty[2] (Knutti et al. 2008). Different numerical approximations of the model equations, spatial resolution, and other model development factors introduce structural uncertainty between different models. The potential for model bias introduces uncertainty. Because this bias is rarely systemic however, this uncertainty can be addressed and mitigated in part by using the ensemble means from multiple models (Overland et al. 2011).

There is no universal method for combining AOGCMs for climate projections (Gleckler et al. 2008, Räisänen et al. 2010), and there is no one best model. Our objective was to reduce the impact of models with large hindcast error. We culled the poor performing models—rather than selecting the best models—and retained several models as a measure of model variability.

4.2.1.1.1.3.1 Data and analytical methods

The CMIP3 model simulations were obtained from the PCMDI on-line at http://www-pcmdi.llnl.gov/. There are several sources of sea-ice data (i.e., observations) 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 15% in a grid cell.

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 12. 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).

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[2] Note that here we use “uncertainty” to refer to statistical measures of variation that should not be confused with the more general use of the term to refer to something that is unreliable or untrustworthy.

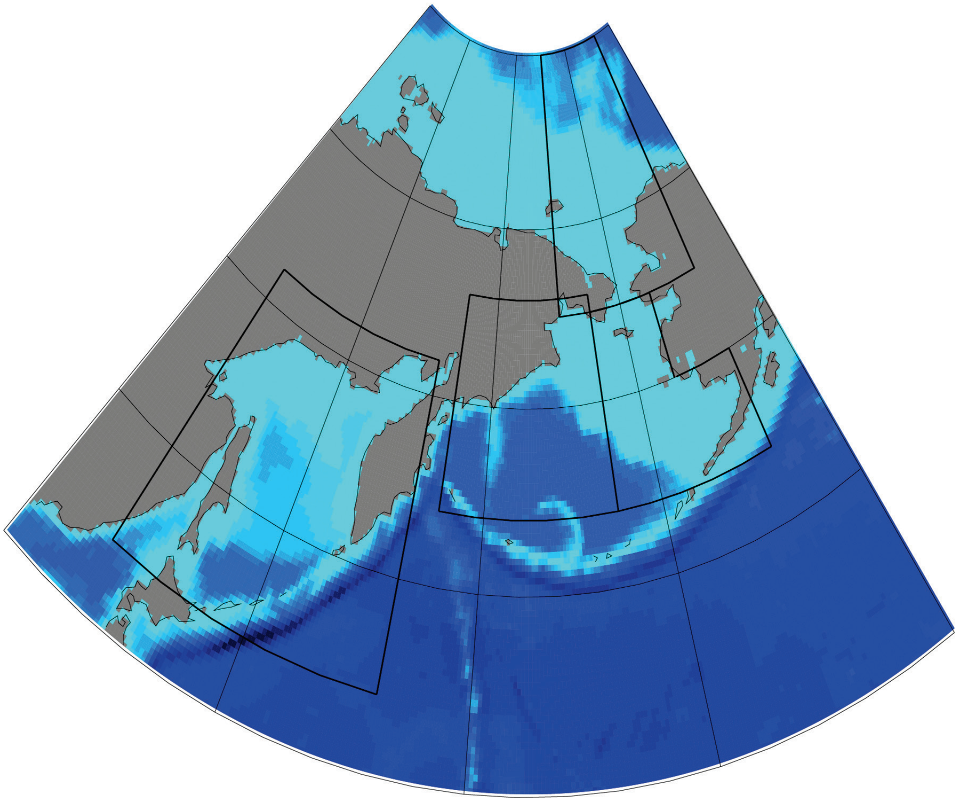


Figure 12. -- Boundaries of selected regions over the North Pacific and Arctic Oceans (from left): the Sea of Okhotsk, western Bering Sea, eastern Bering Sea, and the Chukchi Sea. Note that sea ice models performed poorly over the Sea of Okhotsk, and inference about future sea-ice extent was drawn from air temperature projections relative to the climatology of the recent past.

Because sea-ice conditions in the spring are important for ribbon seals (Section 2.6), 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; that is, the average of April and May sea-ice extent must be within 20% of the observed value.

4.2.1.1.1.3.2 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, 175-155°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 137-162°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.

Below we present our specific analysis for each of the selected regions. 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.

4.2.1.1.1.3.3 Chukchi Sea

The Chukchi Sea is located mostly north of the Arctic Circle, with its northern boundary adjoining the central 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 13). 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.

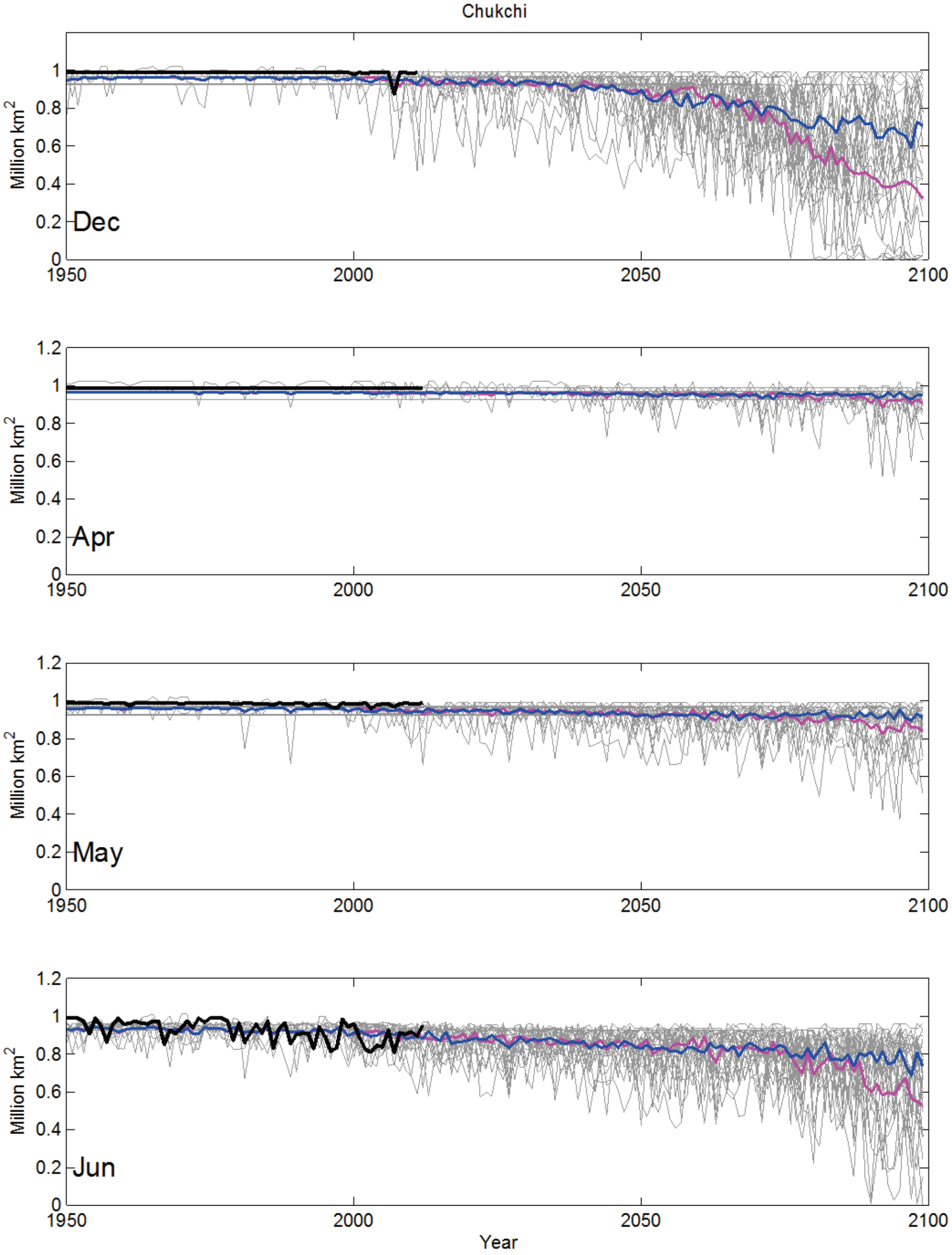


Figure 13. -- Model simulated sea-ice extent (in millions of km^2) over the Chukchi Sea for late autumn (December) and spring (April-June). The black lines (observations) are based on HadISST analysis, and the blue and magenta lines are the ensemble means of the six models (CCSM3, CNRM, ECHO-G, IPSL, MIROC(medres), and UKMO-Hadgem1) under the A1B and A2 emission scenarios, respectively. Each grey line represents one realization by one of these models.

4.2.1.1.1.3.4 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 14 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 autumn 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.

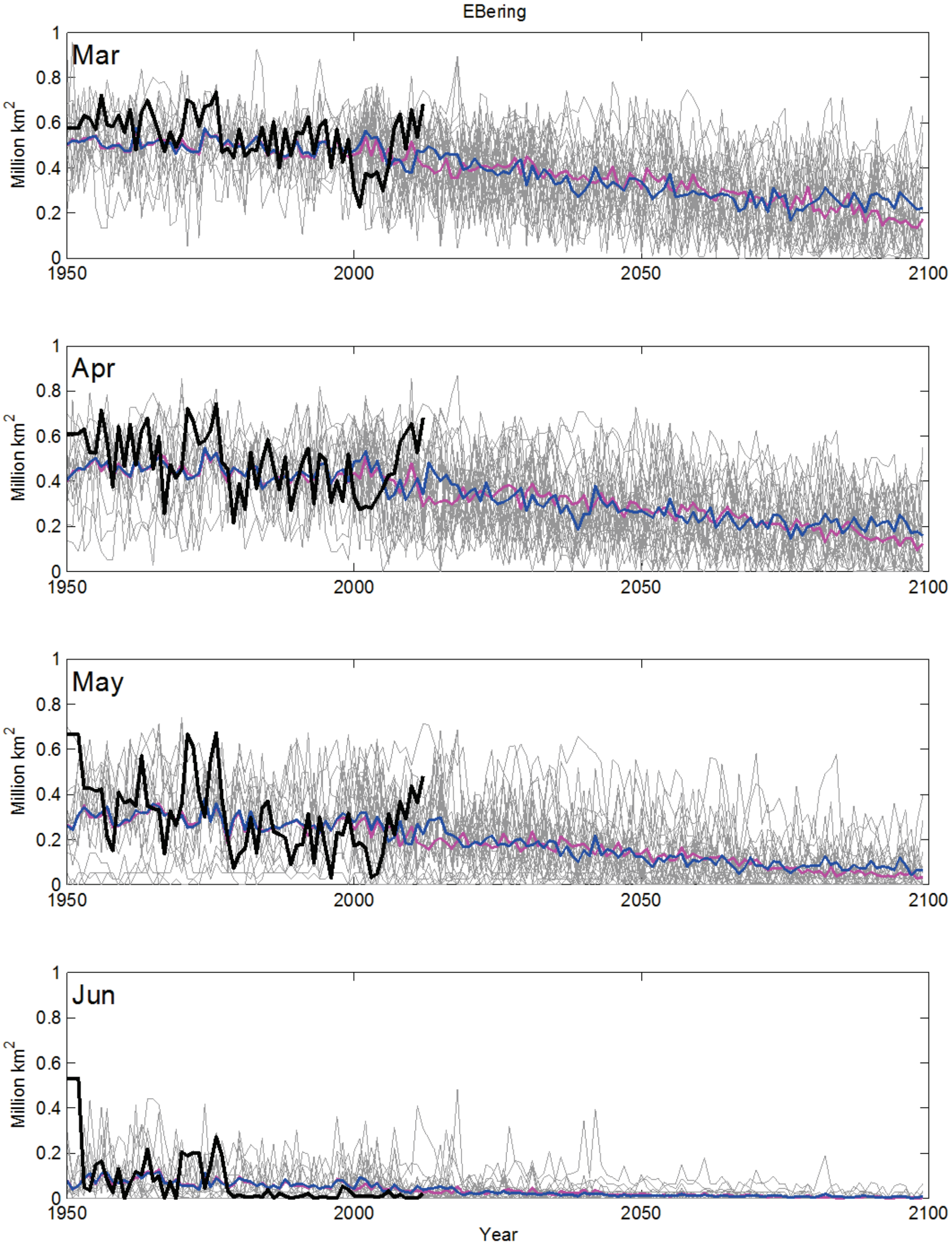


Figure 14 -- Model simulated sea-ice extent (in millions of km^2) over the eastern Bering Sea for the months of March-June. The black lines (observations) are based on HadISST analysis, and the blue and magenta lines are the ensemble means of the four models (CCSM3, CNRM, ECHO-G, and MIROC(medres)) under the A1B and A2 emission scenarios, respectively. Each grey line represents one realization by one of these models.

4.2.1.1.1.3.5 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 15 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 15). The mean linear trends estimated from the CCSM3 model were 28×10^3 km^2/decade (8%/decade) and 17×10^3 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 21st 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 16 shows the proportion of model runs that resulted in zero ice coverage for the months of March-June in 5-year periods throughout the 21st century, for the eastern and western Bering Sea.

Figure 17 shows maps of the projected sea-ice concentration in the Bering Sea, based on the same data used for Figure 14 and Figure 15. The centered, 11-year average and minimum value for each model grid cell is shown for May of 2010, 2050, and 2090. Consistent with the time series plots above, the values for the decade encompassing 2010 are likely to be characterized by average and minimum model predictions that are well below the recently observed ice concentrations, during the relatively cold phase that has occurred recently in the Bering Sea (Stabeno et al. 2012b). Both the 2050 and 2090 decades are expected to have years with essentially no sea ice in the Bering Sea during May. The decade encompassing 2090 is expected to have May sea ice only in the northern Bering Sea.

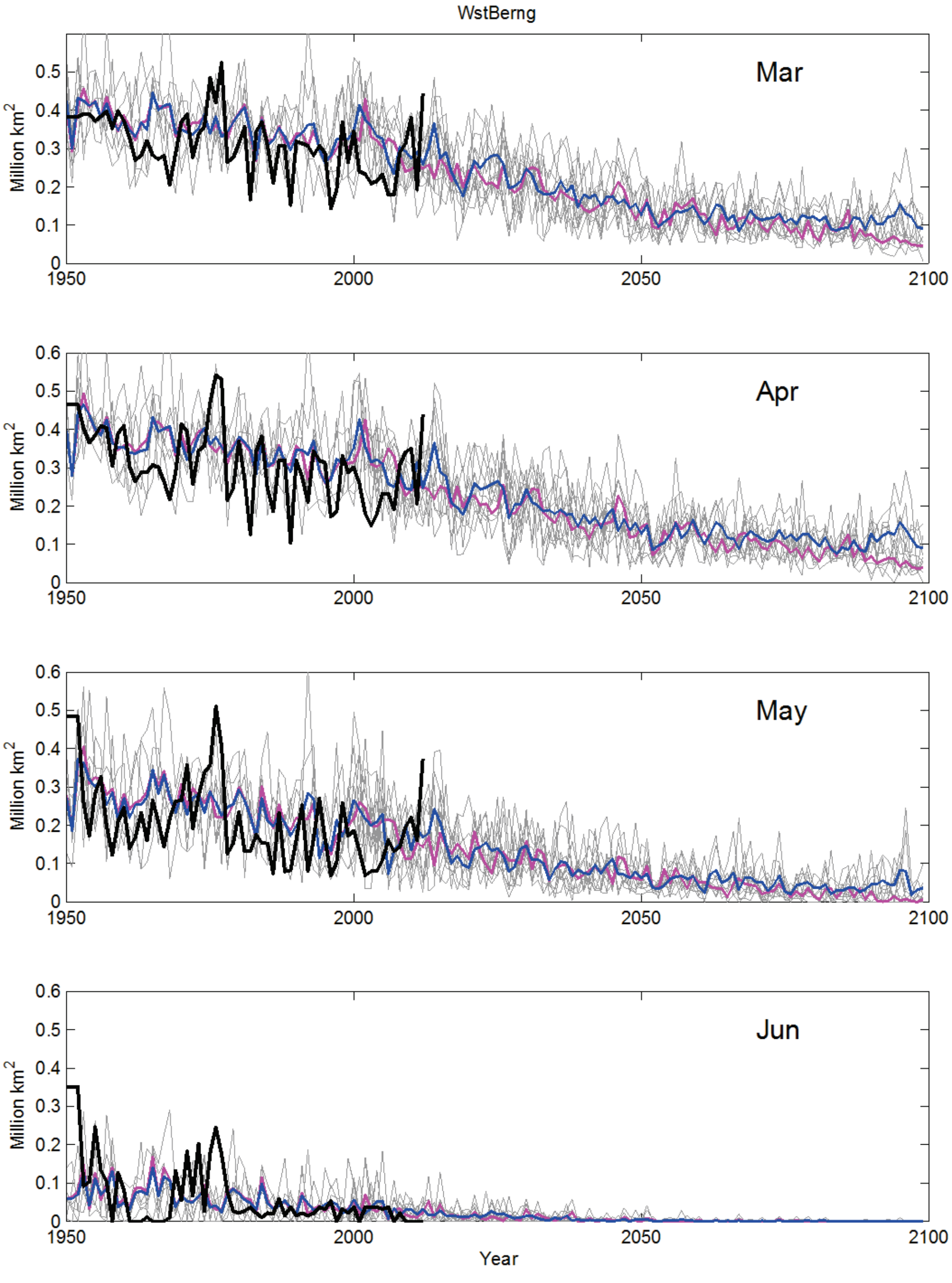
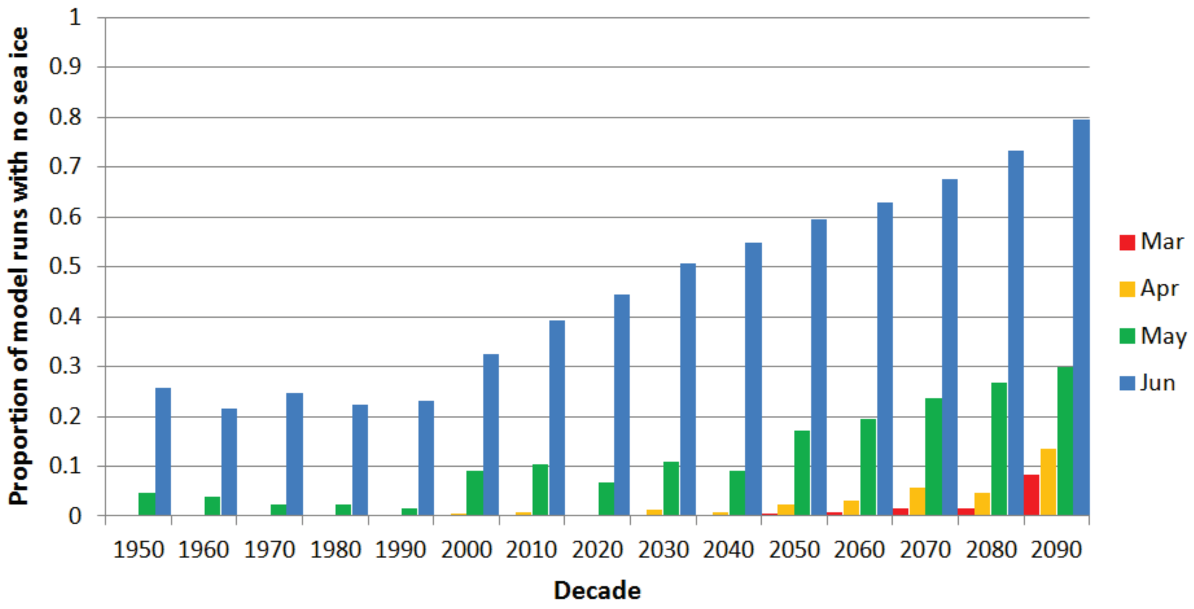


Figure 15. -- Model simulated sea-ice extent (in millions of km^2) over the western Bering Sea for the months of March-June. The black lines (observations) are based on HadISST analysis, and the blue and magenta lines are the ensemble means of the CCSM3 model under the A1B and A2 emission scenarios, respectively. Each grey line represents one realization by this model.

a) Eastern Bering Sea



b) Western Bering Sea

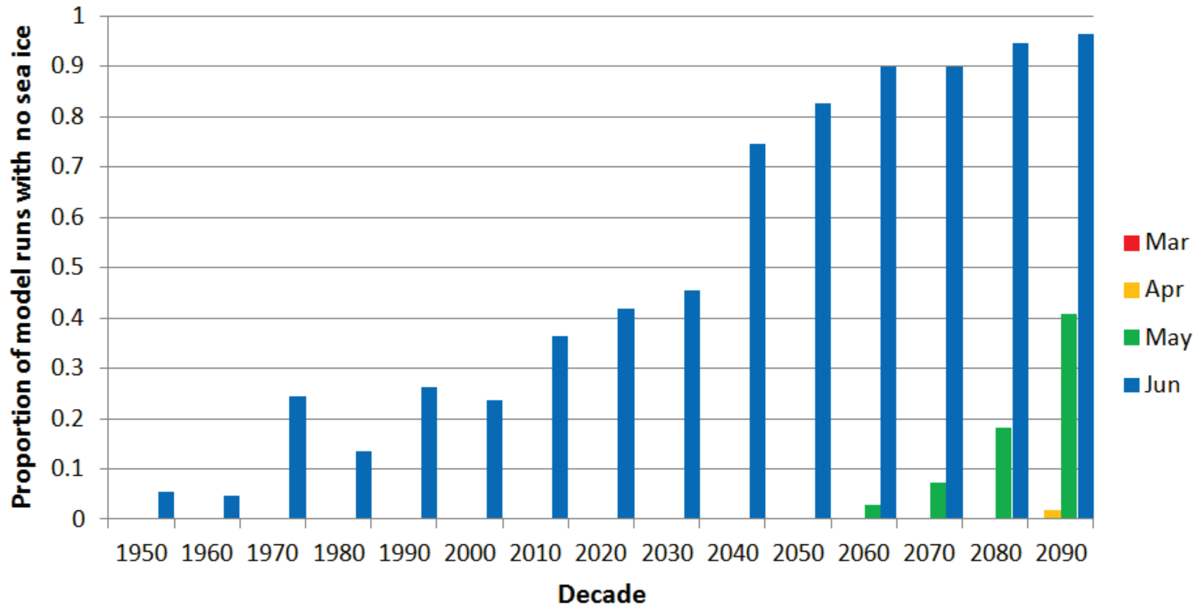


Figure 16. -- Proportion of model runs with zero sea ice coverage in March-June for the Bering Sea, based on the four CMIP3 models selected for the eastern Bering Sea and one model selected for the western Bering Sea. The models were run under both the A1B and the A2 emissions scenarios.

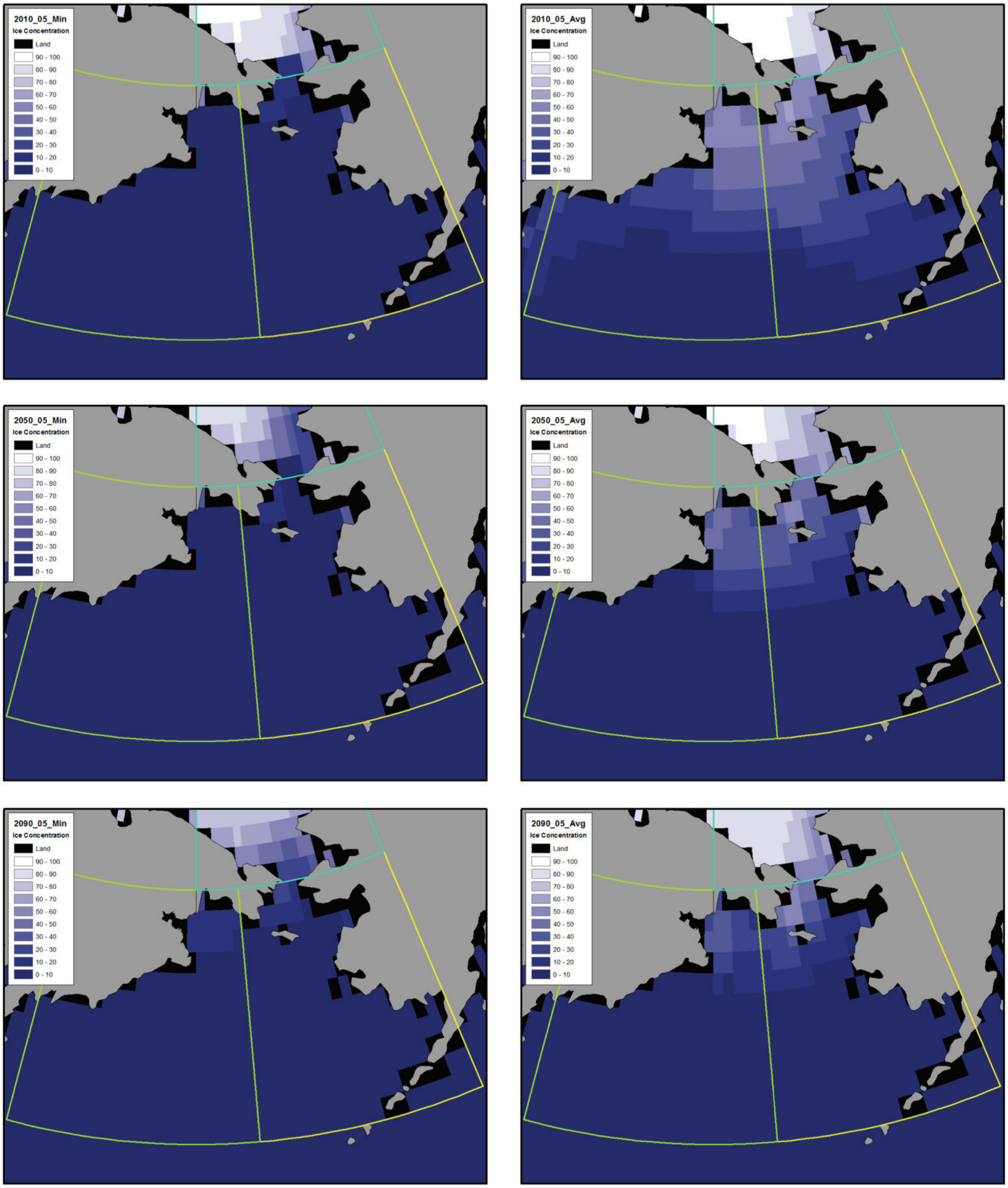


Figure 17. -- Maps of the projected sea-ice concentration in the Bering Sea from the four best performing models for the eastern Bering Sea and one best performing model for the western Bering Sea, as identified by Wang and Overland (2009). The centered, 11-year minimum (left) and average (right) values for each model grid cell is shown for May of 2010 (top), 2050 (center), and 2090 (bottom).

4.2.1.1.1.3.6 Sea of Okhotsk

The sea-ice forecasts for the Sea of Okhotsk are not sufficiently reliable for the ribbon 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 were 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 during March and April in the Sea of Okhotsk for the first half of this century, 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 18) is dominated by the cold continental air mass with temperatures below -6°C for most of the Sea of Okhotsk.

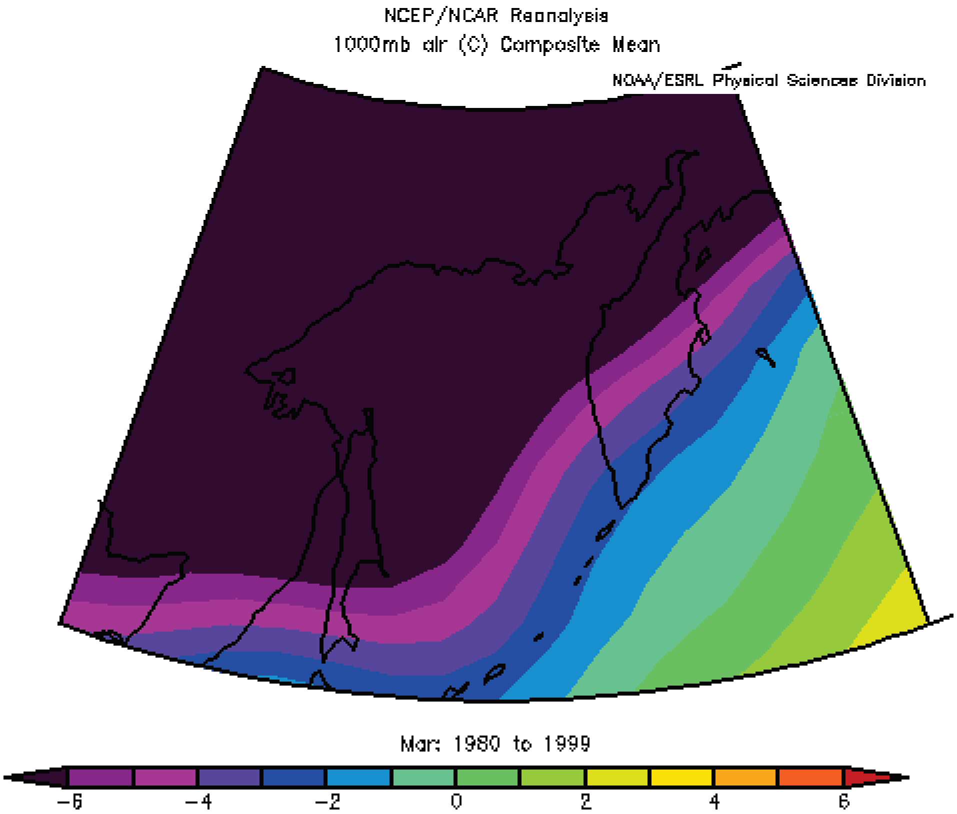


Figure 18. -- Average surface air temperature in March over the Sea of Okhotsk from 1980 to 1999.

During April (Figure 19) 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 20) 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.

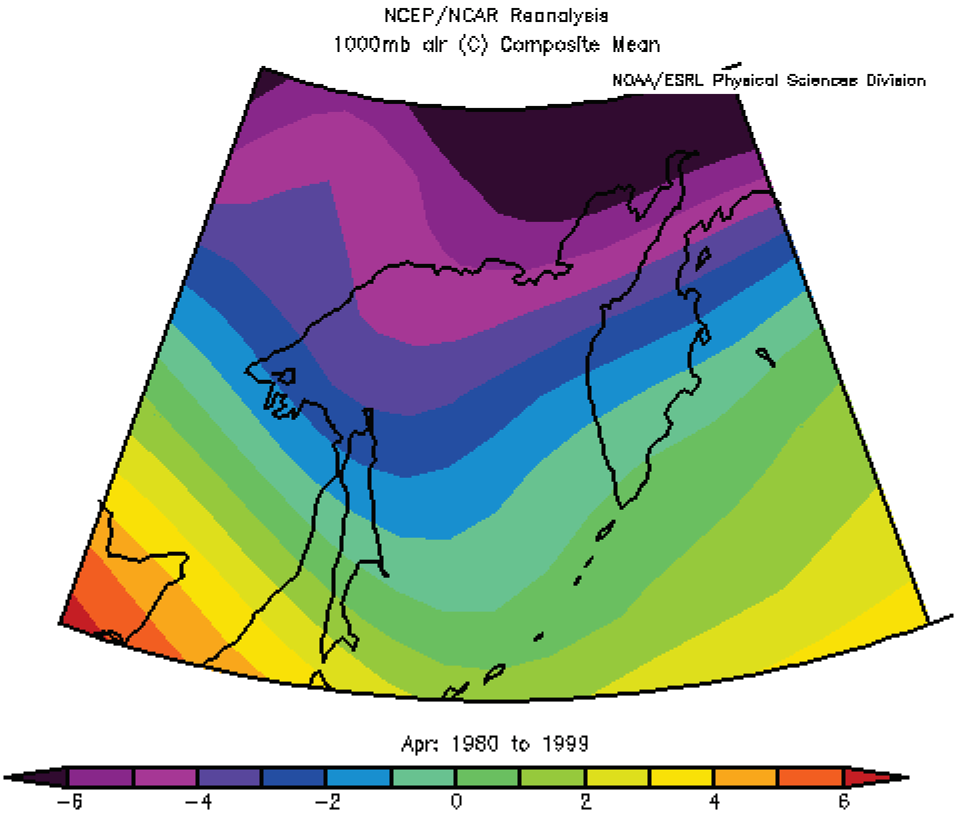


Figure 19. -- Average surface air temperature in April over the Sea of Okhotsk from 1980 to 1999.

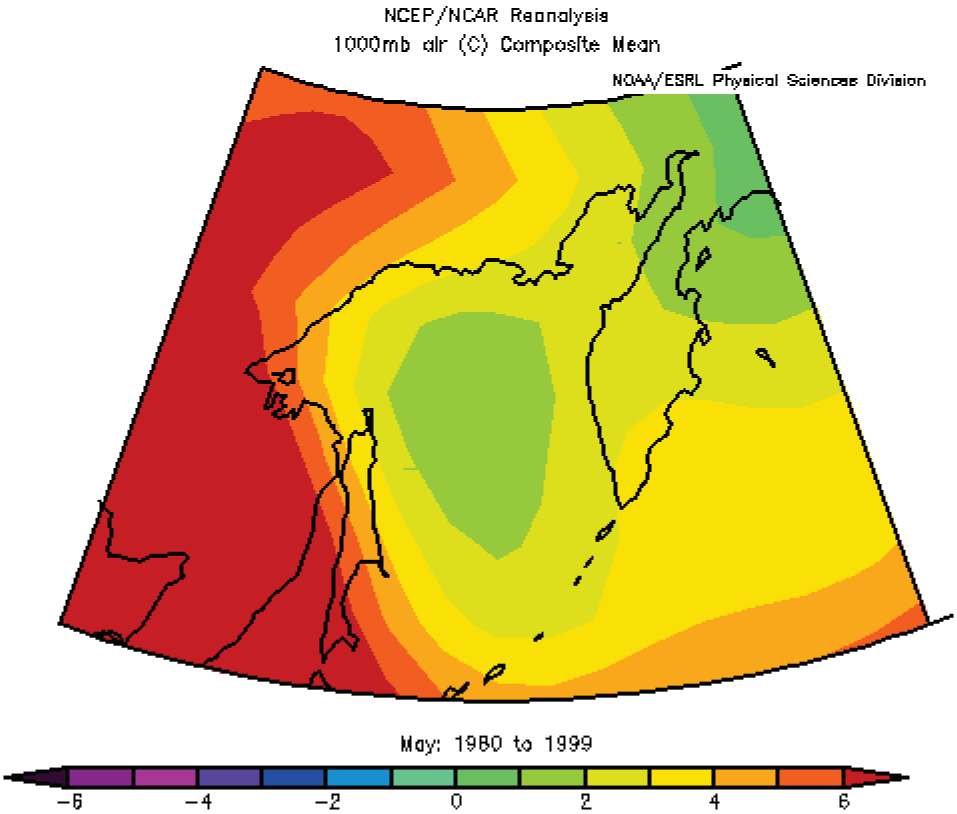


Figure 20. -- Average surface air temperature in May over the Sea of Okhotsk from 1980 to 1999.

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, temperature 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, and there would be no ice in May under the projected conditions because even the recent climatology for May has been above 0°C throughout the region.

4.2.1.1.2 Effects of climate change on the quality of ribbon seals' sea-ice habitat

Despite the expectation that large areas of sea ice in the ribbon 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 ribbon seals have preferred in the past.

The petition to list ribbon seals as threatened or endangered cited declining sea-ice thickness as a threat to ribbon seals (Center for Biological Diversity 2007). 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 ribbon 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 ribbon 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.

4.2.1.1.3 Effects of climate change on ocean conditions

4.2.1.1.3.1 Ocean warming

The western Beaufort Sea, the Chukchi Sea, and northern Bering Sea surface waters have warmed by as much as 3.5°C since 1990 (Steele et al. 2008). Summer temperatures of the southeastern Bering Sea warmed 2°C from 1995-2003 (Overland and Stabeno 2004). Ocean temperatures warmed in summer 2007 and 2008 by as much as 4°C in the East Siberian Sea, 3°C in the Chukchi Sea, 2°C in the Kara Sea, and 1.5°C in parts of the Laptev Sea (Richter-Menge and Overland 2009). In contrast, the Barents, Greenland and parts of the Laptev Seas experienced occasional years of mild (≤1.5°C) cooling over the same period, and from 2006 through 2009 the temperature of the eastern Bering Sea cooled by as much as 2°C since 2000 (Napp 2010).

The warming of sea surface temperatures would likely not have much direct impact on ribbon 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. 2006b), predators, and pathogenic vectors. These effects are considered in Sections 4.2.1.1.3.2.2 and 4.2.3.

4.2.1.1.3.1 Ocean acidification

Since the beginning of the industrial revolution in the mid-18th century, the release of GHGs including CO_2 from human activities, commonly referred to as "anthropogenic CO_2", has resulted in an increase in atmospheric CO_2 concentrations from approximately 280 to nearly 400 ppm, with 30% of the increase occurring in the last three decades. The atmospheric concentration of CO_2 is now higher than experienced on Earth for more than 800,000 years (Lüthi et al. 2008). Over the industrial era, the ocean has absorbed about one-third of anthropogenic carbon emissions (Canadell et al. 2007). When anthropogenic CO_2 is absorbed by seawater, chemical reactions occur that reduce both seawater pH and the concentration of carbonate ions in a process known as "ocean acidification."

Results from global ocean CO_2 surveys over the past two decades have shown that ocean acidification is a predictable consequence of rising atmospheric CO_2 levels. Seawater carbonate chemistry is governed by a series of abiotic chemical reactions (CO_2 dissolution, acid/base chemistry, and calcium carbonate dissolution) and biologically mediated reactions (photosynthesis, respiration, and calcium carbonate precipitation). The pH of ocean surface waters has already decreased (i.e., become less alkaline) by about 0.1 units since the beginning of the industrial revolution (Caldeira and Wickett 2003, Caldeira and Wickett 2005), with a decrease of ~0.0018 yr^{-1} observed over the last quarter century at several open ocean sites (Bates 2007, Bates and Peters 2007, Santana-Casiano et al. 2007). By the middle of this century, atmospheric CO_2 levels could reach more than 500 ppm and over 800 ppm by the end of the century (Orr et al. 2005). The result would be an additional decrease in surface water pH of approximately 0.3 pH units by 2100. Acidity in the ocean would increase by about 150% relative to the beginning of the industrial era.

As the pH of the ocean decreases, the equilibrium between calcium carbonate ($CaCO_3$) and its dissolution products (Ca^{2+} and CO_3^{2-}) favors dissolution. Ocean acidification reduces the calcium carbonate saturation levels, which stresses calcifying organisms by making calcification more difficult. Significant reductions in calcium carbonate saturation have been observed in the 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 by organisms can occur. 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). Shoaling of undersaturated waters has been observed in the high latitude North Pacific (Feely et al. 1988) and the Chukchi Sea (Bates and Mathis 2009) where the seasonal undersaturation of carbonate minerals in subsurface waters is enhanced by the sinking organic matter. Local upwelling can exacerbate the ocean acidification impacts by bringing deep, CO_2 rich waters to the surface exposing organisms to strongly corrosive conditions (Feely et al. 2008). Two recent studies suggested that aragonite undersaturation due to ocean acidification will develop in Arctic surface waters by or before mid-century under the B1 and A2 IPCC emissions scenarios (Orr et al. 2009, Steinacher et al. 2009).

The process of ocean acidification has long been recognized (Broecker and Takahashi 1966, Broecker et al. 1971, Bacastow and Keeling 1973, Feely and Chen 1982, Feely et al. 1988), but the ecological implications of such chemical changes have only recently begun to be appreciated. Although initial concerns about the effects of acidification focused on the negative effect that decreased calcium carbonate saturation state has on the ability of organisms to produce calcium carbonate shells, it is becoming increasingly clear that changes in CO_2 and pH *per se* can affect the growth, survival, and behavior for a range of marine organisms (Fabry et al. 2008, Guinotte and Fabry 2008, Pörtner 2008). Many non-calcareous species are affected by acidification, and the ability of calcareous species to produce shells can be affected by acidification factors other than just saturation state (Fabry 2008, Pörtner 2008). In addition to the effects of changes in CO_2, pH, and saturation state, secondary chemical reactions can change other components of seawater, such as the concentration of various forms of trace elements and nutrients, which in turn can affect species growth and survival (Doney et al. 2009). Ocean acidification also affects sound absorption in the ocean. Brewer and Hester (2009), for example, suggest that changes in borate and carbonate ion concentrations associated with ocean acidification is reducing the absorption of low frequency sound (~300 Hz-10 kHz) important to some marine mammals. Potential direct effects of ocean acidification include:

- Reduced calcification rates – The reduced saturation state affects the ability to produce calcium carbonate shells, makes the process more physiologically costly, or leads to dissolution of existing calcium carbonate structures.
- Altered survival and reproduction from reduced pH – Organisms generally require energy to maintain appropriate inter-cellular pH balance. Altering the external pH of seawater can overwhelm pH control mechanisms, affecting survival or reproduction.
- Reduced olfaction in fish – Increased CO_2 in seawater can affect the ability of fishes to detect critical olfactory cues.
- Increased photosynthesis – Because CO_2 is required for photosynthesis, some photosynthetic organisms, especially those without effective carbon concentrating mechanisms, may have increased photosynthetic rates with increased CO_2.
- Hypercapnia – Increased CO_2 in internal fluids, especially in highly energetic species like squid, can affect survival or reproduction. The ability of organisms to decrease CO_2 titers in internal fluids by transferring CO_2 across membranes to seawater is reduced when seawater CO_2 concentrations are high.
- Acoustic disruption from noisier ocean – Changes in ocean pH will alter the acoustic properties of the ocean, increasing transmission of low frequency sounds, which may affect species relying on acoustic information.
- Response to altered metals, nutrient or toxics speciation – Acidification will alter speciation (ionic from) of various metals, nutrients, and toxins in a way which might affect species survival and reproduction.

The numerous pathways for effects (both direct and indirect) imply that ocean acidification will impact many marine species.

The waters of the Arctic and adjacent seas are among the most vulnerable to ocean acidification (Orr et al. 2005, Gehlen et al. 2007, Cao and Caldeira 2008, Fabry et al. 2009). Modeling studies have suggested that the polar seas will experience aragonite undersaturation by the middle of the century. Recent modeling studies (Feely et al. 2009, Steinacher et al. 2009) argue that the surface waters of the Arctic Ocean will start experiencing localized aragonite undersaturation within the next decade.

Seasonal undersaturation has already been documented (Bates et al. 2009, Yamamoto-Kawai et al. 2009). Bates et al. (2009) measured saturation states for aragonite and calcite for the Chukchi Sea shelf and Canada Basin from 2002 to 2004 and found that aragonite undersaturation is occurring in the subsurface waters due to ocean acidification combined with subsurface remineralization of particulate organic carbon. Patches of surface water undersaturated in aragonite were also found in the Canada Basin, which resulted from significant sea-ice melt contributions. In a separate study, Yamamoto-Kawai et al. (2009) also found that the synergistic effects of increasing CO_2 and ice melt resulted in surface waters in the Canada Basin that were undersaturated with respect to aragonite. In the eastern Bering Sea, natural processes including production and remineralization, river runoff, and mixing create large seasonal variability in ocean carbon chemistry (Mathis et al. 2011b, Mathis et al. 2011a). While these natural processes play an important role in seasonally low saturation states, ocean uptake of anthropogenic CO_2 has led to a greater degree of undersaturation in subsurface waters in recent years, becoming nearly undersaturated with respect to aragonite and calcite for several months each year. Finally, in the western Arctic Ocean, Mathis et al. (2012) observed aragonite undersaturation throughout the water column over the Beaufort shelf during a persistent upwelling event in the fall of 2011. Upwelling events along the Beaufort shelf have likely been exacerbated in recent years due to declining sea ice cover and changing atmospheric conditions and are expected to further the expansion of corrosive, undersaturated waters in this region.

4.2.1.1.3.2 Effects of Climate Change on Ribbon Seal Prey Communities

4.2.1.1.3.2.1 Current status of ribbon seal prey

While the list of known prey species of ribbon seals may become more extensive if 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, as emphasized by Węsławski et al. (2006) in a study of other predator-prey relations in north Atlantic systems. Several groups of fish 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 that are represented in the ribbon seal diet as forage species for management purposes, including lanternfishes, sand lance, smelts, gunnels, pricklebacks, and euphausiids (Lauth 2007). In addition, walleye pollock and Arctic cod are very important forage species for ribbon 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.

The species of small pelagic crustaceans preyed upon by newly weaned and first-year ribbon seals (e.g., *Thysanoessa raschii*, *Stylomysis grandis*, and *Themisto* sp.; Table 1) occur in the Bering Sea, Sea of Okhotsk, and Arctic Ocean (Bowman 1960, Kathman et al. 1986). They 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* occurs over continental shelves throughout the year, and although its abundance appeared to decline in the southeastern Bering Sea during the early part of the last decade (Hunt et al. 2008), it has recently become more abundant (Hunt et al. 2011, Ressler et al. 2012). 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 southeastern Bering Sea shelf (Hunt et al. 2008). However, like *T. raschii*, the abundance of this species in the Bering Sea appears to be increasing lately (Hunt et al. 2011). *Themisto pacifica* and *T. japonica* also occur in sub-Arctic waters of the ribbon seal distribution (Bowman 1960). Total zooplankton biomass, which had been low in all areas of the eastern Bering Sea from 1999-2005 (Napp and Shiga 2005, Hunt et al. 2008), appears to be rebounding in recent years in conjunction with a transition from the relatively warm years of 2001-2005 to the colder regime of 2007-present (Hunt et al. 2011, Stabeno et al. 2012b). In the Sea of Okhotsk, zooplankton abundance decreased from the mid-1980s to a low in 1997-1998, returned to higher levels from 1999-2005, and appears to be declining again in recent years (PICES 2005).

A variety of **benthic prey** occurs in the ribbon seal diet. Based on the distribution of these prey (Butler 1980, Mecklenberg et al. 2002) and the diving capabilities of ribbon seals, these species are primarily eaten over the continental shelf. They include shrimp, crab, *Octopus* sp., eelpouts, pricklebacks, flatfishes, sculpins, and others. Many species of shrimp listed in Table 1 occur on continental shelves across most of the ribbon seal’s range in the Sea of Okhotsk and Bering and Chukchi Seas (Butler 1980). Several species of *Pandalus* shrimp vertically migrate into the water column at night and feed on zooplankton (Butler 1980). This may make them more available to predation by young ribbon seals that may have limited diving capability and that may spend more time foraging at night than during the day (Ver Hoef et al. 2013). 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), but bottom-trawl survey data from the eastern Bering Sea indicate that pandalid shrimp abundance has been steadily increasing over the past decade (RACEbase, unpubl. data, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115). Groundfish biomass in the eastern Bering Sea is dominated by cods (Gadidae) and flatfishes (Pleuronectidae), with significant populations of sculpins (Cottidae), eelpouts (Zoarcidae), and several other fish families (Stevenson and Lauth 2012). The overall abundance of sculpins and eelpouts on the Bering Sea shelf shows no clear trend over the past decade, but prickleback abundance appears to be increasing (Spies et al. 2012; RACEbase, unpubl. data, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115), though it has still not returned to pre-1999 levels (Lauth 2011). Major demersal fish species in the Sea of Okhotsk have decreased dramatically in abundance over the past two decades. Total demersal fish biomass declined by about half between 1997 and 2000 and benthic invertebrates (including shrimps) decreased to about one-third (PICES 2005). More recent data indicate that demersal fish abundance is rising again in the Sea of Okhotsk, though it is still only approximately half the level of the 1990s (Radchenko et al. 2010).

Schooling, mobile prey species that are distributed primarily over the continental shelves include Pacific sand lance, Pacific herring (*Clupea pallasii*), capelin, rainbow smelt (*Osmerus mordax*), Pacific cod, saffron cod, Arctic cod, and walleye pollock. All of these species have geographic ranges that equal or exceed the geographic limits of the ribbon seal, either extending farther south into the North Pacific or ranging farther north into the Arctic (Whitehead 1985, Cohen et al. 1990, Mecklenberg et al. 2002, Tokranov 2007, Froese and Pauly 2008). In the southern part of the eastern Bering Sea, the benthopelagic ichthyofauna is dominated by large gadids (walleye pollock and Pacific cod), while in the northern Bering Sea and Chukchi Sea, the groundfish fauna becomes increasingly dominated by smaller gadids such as Arctic cod and saffron cod (Stevenson and Lauth 2012). 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). Since 1979 in the eastern Bering Sea, age 3+ walleye pollock biomass has ranged from 3.4 to 13.1 million metric tons (Ianelli et al. 2012). Pollock biomass has recently been relatively low due to the absence of strong recruiting year classes, but has been increasing since 2008 (Ianelli et al. 2012). Likewise, the biomass of Pacific cod on the eastern Bering Sea shelf has doubled since 2008, and remains relatively high (Thompson and Lauth 2012). The abundance of smaller walleye pollock and Pacific cod 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, Ianelli 2005). The relative abundance of capelin has increased dramatically in the eastern Bering Sea in recent years, while Pacific herring abundance has remained relatively low (Farley and Strasburger 2012). The relative abundance of Pacific sand lance was lower during 1999-2011 than in previous years of the Alaska Fisheries Science Center (AFSC) bottom trawl survey 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, walleye pollock biomass decreased significantly from a relative high observed in 1995 to a low in 2000; it has since rebounded to some extent, but has not returned to mid-1990s levels (Dulepova and Radchencko 2004). The total biomass of the epipelagic fish community in the Sea of Okhotsk declined by approximately one-half from a peak in 1988, as assessed in 2002 (PICES 2005).

Off-shelf prey species inhabiting the continental slope and basin waters of the Bering Sea and Sea of Okhotsk include walleye pollock, lanternfishes, deepsea smelts, and several squid species listed in Table 1 (Nesis 1982, Sinclair et al. 1999, Mecklenberg et al. 2002). However, the smooth lumpsucker is epipelagic, occurring over the outer continental shelves and basin waters of the Bering Sea (Mecklenberg et al. 2002), and boreal chubhook squid (*Onychoteuthis borealijaponica*) and *Ommastrephes* sp. primarily inhabit pelagic waters in the North Pacific transitions zone, south of the Aleutian Islands and east of Japan (Nesis 1982). In the Bering Sea, walleye pollock tend to decrease in abundance away from the continental shelf. In the Aleutian Basin, aggregations of pre-spawning walleye pollock were commercially fished in the late 1980s, but have not been detected in significant abundance since that time. Ribbon seals appear to feed on spawning aggregations of walleye pollock east of Hokkaido Island, Japan (Deguchi et al. 2004). It is unknown whether ribbon seals target pre-spawning aggregations of walleye pollock in other areas, but it is possible they could do so, particularly in winter months along continental slopes before the ribbon seals haul out onto the sea ice. Lanternfishes, deepsea smelts, and several squid species described in the diet of ribbon seals (Table 1) are mesopelagic, vertical-migrators (Sinclair et al. 1999, Mecklenberg et al. 2002). Species of this type are widespread throughout slope and basin waters, and they are often locally abundant with the highest concentrations occurring near the continental slope, over underwater ridges and canyons in the Bering Sea (Sinclair et al. 1999). Sinclair et al. (1999) suggest this is the result of higher productivity near land margins and ridges, as well as prevailing currents that concentrate these species. *Berryteuthis magister* is the most abundant of the squid species. They are dispersed during the summer months in the western Bering Sea, but form large, dense schools over the continental slope during September and October (Ormseth and Jorgensen 2007). Trends in abundance are poorly known for these mesopelagic species, but bottom-trawl survey data in the eastern Bering Sea do not suggest any major changes in squid abundance over the past decade (Ormseth 2012), and in the Sea of Okhotsk, squids slightly increased in number between 1997 and 2000 (PICES 2005).

4.2.1.1.3.2.2 Impacts of ocean warming on prey

In general, marine 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). Warming of the oceans is predicted to drive species ranges toward higher latitudes (Parmesan and Yohe 2003, Grebmeier et al. 2010). Climate warming has been credited with global declines in phytoplankton concentrations (Boyce et al. 2010). Climate change can strongly influence fish distribution and population size (Wood and McDonald 1997) through changes in growth, survival, reproduction, and spawning distribution (Sundby and Nakken 2008).

The demersal fish prey of ribbon seals are likely to be impacted by ocean warming. For example, Arctic cod is primarily an Arctic species associated with cold waters. The location and extent of cold bottom water less than 2°C in the summer (a.k.a. “the cold pool”) in the Bering Sea is linked to the extent of ice cover during the previous winter such that the cold pool is more extensive and expands to the south and east after high ice years. Arctic cod have been found primarily in these cold pool waters such that their summer distribution is also more extensive and further to the south and east after high ice winters. Conversely, Arctic cod distribution is contracted towards the north and west in summers following low winter ice cover (Wyllie-Echeverria and Wooster 1998). Thus, continued ocean warming and decreased winter ice extent in the future could potentially reduce the southerly and easterly extent of the distribution of Arctic cod in the Bering Sea. Arctic cod in the Beaufort Sea are similarly associated with cold waters. A survey of marine fish of the Beaufort Sea conducted in summer 2008 showed that adult Arctic cod in both benthic and pelagic habitats apparently prefer the very cold winter water that emanates from the Chukchi Sea (Logerwell et al. 2010). This is the region of the cold halocline that characterized Chukchi Sea outflow through Barrow Canyon, and fish distributions and model results suggest that the fish prefer these low temperatures. The Chukchi Sea outflow of cold, winter-formed waters are also rich in dissolved and particulate organic carbon, with this water carried offshore into the halocline (Pickart et al. 2005, Mathis et al. 2007). Previous studies in the marine coastal habitat of the Beaufort Sea have similarly shown that Arctic cod prefer waters that are cold (-1° to 3°C) and of high salinity (27-32 ppt; Craig 1984). Future warming of Chukchi and Beaufort Seas will potentially bring about changes in the distribution and/or numbers of Arctic cod.

Ocean warming will not only impact gadids such as Arctic cod. Community-wide responses to warming conditions involving a number of demersal fish and invertebrate species have been observed in the Bering Sea, such as northward distribution shifts, changes in community metrics such as total biomass, species richness, and average trophic level. Those observations suggest the potential for highly disruptive responses of the benthic community to continued climate change (Mueter and Litzow 2008). Demersal fish in the Atlantic Arctic have also demonstrated sensitivity to ocean warming. Nearly two-thirds of exploited and non-exploited demersal 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 (Perry et al. 2005). 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. In the northwest Atlantic Ocean, centroids of mean catches of fish from bottom trawl surveys also shifted north by 0.5-0.8 degrees of latitude for each 1°C increase in average water temperature (Murawski 1993).

Ocean warming may also impact the distribution of pelagic fish that are prey for ribbon seals. There have been range extensions of pelagic fish such as walleye pollock in the northern Bering Sea associated with increased temperatures and decreased ice cover, and the evidence is for a continued trend towards more subarctic conditions in that area (Grebmeier et al. 2006b). In the Barents Sea, higher zooplankton biomass has been observed during recent years with warm ocean temperatures and increased inflow of North Atlantic water (1991-2000) compared to previous cold years (1984-1990) (Dalpadado et al. 2003). Thus, warm years would be expected to be favorable for pelagic zooplanktivorous fish such as capelin and herring. In addition, the distribution of capelin has been shown to be linked to ocean temperatures, being shifted to the north and east during warm ocean years (Loeng 1989). In the Russian North Pacific, model predictions indicate cooling until approximately 2020 with decreases in “warm water” pelagic species such as pollock, and sardines and then increases after 2020. Herring and other “cold water” species will increase until 2020 and then decline (Dulepova and Klyashtorin 2008). The pelagic zooplankton prey of ribbon seals may also be impacted by future ocean warming. Observations that warming associated with the 1976/77 regime shift led to decreases in zooplankton crustaceans in the Bering Sea and sub-Arctic Pacific support this hypothesis (Sugimoto and Tadakoro 1997, Schumacher et al. 2003, Bluhm and Gradinger 2008).

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 ribbon seals have size preferences for forage fishes, then this could impact their feeding dynamics. 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. However, recent advances in the understanding of walleye pollock recruitment suggest that while warm spring conditions enhance the survival of early larvae, high temperatures in late summer and autumn are associated with poor feeding conditions for young-of-year pollock and reduced recruitment the following year (Hunt et al. 2011). Based on a range of IPCC climate projections of late summer temperatures, Mueter et al. (2011) expected walleye pollock recruitment in the eastern Bering Sea to decline by 32-58% by 2040-2050. The influence of large-scale patterns of atmospheric circulation variability, such as the North Atlantic Oscillation (NAO; Hurrell 1995) and Pacific Decadal Oscillation (PDO; Hare and Mantua 2000), have direct effects on local 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 show 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 have been reported (Drinkwater 2005) as have unspecified influences on New England groundfish stocks (Brodziak and O'Brien 2005). Sometimes the effects are localized regionally. 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).

4.2.1.1.3.2.3 Impacts of changes in oceanographic processes on prey

Several of the dominant zooplankton taxa that are either preyed upon directly by seals or are food of pelagic fish upon which seals prey are linked to the Arctic oceanographic regime. Thus, fluctuations or long-term changes in large-scale oceanographic processes could alter the species composition of zooplankton on Arctic shelves (Bluhm and Gradinger 2008). For example, greater inflow of North Atlantic water into the Barents Sea is associated with warm ocean conditions and higher zooplankton biomass overall (Dalpadado et al. 2003). Greater inflow of Atlantic water, however, is associated with lower biomass of Arctic amphipod species such as *Themisto libellula* (Dalpadado 2002). 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. 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).

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). 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. 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, Grebmeier et al. 2010).

4.2.1.1.3.2.4 Impacts of changes in distribution and characteristics of sea ice on prey

Ice algae contribute 4-26% of the production in seasonally ice-covered waters and greater than 50% in the permanently covered central Arctic (Gosselin et al. 1997). Spring algal blooms in the bottom layer of sea ice can be substantial, above 70 mg Chl *a* m^{-2} (Smith et al. 1993). The ice community is important to the Arctic ecosystem not only because it contributes to primary production but also because it extends the grazing season of herbivores (i.e., ice algae blooms are available before the open water spring bloom). In addition, high densities of algae on the more 2-dimensional undersurface of the ice my increase the grazing efficiency of zooplankton compared to the 3-dimensional open-water habitat (Bradstreet and Cross 1982). The association of Arctic cod with sea ice is well documented in coastal and offshore Arctic locations across the globe (reviewed in Bradstreet et al. 1986). Arctic cod appear to use sea ice for both feeding and for protection from predators by hiding in water wedges along the edges of ice floes (Gradinger and Bluhm 2004). For example, several species of Gammaridean amphipods are endemic consumers of algal ice production in many different areas of the Arctic and, in turn, are important prey for Arctic cod (Bradstreet and Cross 1982, Lønne and Gulliksen 1989, Lønne and Gulliksen 1991a, Lønne and Gulliksen 1991b, Carey 1992, Polterman et al. 2000, Werner and Gradinger 2002). It is expected that thinning of Arctic sea ice and the resulting increased meltwater and change in morphology of floes will have a negative effect on these under-ice amphipods (Werner and Gradinger 2002).

Loss of summer sea ice due to ocean warming could result in a decrease in the availability of this ice-based food web for foraging seals (Bluhm and Gradinger 2008). On the other hand, increased summer ice melt could result in increased primary productivity as more of the ocean surface is exposed to sunlight (Anderson and Kaltin 2001). Nutrients, however, could limit the extent of increases in production. Scenarios based on contemporary nutrient concentrations suggest a doubling of production in the central Arctic with loss of summer sea ice, but no increase in coastal and shelf regions (Bluhm and Gradinger 2008). Increased sea-ice melting is also expected to lead to more brackish conditions (i.e., warmer and fresher water) with potential impacts on the ice-associated food web. For example, since the 1970s-1980s, there have been changes in the ice-associated phytoplankton and zooplankton communities of the Canada Basin attributed to ice melt and subsequent warming and freshening. Specifically observed were changes in the species composition of phytoplankton, a decrease in viable populations of copepods and amphipods within the ice interior, and a decrease in the number of species and overall biomass of zooplankton associated with the under surface of the ice (Melnikov et al. 2002).

Ocean warming and loss of winter sea ice may alter the coupling between pelagic and benthic production, further impacting Arctic food webs. In the northern Bering Sea, late retreat of winter ice cover is thought to result in an ice-associated phytoplankton bloom early in the spring. Herbivorous zooplankton are in an early phase of their annual ontogenetic cycle at this time and cannot graze down the phytoplankton bloom with the result that much of the production sinks to the bottom and fuels a benthic food web (Hunt et al. 2002, Grebmeier et al. 2006a). In contrast, early retreat of winter ice cover associated with warmer ocean waters is hypothesized to result in a later spring phytoplankton bloom in open water. In this situation, herbivorous zooplankton would be further along in their ontogenetic cycle and able to graze the phytoplankton bloom such that less production goes to the benthos. By a similar mechanism, zooplankton in the Barents Sea are able to crop more of the primary production in years when water temperatures are high (Rey et al. 1987, Skjoldal et al. 1987). Thus, warming and decrease in ice extent could increase pelagic productivity in favor of pelagic foraging by ribbon seals (Bluhm and Gradinger 2008).

4.2.1.1.3.2.5 Impacts of ocean acidification on prey

Ocean acidification is expected to hamper the ability of phytoplankton such as foraminifera and coccolithophorids to maintain their calcareous structures, with negative consequences for the rest of the marine food web (Feely et al. 2004, Orr et al. 2005). Laboratory experiments on the coccolithophore, *Emiliania huxleyi*, have resulted in inconsistent results (Riebesell et al. 2000, Iglesias-Rodriguez et al. 2008). Further research on species-specific responses of phytoplankton to increased ambient CO_2 is needed. Ocean acidification also could have severe consequences for calcifying zooplankton, especially shelled pteropods which are prey for carnivorous zooplankton and fish such as salmon, herring, and cod (Lalli and Gilmer 1989, Willette et al. 2001, Boldt and Haldorson 2003, Orr et al. 2005). Experiments and *in vitro* measurements show that pteropods are unable to maintain their shells in waters that are undersaturated with calcium carbonate, a consequence of ocean acidification, with expected negative impacts on their survival (Byrne et al. 1984, Feely et al. 2004, Orr et al. 2005). Yamada and Ikeda (1999) found that exposure to very high CO_2 concentrations (> 2,000 ppm) does reduce survival of six different copepod species, but levels expected over the next century do not seem to have a significant impact (Kurihara and Ishimatsu 2008). Lower trophic levels may also be modified because of changes in nutrient availability (Zeebe et al. 2008), including the ratio of ammonia to ammonium and availability of iron (Andreev et al. 2009, Shi et al. 2010), speciation of trace metals (Mouvet and Bourg 1983), and the potency of pH-sensitive marine toxins.

In addition to interfering with calcification of organisms at lower trophic levels, changes in ocean chemistry can have direct effects on the physiology of marine invertebrates and fish. In general, the expectation is that an increase in CO_2 will cause changes in the mode of metabolism of marine organisms, with possible reductions in growth and reproduction. The hypothesis, however, has not been tested in long-term field experiments (Pörtner et al. 2004). CO_2 impacts animal physiology predominantly through its acidifying effect on acid-base balances. Changes in acid-base balance will impact membrane-bound ion regulation, as observed for both fishes and crabs. Compensation for increased acidity causes potentially unfavorable changes in the ionic composition of plasma and other body fluids (Pörtner et al. 2004). These processes are not likely to be life-threatening but are expected to hamper growth, reproduction, and survival (Pörtner et al. 2005). For example, studies have demonstrated detrimental effects of low pH on the growth of shrimp and sturgeon (Wickins 1984, Crocker and Cech 1996), and on reproductive success of perch (Vinogradov and Komov 1985). Another common adaptive strategy to increased CO_2 is to suppress aerobic energy rates, or "metabolic depression" (reviewed in Guppy and Withers 1999). Comparing patterns seen in fish with those found in invertebrates indicates that the effect of metabolic depression occurs with smaller increases in CO_2 in invertebrates. Vertebrates apparently have an enhanced capacity to avoid early metabolic depression in the face of long-term elevated CO_2 levels. The processes that control vertebrate metabolism under conditions of increased CO_2, however, reflect changes in energy use and allocation with potential consequences for long-term survival (Pörtner et al. 2005).

Squid may be particularly intolerant of increases in CO_2 due to their unusually high metabolic rate and their unique respiratory physiology. Compared to squid, fish are expected to be more tolerant of increases in CO_2, a result of their lower metabolic rate and venous oxygen reserve. Deep-sea fishes are expected to be the least tolerant group of fishes because of their adaptations to respiration in low-oxygen environments (Pörtner et al. 2004). A laboratory experiment on a Mediterranean sea bream, *Sparus aurata*, indicated that prolonged exposure to moderate increases in CO_2 caused shifts in metabolic pathways from aerobic to anaerobic metabolism (Michaelidis et al. 2007). Other studies have shown an alteration in protein biosynthesis or patterns of gene expression (Langenbuch and Pörtner 2003). It is not known whether these processes are adaptive to long-term increases in ocean CO_2 concentrations or whether they would contribute to decreased growth and survival (Pörtner et al. 2005).

Additional concerns about ocean acidification are related to the fact that future climate change scenarios will involve not only increases in oceanic CO_2 concentrations but also increased warming and decreased dissolved oxygen due to eutrophication. Because CO_2 affects several physiological mechanisms that are also affected by thermal extremes and oxygen deficiency, it has been suggested that current trends of warming, CO_2 increase, and oxygen reduction in marine waters may exert harmful synergistic effects on marine organisms (Pörtner et al. 2005). For example, physiological responses to increased CO_2 will likely result in a narrowing of the thermal tolerance of marine organisms, which would be most detrimental for animals living at the edges of their distributional range. This interaction could cause shifts in geographical distribution as well as alteration of ecosystem composition and functioning (Pörtner et al. 2005).

Current rates of change in ocean acidity are more than 100 times greater than any changes in the past 100,000 years (Raven et al. 2005). The high rate of increase in CO_2 concentration means that organisms are being exposed to changes that are faster than they have encountered in their recent evolutionary history. The capacity of calcifying marine organisms to adapt to progressively acidified oceans is not known, but will depend, in part, on the species' generation time. Long-lived species—such as benthic molluscs—will be less able to respond adaptively. Shorter generation times may afford increased opportunities for micro-evolutionary adaptation (Raven et al. 2005). A recent National Academies report concluded that “the chemistry of the ocean is changing at an unprecedented rate and magnitude due to anthropogenic CO_2 emissions; the rate of change exceeds any known to have occurred for at least the past hundreds of thousands of years” (National Research Council 2010). The report went on to point out that while the ultimate consequences of ocean acidification are still unknown, both the magnitude and rate of change present a risk of ecosystem changes that threaten coral reefs, fisheries, protected species, and other natural resources of value to society.

4.2.1.1.4 Impacts of global climate change on ribbon seals

4.2.1.1.4.1 Sea-ice-related impacts

The seasonal formation of sea ice in the northern Bering Sea and Sea of Okhotsk is substantially decoupled from the summer ice extent in the Arctic Ocean, and is expected to continue annually through the foreseeable future, along with typical, large interannual variations in extent and duration of persistence. Large areas of sea ice in the ribbon seal’s range will form and persist through April in most years throughout this century. There will be ice in May in most years through the middle of the century, but in the latter half of the century, many or most years will have little or no ice. June will be highly variable through the middle of the century, as it has been in the past, but the models predict essentially no ice for the latter half-century. Thus, in association with a long-term warming trend there will likely be declines in the frequency of years with extensive ice, the quality of ice, and the duration of its persistence that may impact the amount of suitable habitat in the geographic areas that ribbon seals have preferred in the past. An assessment of the risks posed by these changes must consider the ribbon seal life-history functions associated with sea ice and the potential effects on the vital rates of reproduction and survival.

Our analysis indicates that the late March to early May period in which the peak of ribbon seal reproduction occurs will continue to have substantial ice through the middle of the 21st century. 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 ribbon 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. How resilient will ribbon seals be to these changes?

Observed distributions of ribbon seals indicate that they have adjusted their breeding locations to interannual variations in the position of sea ice (e.g., Fedoseev 1973, Braham et al. 1984, Fedoseev et al. 1988). Burns (1981) remarked that,

> *“Extreme dispersal of ribbon seals within their effective range is associated with years of unusual ice conditions. The formation of extensive ice in the Bering and Okhotsk Seas results in the occurrence of large numbers of these seals further south than they normally occur. The reverse is also true*”.

There has not been, however, any study that would verify whether vital rates of reproduction or survival have been affected by these interannual variations in ice extent and breeding, despite a regular presence by the Soviet seal hunting fleet in the Sea of Okhotsk and Bering Sea for several decades. Whelping, nursing of pups, and maturation of weaned pups could be impacted in years when the ice does not extend as far south as it has typically in the past, because the breeding areas would be farther from the continental shelf break, a zone that seems to be a preferred foraging area during spring (Burns 1981, Lowry 1985). If these conditions occur much more frequently, as anticipated from projections of climate and sea ice for the latter half of this century, reproduction and survival of young would likely be impacted.

Lacking direct studies of ribbon seal vital rates in response to interannual variations in sea ice extent, one approach would be to consider other species as analogs. Harp seals, which are the ribbon seal's closest relative, were observed to suffer breeding failure in 1981 (Sergeant 1991), a very light ice year in the western North Atlantic Ocean, and have been assumed to have had similar failures in other recent years (Hammill and Stenson 2003). However, despite the close relation between the two species, harp seals form very much more dense whelping and molting aggregations, and seem more closely tied to traditional geographic locations than ribbon seals. These traits may make harp seals more vulnerable than ribbon seals to interannual variations in ice extent, and not a reliable analog for assessing the risk posed to ribbon seals by an increase in frequency of years with less ice during breeding. Nevertheless, at some unknown but higher frequency of years with low ice extent, common sense dictates that ribbon seal recruitment would be affected. Lacking relevant data, the most parsimonious approach is to assume that the population has been at equilibrium with respect to conditions in the recent past, and that a change such as more frequent breeding farther from preferred foraging habitats will have some impact on vital rates. Given the uncertainties, the BRT suggests a precautionary conclusion that the anticipated increase in frequency of years with low ice extent in April and May (Sections 4.2.1.1.1.3.4 - 4.2.1.1.1.3.5) is likely to have some impact on recruitment.

The mechanisms for depressed recruitment from increased frequency of years with less ice could include reduced nutrition during the nursing period caused by mothers unable to reach preferred shelf-break foraging areas; pup mortality caused by more frequent failures for mothers to reunite with pups left on the ice during foraging trips; and mortality or reduced condition of maturing weaned pups caused by reduced availability of suitable ice for hauling out.

As described in Section 2.5, ribbon seals have an apparent affinity for stable, clean, moderate-sized ice floes, slightly but not deeply interior to the pack ice edge. Ice of this type is likely to occur annually in the Bering Sea and Sea of Okhotsk through the middle of this century, but it may more frequently be confined to smaller areas or areas farther north than in the past. It is more difficult to determine whether this type of ice will be relatively more or less available as the amount of ice declines as projected through the latter half of the century. The availability of moderately-thick, stable ice floes could logically be expected to influence ribbon seal demography, particularly in May, via survival rates of weaned pups. Burns (1981) noted that pups spend a great deal of time on the ice during a transition period of 2-3 weeks following weaning, presumably developing their capabilities for self-sufficient foraging. Weaned ribbon seal pups tagged with SDRs in 2005-2007 made frequent forays into the water, interspersed with haul-out bouts mostly less than 24 hours in duration (unpubl. data, Peter Boveng, NMML, 7600 Sand Point Way NE, Seattle, WA 98115). Thus, although they are likely dependent on ice, weaned pups may not require ice floes that can persist for weeks to meet their basic haul-out needs. They may, however, be relatively limited in their capability to respond to rapidly deteriorating ice fields by relocating over large distances, a factor that could occur more frequently in the foreseeable future.

There is no evidence that ribbon seals have experienced conditions during the current warming trend that have been severe enough to cause major reductions in survival of young. In 2007, NMFS research cruises in the Bering Sea encountered subadult ribbon seals in approximately the expected proportions. Of 31 ribbon seals caught, 6 were subadults, 22 were adults, and 3 were young of the year (which were commonly encountered but not always pursued for tagging). In other words, the obvious presence of seals in the subadult age class did not indicate that catastrophic losses had occurred in the ribbon seal cohorts produced during the warm years of 2001-2005 (Section 4.2.1.1.1.2.2). Subadult ribbon seals, which molt earlier than adults, during March to mid-May, and which are not constrained by habitat requirements for whelping and breeding, may be the least sensitive to the availability and quality of sea ice.

Adult ribbon seals, which are the last to molt, might be expected to be the most sensitive to the duration of seasonal ice persistence and timing of the ice melt. Tikhomirov (1964) claimed that molting ribbon seals rarely enter the water and that stable ice is critical during this period. 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 ribbon seal), could not complete its molt entirely in the water at temperatures that the species would normally encounter in the wild. Analysis of haul-out records from SDRs (Section 2.5.1) indicated that individual adult ribbon seals do haul out almost continuously for a period of 2-3 weeks, mostly during mid-May to late June, corresponding to the observed peak in molting. As is evident from Figure 14 and Figure 15, sea ice coverage in June will likely be low or absent more frequently in the foreseeable future. The implications of a loss of access to a haul-out substrate during this period are unknown, but they may include energetic costs, reduced fertility, increased susceptibility to skin disorders and pathogens, and possibly increased exposure to any risks that the hair normally protects a seal from (e.g., abrasion from crawling over snow and ice). Many or most recent reports of ribbon seals out of their normal range or habitat have been associated some pelage abnormalities, usually consistent with a disrupted or delayed molt. Unfortunately, the ultimate effect of a lack of a suitable haul-out platform for molting, on adult survival rate, is currently difficult or impossible to model in a way that is not simply a reflection of assumed input values.

The mechanisms identified above for impacts on ribbon seal survival and reproduction in years of low ice extent, poor ice quality, 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. As above, in the assessment of impacts on reproduction, the BRT suggests a precautionary conclusion, that the anticipated increase in frequency of years with low ice extent in April, May, and June is likely to have an impact on survival rates.

The extent to which ribbon seals might adapt to more frequent years with early ice melt by shifting the timing of reproduction and molting is unknown. 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 ribbon 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.

Several factors are noteworthy for their potential to mitigate the impacts on ribbon seals from future sea-ice scenarios depicted in Figure 17. First, adult ribbon 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). Therefore, they may be capable of considerable shifts in distribution to ensure contact with suitable ice through the molt period, especially in the Bering Sea where there is access through Bering Strait to the Chukchi Sea, in which ice will persist more frequently in June. Second, and very importantly, the models on which the BRT based its assessment of future ice conditions used a spatial resolution (~1° of latitude) that is much coarser than the scale at which ribbon 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 in areas where ribbon seals remain capable of finding suitable ice. For example, Figure 14 shows zero ice in June 2008. Yet, on 27 June 2008, the NOAA ship *Oscar Dyson* encountered a field of ice with numerous ribbon and spotted seals at 60°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 (Cavalieri et al. 2004, updated daily). And third, the age of maturation for females has been very low and pregnancy rates have been high in the recent past (Section 2.7), implying that foraging conditions have been favorable, a scenario more likely to reflect population growth rather than equilibrium; if so, there may be some capacity to withstand a reduction in vital rates for the near future without incurring an actual population decline.

In summary, several mechanisms were identified that could potentially translate more frequent future years of reduced spring ice extent or ice quality into reduced vital rates of ribbon seal reproduction and survival. These potential impacts are premised on the simple assumption of a population at equilibrium with conditions in the recent (cooler) past and the related common-sense notion that changes such as displacement of breeding locations or reduced availability of preferred ice types will have some energetic costs that will ultimately be reflected in vital rates. In the absence of relevant data, it is infeasible to state the quantitative magnitude of the anticipated impacts.

4.2.1.1.4.2 Ocean-condition-related impacts

Ocean acidification is likely to have increasingly profound impacts on the ecosystem structure in the ribbon seals' habitats. The exact nature of these impacts cannot be predicted, and some likely will amplify more than others.

Ribbon seals eat a variety of fishes (e.g., walleye pollock, saffron and Arctic cod, eelpout, and Greenland halibut), cephalopods (octopuses and squids), and crustaceans (primarily shrimps and mysids) (Lowry 1985). As shown in Section 4.2.1.1.3.2.5, impacts of ocean acidification are expected to stem not only from interference with calcifying life stages, but from more general physiological and chemical processes vital to a broad range of species. For example, upper trophic level pelagic species' abundance may decline if their early life stages consume prey items (e.g., pteropods (Comeau et al. 2009, Comeau et al. 2010)) that cannot survive the added stress of ocean acidification. Pteropods are important food sources for larval and juvenile walleye pollock, Pacific herring, and cod which are important prey of ribbon seals. Therefore, the loss of calcifying species like pteropods from the ecosystem could have a cascading effect on ribbon seals. But there are also a number of potential direct impacts of highly elevated CO_2 on embryo and larval fish that could affect the availability of cod and other fish as a food source for ribbon seals in the future (Ishimatsu et al. 2005). Among invertebrates, squid are expected to be particularly sensitive.

Changes in ribbon seal prey, anticipated in response to ocean acidification, have high potential for negative impacts. These ecosystem responses may have very long lags as they propagate through trophic webs. Although ribbon seals' varied diet would appear to confer some flexibility or resilience to shifts in prey availability, major disruptions in the amount of productivity reaching pelagic, upper trophic species would be expected to have demographic impacts. Survival of juvenile ribbon seals would be expected to be the most sensitive, as their diet is narrower and more skewed toward invertebrates. Sufficiently large ecosystem shifts that persist more than a few years could also impact adult survival and reproductive rates. The range of potential ecological scenarios, however, is extremely complex and may even include some that could be ameliorative or beneficial to ribbon seals. The vast preponderance of ocean acidification impacts that have been identified, however, seem negative for ribbon seal prey. In the absence of compelling evidence for specific positive effects, the net effect of ocean acidification is expected to be negative.

4.2.1.1.5 Potential for resilience to climate-related impacts

Ultimately, the question of whether ribbon seals, as a species, can survive a major shift to a warmer climate hinges on their capability to adapt to altered physical and biological conditions. Short-term adaptations are already a part of ribbon 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 even less certain. Given that the current genetic diversity in ribbon seals appears to be high (Quakenbush and Citta 2008), the species likely retains the genetic raw materials for adaptation to conditions reflected in its evolutionary history, given sufficient time to respond. Paleoclimate reconstructions indicate that ribbon seals have experienced many large deviations from current climatic conditions during the past 4 to 8 million years since diverging from their common ancestor with harp seals.

Pre-Quaternary (>2.5 mya) temperatures and atmospheric CO_2 levels were generally higher than present (Jansen et al. 2007). In the Mid-Pliocene (about 3 mya) there was a sustained period with high CO_2 concentrations (up to 30 ppm above present), reduced ice sheets, and global mean temperatures 2-3^{o}C higher than present, mostly due to high-latitude warming (Jansen et al. 2007). Thus, the evolution of the ribbon seal includes at least one period when the conditions were in many respects similar to consensus model projections for high northern latitudes in the late 21st century.

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). Because sea levels were reduced during the cold (glacial) phases, much of the ribbon seal's present range in the Bering and Chukchi seas was above sea level for a large portion of the time (Hopkins 1973). 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, ribbon 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. Moroever, none of the paleoclimatic shifts were accompanied by human-caused environmental perturbations such as pollutants, noise, fisheries, and ocean acidification. So, a great deal of uncertainty remains about how quickly ribbon 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, 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). 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 ribbon 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 Younger Dryas interval has matched its magnitude or rapidity (Alley 2000). Thus, there is ample evidence that ribbon seals have adapted successfully many times to both large and rapid ecological changes. This paleoclimatic history is not on its own an assurance that ribbon 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 several million years.

The life history of ribbon 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 (see also Section 4.3.5):

- Ribbon seals are highly mobile and migratory, providing the potential for adjusting to changes in conditions by moving to more suitable habitat patches.
- Ribbon seals are known to have a diet that is ecologically and trophically diverse, even though the data come primarily from only the ice-associated part of the species' distribution and annual cycle. They are able to forage over a wide range of ocean depths. These characteristics should enhance resilience to climate-related changes in prey communities.
- Initial data from satellite tracking, and a lack of observations of large groups of ribbon seals at sea, indicate that they tend to be highly dispersed and mostly solitary during the ice-free

season. This should 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).

Several changes to the ribbon seal's physical and biological environment were identified as likely to occur in the foreseeable future, most with negative or uncertain anticipated effects on the population. The anticipation of negative effects is based primarily on the common-sense notion that the observed habitat preferences of ribbon seals reflect requirements for maintenance of the present population size. This is a basic ecological principle, with numerous examples of species that have declined or even gone extinct in response to environmental change. In the absence of data supporting a quantitative assessment of the impacts, however, it is necessary to consider qualitatively whether and to what extent the species is capable of adjusting to the change.

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

4.2.2.1 Commercial harvest

Commercial harvesting of ribbon seals began in Russia in 1932, when ships were first used to access the seals in far offshore ice (Heptner et al. 1976). Hunting was conducted only in the Sea of Okhotsk during the first three decades, and the relatively low harvest levels during the first two decades did not affect the natural state of the population (Heptner et al. 1976). The commercial harvest in the Sea of Okhotsk increased substantially during the mid-1950s as the sealing fleet grew in size, skill, and intensity (Krylov et al. 1964, Fedoseev 2000). Commercial harvesting expanded to the Bering Sea in 1961, and unrestricted hunting continued in both seas for 8 years (Fedoseev 1973, Fedoseev 2000). Although harvest statistics reported in the literature vary from source to source, it is clear that the commercial harvest was very high during 1957-1968 (Table 3) with total catches ranging between 11,300 and 27,100 ribbon seals per year (Fedoseev 1973).

Fedoseev (2000) also noted that the actual number of seals killed was always higher than the reported number of seals harvested, since on average 15-20% of the ribbon seals that were shot escaped into the water or sank before they could be collected. This heavy exploitation resulted in a number of adverse effects on the species including a lowering of the average age of the population, a decrease in reproductive capacity, and an overall reduction in abundance (Shustov 1965b). Quotas were imposed on the Soviet sealing fleet beginning in 1969, with limits set at 7,000 ribbon seals per year in the Sea of Okhotsk and 3,000 ribbon seals per year in the Bering Sea (Fedoseev 1973).

Table 3. -- Number of ribbon seals harvested in the Sea of Okhotsk and Bering Sea by the Soviet commercial sealing fleet during 1954-1972 (Source: Fedoseev 1973, Table 9).

Year	Sea of Okhotsk	Bering Sea	Total
1954	2,200	-	2,200
1955	9,300	-	9,300
1956	5,600	-	5,600
1957	17,200	-	17,200
1958	11,300	-	11,300
1959	18,500	-	18,500
1960	16,000	-	16,000
1961	15,500	3,400	18,900
1962	15,000	12,100	27,100
1963	13,500	8,800	22,300
1964	16,000	6,000	22,000
1965	5,100	13,500	18,600
1966	2,600	15,500	18,100
1967	11,200	11,500	22,700
1968	10,300	6,200	16,500
1969	4,200	2,700	6,900
1970	5,200	3,900	9,100
1971	7,300	-	7,300
1972	7,400	-	7,400

By the early 1980s, the quota in the Sea of Okhotsk was reportedly further reduced to 3,500 ribbon seals per year (Popov 1982); however, several sources suggest that these regulations were not actually followed. Fedoseev (2002) reported that the commercial harvest was 5,000-6,000 ribbon seals per year in the Sea of Okhotsk during 1969-1992, and an analysis of Soviet sealing logs during the same period indicated that harvest levels were actually even higher during 1982-1989, ranging between about 9,000 and 15,000 ribbon seals per year in the Sea of Okhotsk (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, October 3, 2008, pers. comm.). Grachev (2006) also published data from the Sea of Okhotsk indicating that commercial harvest levels remained high during the early 1990s (Table 4). Soviet commercial harvest levels in the Bering Sea apparently remained relatively low (i.e., 3,000-4,000 ribbon seals per year) throughout this time (Fedoseev 2002; V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, October 3, 2008, pers. comm.).

Table 4. -- Number of ribbon seals harvested in the Sea of Okhotsk by the Russian commercial sealing fleet during 1990-1994 (Source: Grachev 2006).

Year	No. of vessels	Ribbon seals harvested
1990	4	14,625
1991	4	14,626
1992	3	11,381
1993	3	13,447
1994	1	3,519

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., skins, oil, animal food, and fertilizer) became unprofitable in the new economic conditions (Grachev 2006). The commercial harvest of ribbon seals from large ice-reinforced ships ended in the Bering Sea in 1991 and in the Sea of Okhotsk in 1994 (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, August 20, 2008, pers. comm.). In the early 2000s, the Russian Federation increased their quotas on ribbon seals in Russian waters, with total allowed catches ranging between 16,700 and 21,000 individuals per year during 2002-2005 (Marine Mammal Council 2008). However, the actual harvest levels during this period were only a small fraction of these figures (Grachev 2006), and current harvest levels remain very low, likely ranging in the tens to few hundreds of ribbon seals per year (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, August 20, 2008, pers. comm.).

The recent high quotas for ribbon seals in Russian waters present a potential risk. If economic conditions were to change so that commercial sealing was once again profitable, allowing such high levels of harvest could adversely affect the species, as occurred during the 1950s and 1960s. Therefore it is of particular concern that studies were recently conducted in Russia to develop new, more profitable uses of raw materials obtained from marine mammals, such as biologically active substances, collagen, bacteriological peptone, and omega-3 fatty acid, for use in the medical, pharmaceutical, and veterinary industries (Berzin et al. 1990, Grachev 2006). Grachev (2006) proposed that 33,000 seals could be harvested per year by three commercial sealing vessels (15,000 of which were suggested to be ribbon seals) and stated that the new industry would become profitable in 3-5 years, suggesting that commercial harvesting would last a longer term. Grachev also stated that the new industry would be sustainable; however, the proposed level of harvest is comparable to the commercial harvest levels of the 1950s and 1960s, which was shown to be unsustainable (Shustov 1965b) and “disastrous” to this species (Fedoseev 1973).

Commercial hunting of marine mammals is prohibited in U.S. territorial waters by the Marine Mammal Protection Act (MMPA) (16 U.S.C. 1361 et seq.), and therefore, is not considered a threat to the species in this part of its range.

4.2.2.2 Subsistence hunting

Numbers of ribbon seals harvested for subsistence use by indigenous hunters in Russia and Alaska are considered insignificant by most researchers, primarily due to the difficulty of accessing the seals in far offshore ice (Shustov 1965b, Heptner et al. 1976, Burns 1981, Lowry 1985, Kelly 1988, Fedoseev 2000). Historically, the subsistence catch of ribbon seals in Russia was “very limited” and the “level of hunting had hardly any impact on the seal reserves and the population maintained a natural equilibrium” (Heptner et al. 1976). Fedoseev (2000) stated that prior to the commercial harvest, ribbon seals were “practically not hunted” by Russian Natives. The current subsistence harvest in Russia is reportedly very low and is not thought to be a threat to the species (Hovelsrud et al. 2008; V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, August 20, 2008, pers. comm.).

In Alaska, ribbon seals are harvested in low numbers by Alaska Native subsistence hunters from St. Lawrence and Little Diomede Islands, and to a lesser extent, from villages along the Chukchi Sea coast (Kelly 1988). Burns (1981) stated that the subsistence harvest in Alaska was less than 100 ribbon seals annually during 1968-1981. Kelly (1988), citing a personal communication with the Eskimo Walrus Commission, also put the subsistence take in Alaska at less than 100 ribbon seals per year. Lowry (1985) reported that the annual harvest is usually less than 250 ribbon seals, and that this number was highly dependent on the spring ice extent which determines the proximity of the ice front (and seals) to coastal villages. The highest recorded annual subsistence harvest in Alaska was estimated to be 1,100 ribbon seals in 1967, a year characterized by unusually warm winter temperatures, storms, and prevailing south winds which fragmented the Bering Sea ice field and forced the ice edge (and ribbon seals) much farther north than normal, near the vicinity of St. Lawrence and Little Diomede Islands, where ribbon seals were hunted in much higher numbers than normal (Burns 1969). As of August 2000, the average subsistence harvest in Alaska was estimated to be 193 ribbon seals per year; however, some of the data that were used to arrive at this figure were extrapolated and did not have associated measures of uncertainty (Angliss and Outlaw 2008). Currently, there are no comprehensive efforts to quantify the level of harvest of ribbon seals by all Alaska communities; however, the USFWS collects information on the level of ribbon seal harvest in five communities incidental to their Walrus Harvest Monitoring Program. Results from this program indicated that an average of 13 ribbon seals were harvested annually at Little Diomede, Gambell, Savoonga, Shishmaref, and Wales during 1999-2003 (Angliss and Outlaw 2008); the actual number could be higher if ribbon seals are taken outside the 1-2 months in spring when the program is active. These communities are likely to have the highest levels of ribbon seal subsistence harvest in Alaska due to their proximity to ribbon seal breeding and molting areas and movement corridors. Because ribbon seals do not normally frequent other coastal areas of Alaska, they are rarely encountered by hunters in those areas.

Although the estimates of subsistence harvest in Alaska are varied, all are low and sustainable relative to the population size. Even if future subsistence harvest levels were to increase by an order of magnitude (e.g., to >1000 seals per year) as occurred during 1967 and which may be expected to occur if ribbon seals are forced to inhabit a reduced ice field closer to hunting villages in the northern Bering Sea, the population would not likely be seriously impacted.

4.2.2.3 Scientific and educational utilization

The MMPA generally prohibits the “taking” of marine mammals in U.S. waters, but does provide some exceptions, such as for scientific and educational purposes. However, the permitting and authorization process regulating these activities is fairly stringent, the number of allowed takes is typically very low, and the number of research permits granted is likely also very limited.

There are no similar laws providing protection to marine mammals in Russia, but the current utilization of ribbon seals for scientific or educational purposes is reported to be low or non-existent there as well (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, August 22, 2008, pers. comm.).

4.2.3 Diseases, Parasites, and Predation

4.2.3.1 Diseases

Serological surveys indicate that herpesvirus infections occur in several species of pinnipeds from waters between Alaska and Russia, including ribbon seals (Zarnke et al. 1997, Kennedy-Stoskopf 2001, House et al. 2002, Moeller 2003, Burek et al. 2005). Zarnke et al. (1997) tested 24 serum samples from ribbon seals collected between 1978-1979 in the Bering Sea for the presence of herpesvirus antibodies. Seven of the 24 (29%) tested positive for phocid herpesvirus-1 (PhHV-1) antibodies, 7 (29%) tested positive for phocid herpesvirus-2 (PhHV-2) antibodies, and 5 (21%) tested positive for antibodies to both PhHV-1 and PhHV-2. Sera from 15 (63%) were found to be seronegative to both PhHV-1 and PhHV-2 (Zarnke et al. 1997). Quakenbush and Citta (2008) tested samples from 14 ribbon seals collected near Little Diomede Island, Alaska; all were seronegative for antibodies to PhHV-1, PhHV-2, and phocine distemper virus (PDV). Serum samples were collected from 63 ribbon seals in the Bering Sea in spring of 2007-2010, six (9.5%) of which tested seropositive for antibodies to PhHV-1 (unpubl. data, Peter Boveng, NMML, 7600 Sand Point Way NE, Seattle, WA 98115; Tracey Goldstein, University of California, 25 January 2012, pers. comm.).

Most animals that test seropositive to herpesviruses do not demonstrate clinical disease (Moeller 2003). PhHV-1 is highly contagious and transmission is primarily via the respiratory tract (Zarnke et al. 1997). Routes of transmission for PhHV-2 are unknown, although the cell-associated nature of PhHV-2 makes airborne transmission unlikely. Fatal PhHV-1 infections have occurred in seals with immature or compromised immune systems (Zarnke et al. 1997). Herpesviruses are considered enzootic in the waters of Alaska and Russia; however, because PhHV-1 is capable of causing morbidity and mortality in immuno-compromised seals, the potential for epizootics of clinical disease exists (Zarnke et al. 1997).

Serum antibody prevalence of *Neospora caninum* and *Toxoplasma gondii* was examined in serum samples from 14 ribbon seals collected in Alaska waters between 1976 and 1998 (Dubey et al. 2003). They reported the first known occurrence of *T. gondii* antibodies in ribbon seals, although their statement is contradicted by data presented in their Table 2 and within the text summarizing the results of the study, in which it is stated “Antibodies to *T. gondii* were found in all species of marine mammals tested except ribbon seals and beluga whales”. *Neospora caninum* and *T. gondii* are related protozoans that cause mortality in many species of domestic and wild animals, and *N. caninum* can cause encephalitis in dogs, cattle, sheep, goats, deer, and horses (Dubey et al. 2003). Several harbor, ringed, and bearded seals from Alaska tested positive for antibodies to *T. gondii* and *N. caninum*; one spotted seal sample from Alaska tested positive to *T. gondii* antibodies, but no samples tested positive to *N. caninum* antibodies. Two main sources of postnatal *T. gondii* infection are ingestion of oocysts in contaminated food or water and the ingestion of *T. gondii* infected tissues (Dubey et al. 2003). Felids are the only known hosts that can excrete environmentally resistant oocysts, and surface runoff of contaminated cat feces was believed to be a factor in *T. gondii* infection in sea otters (*Enhydra lutris*) (Miller et al. 2002). Fujii et al. (2007) found four ribbon seals sampled near Hokkaido, Japan were seronegative for antibodies to *Toxoplasma gondii* and *Neospora caninum*. Harbor and spotted seals, in larger samples, tested seropositive. Serum collected from 63 ribbon seals from the Bering Sea during spring 2007-2010 were tested for antibodies to *T. gondii* and *Sarcocystis neurona*. All of the ribbon seals were seronegative (unpubl. data, Peter Boveng, NMML, 7600 Sand Point Way NE, Seattle, WA 98115). *S. neurona* is a protozoan that is related to *T. gondii* and has caused encephalitis in a Pacific harbor seal (Miller et al. 2001).

Quakenbush and Citta (2008) found *Brucella abortus* antibodies in 2 of 14 ribbon seals collected near Little Diomede Island, Alaska; both were young females. Antibodies to *Brucella* spp. were found in 3 of 57 ribbon seals (5.3%) sampled in the Bering Sea. Further testing with PCR and MLVA genotyping indicated that the *Brucella* spp. in one of these seals was most similar to *B. abortus* (unpubl. data, Peter Boveng, NMML, 7600 Sand Point Way NE, Seattle, WA 98115). *Brucella* is known to cause reproductive problems in marine mammals, including placental infections and abortion (Miller et al. 1999) and has been identified in harbor seals in the Gulf of Alaska (Zarnke et al. 2006).

Danner et al. (1998) tested 14 ribbon seals from Alaska for antibodies to influenza A, but all were seronegative. An additional 63 ribbon seals from the Bering Sea were tested for influenza A antibodies, and 3 (4.8%) were seropositive (unpubl. data, Peter Boveng, NMML, 7600 Sand Point Way NE, Seattle, WA 98115). Low prevalences of influenza A antibodies have been found in ringed seals from Alaska (3.1%) and Arctic Canada (2.5%) (Danner et al. 1998, Nielsen et al. 2001). However, influenza A strains have caused mass mortality events in harbor seals on the New England coast multiple times in the last 30 years, the most recent of which occurred fall 2011 (Geraci et al. 1982, Hinshaw et al. 1984, Callan et al. 1995, Anthony et al. 2012).

Barlough et al. (1987) tested serum samples from four ribbon seals and found no antibodies to Tillamook calicivirus (TCV), although TCV seropositive samples were found in California sea lions (*Zalophus californianus*) and Steller sea lions (*Eumetopias jubatus*) collected over a wide area from the Bering Sea to the Santa Barbara Channel.

Fifty-seven ribbon seals from the Bering Sea were also tested for antibodies to six *Leptospira interrogans* serovars (bratislava, canicola, grippotyphosa, hardjo, icterohemorrhagiae, pomona) and all were seronegative (unpubl. data, Peter Boveng, NMML, 7600 Sand Point Way NE, Seattle, WA 98115).

Dermatitis is another disease known to commonly occur in ribbon seals (Roest 1964, Shustov 1969b, Fay et al. 1978, Kelly 1988). Microbial infections to the skin are a threat to seals during the molt, when they are particularly vulnerable to skin infections (Fay et al. 1978). If climate-related changes in sea ice cause ribbon seals to prolong their molt, they could be more susceptible to these infections.

Although antibodies to several pathogens have been found in ribbon seals and sympatric phocid species, no mass mortality events have been observed of the type and scale that occurred in European harbor seals (Härkönen et al. 2006). The BRT found only one reference to an event that may have indicated a significant outbreak of disease. The event, documented only by a Russian web page (Kavra 2004), involved about 100 emaciated and ill-looking ribbon seals observed on ice near Kresta Bay, Chukotka, Russia, in early April 2004. The seals were near open water but stayed on the ice, even when approached by people. Similar events were reported to have occurred 1-2 times per decade in that area.

In July and August 2011, hunters and researchers began finding higher than normal numbers of sick and dead ringed seals along the coast of the North Slope of Alaska (National Marine Fisheries Service 2013). Symptoms exhibited by the sick pinnipeds included skin ulcers, abnormal hair loss (alopecia), delayed molting, labored breathing and lethargy. Necropsies revealed significant lesions in the skin, respiratory system, liver, lymphoid system, and heart. In December 2011, after hundreds of pinnipeds were found with similar symptoms, the National Marine Fisheries Service and U.S. Fish and Wildlife Service declared the pinniped Arctic disease event a multi-species unusual mortality event (UME). Species with UME symptoms included ribbon, ringed, spotted, and bearded seals and walrus, which were found in northern Alaska, Canada (Northwest Territories), Russia (Chukotka), and Japan.

Most pinnipeds with UME symptoms were ringed seals from the North Slope, but sick walruses, spotted and bearded seals were also found on the North Slope and in the Bering Strait region. Only one ribbon seal, a yearling, was reported with UME symptoms. The ribbon seal was found hauled out near Yakutat, Alaska, and it was mostly bald, sickly looking, and lethargic. It was captured and sent to Anchorage to be examined by pathologists and veterinarians, but by the time it arrived, it had to be euthanized.

A large effort is underway to determine the cause or causes of the UME (National Marine Fisheries Service 2013). Samples from diseased seals have been tested for a wide variety of viral and bacterial pathogens known to affect marine mammals. However, samples were all negative for phocine distemper virus, influenza A/B, leptospirosis, calicivirus, orthopoxvirus, poxvirus, herpesvirus, morbillivirus, papillomavirus, as well as for less well-known viruses including parapoxvirus, circovirus, lentivirus, retrovirus, gammaherpesvirus, arterivirus, adenovirus, coronavirus, enterovirus, flavivirus, orbivirus, orthrohepadnavirus, paramyxovirus, rhabdovirus, papovavirus, foot and mouth disease, vesicular exanthema of swine virus, pan picornavirus, and rickettsial agents. Due to the timing of the UME in relation to the Fukushima Daiichi nuclear power plant accident in Japan (March 2011), radiation exposure was a concern, so tissues from healthy and sick animals were tested for radionuclides. Preliminary testing indicated that radiation levels in all samples were within the typical background range for Alaska and were not high enough to directly cause the UME symptoms observed in the pinnipeds. Further testing for presence of cesium-134 and cesium-137 is also being conducted. Tests for common harmful algal blooms were negative for domoic acid, saxitoxin (paralytic shellfish poisoning), and okadaic acid. Currently, the cause of the UME is still unknown, but additional bacterial and fungal testing and advanced molecular screening for unknown viruses are being conducted in a continuing effort to determine an explanation (National Marine Fisheries Service 2013).

There are a couple possibilities that may explain why only one sick ribbon seal was found during this UME. Ribbon seals are primarily pelagic and solitary during the summer and fall months when most of the UME seals were found. Thus, they might not have gotten sick in the same numbers as other ice seals because disease transmission among individuals may be limited due to their solitary lifestyle. However, it is also possible that many ribbon seals did become sick during the UME, but because they are pelagic they may have died at sea and not stranded in areas where they could be found.

4.2.3.1.1 Potential influence of climate change on disease

Changes in climate may affect the health of northern marine mammals both directly and indirectly. Although much of the literature about the potential influence of climate change on health and disease is speculative, an increasing number of studies exist on the effects of changing environmental conditions and climate on ocean health (Harvell et al. 1999, ACIA 2005, Burek et al. 2008). In order to measure both direct and indirect effects of climate change, baseline data on the health of northern marine mammal populations are needed immediately (Burek et al. 2008). The lack of baseline information on normal disease levels and epidemiology preclude the ability to assess novel disease outbreaks, increases in pathogen transmission, and decreases in host resistance (Harvell et al. 1999, Burek et al. 2008). Potential influences of climate change on the health of northern marine mammals include a decline in overall body condition, habitat loss, exposure to new diseases or hosts, and direct and indirect effects of human activity (Harvell et al. 1999, Ward and Lafferty 2004, ACIA 2005, Burek et al. 2008).

Habitat loss, particularly loss of sea ice, may put additional physiological stressors on animals. Such stressors may compromise host disease resistance, putting individuals at an increased risk of disease and susceptibility to epizootics (Harvell et al. 1999, Burek et al. 2008). An increase in host density, especially if a result of decreased habitat, could lead to an increase in disease transmission and occurrence (Ward and Lafferty 2004, Burek et al. 2008). One secondary effect of habitat loss could be a decline in overall health or body condition, which could make the animals more susceptible to disease (Burek et al. 2008); however, based on an examination of 59 ribbon seals collected in the Bering Sea, Quakenbush and Citta (2008) found that ribbon seal body condition had not changed significantly since the 1960s.

Changes in climate and human activities have resulted in novel and expanded distributions and transport of some species, which can result in the introduction of pathogens and previously unexposed host populations (Harvell et al. 1999, Ward and Lafferty 2004, Burek et al. 2008). Humans may have facilitated the introduction of terrestrial and domestic animal diseases to marine mammals, as in the case of canine distemper virus (CDV) in Antarctic seals (Bengtson et al. 1991). Both CDV and PDV (phocine distemper virus) have been determined to be endemic in populations of Alaska carnivores (Harvell et al. 1999). Most new diseases are not caused by new micro-organisms, but instead by exposure of known agents to new hosts (Harvell et al. 1999). A warming climate and continued reduction in sea ice could also result in the northward expansion of sub-Arctic species, which could increase the potential for disease (Moore and Huntington 2008). For example, an outbreak of morbillivirus in northern Europe in 1988 is believed to be the result of direct exposure of carrier Arctic and sub-Arctic seal species to an immunologically naïve population of harbor seals (*Phoca vitulina*) (Burek et al. 2008). Changes in climate and weather can lead to range extension for some pathogens, changes in survivability of pathogens, and influence the timing of disease outbreaks (Burek et al. 2008). An increase in water temperature can enhance the survivability of some marine bacterial pathogens, such as *Vibrio parahaemolyticus*, a known pathogen of marine mammals (Burek et al. 2008). Helminth parasites, which are known to infect ribbon seals, are very susceptible to changes in temperature and humidity (Harvell et al. 2002, Burek et al. 2008).

4.2.3.2 Parasites

Helminths are common parasites of ribbon seals (Shustov 1969b, Eley 1981, Shults 1982, Fortunato 1985, Shults and Frost 1988, Hoberg 1992, Measures 2001). The helminth fauna known to parasitize ribbon seals include various species of cestodes, trematodes, nematodes, and acanthocephalan worms (Table 5). Popov presented data on helminth parasites found in ribbon seals collected in the southern (1975, cited in Measures et al. 1997) and northern (1976, cited in Shults and Frost 1988) Sea of Okhotsk. Shustov (1969b) and Delamure et al. (1976, cited in Shults and Frost 1988) summarized helminth parasites found in ribbon seals from the western Bering Sea, and Delamure and Yurakhno (1974, cited in Shults and Frost 1988) examined helminths from ribbon seals from the northwestern Bering Sea. Shults and Frost (1988) present data on helminth parasites of ribbon seals and their intermediate hosts from the central Bering Sea (Table 5).

Table 5. -- Helminth species of ribbon seals from the Bering Sea and Sea of Okhotsk. Modified from Shults and Frost (1988).

Cestodes

Anophryocephalus ochotensis
A. skrjabini
A. pacificus
Diplogonoporus tetrapterus
Diplogonoporus sp.
Diphyllobothrium cordatum
D. lanceolatum
Diphyllobothrium sp.
Diphyllobothriidae gen. sp.
Pyramicocephalus phocarum

Trematodes

Orthosplanchnus fraterculus
O. *arcticus*

Nematodes

Contracaecum osculatum
Pseudoterranova decipiens
Phocascaris cystophorae
P. phocae

Nematodes (cont'd)

Anisakis simplex
A. pacificus
Anisakis sp.
Anisakidae gen. sp.
Terranova azarasi
T. decipiens
Terranova sp.
Otostrangylus circumlitus
Dipetalonema spirocauda

Acanthocephala

Corynosoma semerme
C. *strumosum*
C. *validum*
C. *villosum*
C. *hadweni*
C. *ventronudum*
Bolbosoma nipponicum
Bolsosoma sp.

Shults and Frost (1988) identified helminths from ribbon seals in each of three collection areas of the central Bering Sea between 1976 and 1979: Area I, between the Pribilof Islands and St. Matthew Island; Area II, between St. Matthew and St. Lawrence Islands; and Area III, north of St. Lawrence Island. The lungs, heart, liver, stomach (including contents), and entire intestinal tract were examined for the presence of helminths. A total of 13 species of helminth parasites were found in the 61 ribbon seals collected between March and June from the southern edge of the spring pack ice in the central Bering

Sea (Shults and Frost 1988). The species found include: *Anophryocephalus ochotensis*, *Diphyllobothrium cordatum*, *D. lanceolatum*, *Orthosplanchnus fraterculus*, *Contracaecum osculatum*, *Pseudoterranova decipiens*, *Dipetalonema spirocauda*, *Corynosoma semerme*, C. *strumosum*, C. *validum*, C. *villosum*, C. *hadweni*, and *Bolbosoma* sp.; four of these species (*D. cordatum*, *D. lanceolatum*, O. *fraterculus*, and C. *hadweni*) were new host records. *Diphyllobothrium cordatum* have also been recovered from ribbon seals in the Chukchi Sea (Shults 1982). Eighteen fish species known to be prey species of ribbon seals were collected and examined as possible intermediate hosts of the parasites. All 10 taxa of larval helminths identified from the fish specimens examined have previously been found as adults in ribbon seals of the Bering Sea or Sea of Okhotsk (Shults and Frost 1988). Konishi and Sakurai (2002) examined definitive hosts of *C. osculatum*—including Steller sea lions, northern fur seals (*Callorhinus ursinus*), spotted seals, and ribbon seals—and found that few larvae mature to adulthood except in ribbon seals. Based on these findings, Konishi and Sakurai (2002) believe the distribution of ribbon seals in the Sea of Okhotsk influences the infection of *C. osculatum* in walleye pollock.

Shults and Frost (1988) found two genera of cestodes (*Diphyllobothrium* and *Anophryocephalus*), a single species of trematode (*Orthosplanchnus fraterculus*), and two genera of acanthocephalans (*Bolbosoma* sp. and *Corynosoma* spp.) in the small intestines of ribbon seals*.* The presence of *O. fraterculus* in the small intestine may have been due to postmortem migration from the bile ducts, as it is commonly found in the bile ducts and gall bladder of bearded seals, sea otters, and walruses (*Odobenus rosmarus*). *Corynosoma semerme* was found at the ilel-caecal junction. *Contracaecum osculatum* was found in the stomach and small intestine, *Pseudoterranova decipiens* in clusters attached to the stomach wall, and *Dipetalonema spirocauda* in the heart and testicular sheath. Takahashi (1999) examined stomachs from 28 ribbon seals captured off Hokkaido for the presence of nematodes. Adults of *C. osculatum*, *P. decipiens*, and *P. cystophorae* were found; larvae of *C. osculatum*, *Phocascaris* sp., *Anisakis simplex*, and *P. decipiens* were also found. Fourth stage larvae of *Phocascris* sp. were dominant among the larvae identified; however, its adult stage was not commonly found suggesting that the ribbon seal is not an important host of this species (Takahashi 1999). Eley (1981) reported on the first known occurrence in ribbon and bearded seals of *D. spirocauda*, also found in ringed, spotted, and harbor seals examined from Alaska. These heartworms were found primarily in the right ventricle of the heart, although it also occurred in other areas of the heart and pulmonary artery.

The effects of helminth infection on ribbon seals are unknown (Shults and Frost 1988, Measures 2001). Shults and Frost (1988), citing a dissertation by Yurakhno (1971, original not seen), reported that *Orthosplanchnus arcticus* causes severe growth of connective tissue around ducts and vessels of the liver, as well as between and within the liver lobules; *Bolbosoma nipponicum* often perforates the intestinal wall, and *Phocascaris cystophorae* severely affects the alimentary tract. That study also stated that helminths are believed to be responsible for the high mortality rate in both young and old seals, and that helminth infections are harmful to pregnant females, based on a report of a 3-year-old female with 372 helminths present (species not specified) giving birth to a dead pup. Nematode infestations in ribbon seals caused ulcers and damage to the mucosa membranes, submucosal, and muscular layers of the stomach and small intestine (Shustov 1969b). Of the helminth species found in the Sea of Okhotsk ribbon seals, *B. nipponicum*, C. *osculatum* and *D. spirocauda* were considered to be the most pathological (Popov 1975, cited in Measures et al. 1997). None of the ribbon seals examined by Shults and Frost (1988) exhibited any of the pathological conditions; they believe helminths play a limited role in the mortality of ribbon seals in the Bering Sea.

Otostrongylus circumlitus is a large parasitic roundworm found in phocids, including ribbon seals; its distribution is Holarctic. This lungworm is most often found in the primary airway, although the pulmonary artery, right ventricle of the heart, and blood vessels of the liver are occasionally infected (Measures 2001). Infections occur primarily in seals less than 1 year old. It is believed to influence the health and diving ability of the seal, affecting the feeding, growth, and survival. Fatal infections have occurred (Measures 2001). *O. circumlitus* is not known to be a vector of viral, bacterial, or protozoan pathogens, as has been demonstrated by other nematodes.

Rausch et al. (1956) sampled 310 seals from the Arctic coast and St. Lawrence Island and tested them for the presence of *Trichinella*. Larvae were recorded from two seals. Identifications were not made to the species level for some seal specimens, and the analyses were done on the group as a whole as "phocids". The majority of specimens were ringed and "harbor seals" (likely spotted seals, given their origin from St. Lawrence Island and the Arctic coast); however, a few ribbon seals were also included. Therefore, it is unknown which species tested positive for *Trichinella*, although its presence is confirmed in confamilial sympatric species. Although there are no known reports of *Trichinella* in ribbon seals, this parasite does have a circumpolar Arctic distribution in other marine mammals (Forbes 2000). It is commonly found in polar bears, Arctic foxes (*Alopex lagopus*), domestic dogs (*Canis familiaris*), and increasingly in walruses where it presents a significant zoonotic hazard. *Trichinella* has been reported infrequently in bearded seals and ringed seals, and there is one known case in a beluga whale (*Delphinapterus leucas*). Isolates from marine mammals have been identified as *Trichinella native*, which are cold tolerant and infectious to humans (Forbes 2000).

The scarcity of ectoparasites in ribbon seals has been attributed to the species' low level of gregariousness (Fay et al. 1979). Fay and Furman (1982) examined 58 ribbon seals for the presence of halarachnid mites (a nasal mite known to affect other pinniped species in Alaska waters) in the respiratory tract and nasal passage, and none were infected. Anopluran lice (*Echinophthirius horridus*) occur in low numbers in ribbon seals (Measures 2001). *Acanthocheilonema spirocauda* infections are commonly reported in pinnipeds, including ribbon seals (Eley 1981, Shults and Frost 1988, Leidenberger et al. 2007). *Acanthocheilonmea spirocauda* is a parasitic roundworm inhabiting the right ventricle of the heart and pulmonary arteries of pinnipeds, which can cause cardiovascular and pulmonary arterial lesions; severe infections may occlude the arteries (Measures et al. 1997). Leidenberger et al. (2007) suggest the possibility that seal lice, *Echinophthirius horridus*, serve as an intermediate host for transmitting the heartworm, *A. spirocauda*, among seals. As is the case with heartworms, seal lice are frequently found on weak and young animals, yet rarely on healthy adult seals.

4.2.3.3 Predation

4.2.3.3.1 Past and present scenarios

Direct observations or data on predation of ribbon seals are limited. Potential predators of ribbon seals are humans, polar bears, walruses, killer whales (*Orcinus orca*), Pacific sleeper sharks (*Somniosus pacificus*), eagles, and gulls (Bailey and Hendee 1926, Heptner et al. 1976, Popov 1982, Lowry 1985, Kelly 1988). Polar bears, killer whales, and walruses are known to prey on other species of seals, so it is believed that they also take ribbon seals, but there are no direct observations of predation (Kelly 1988) and ribbon 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). Shustov (1969b) observed gulls and eagles eating ribbon seal carcasses but did not know if the birds killed the seals; he saw possible polar bear claw marks on the back of a ribbon seal from the Bering Sea. Heptner et al. (1976) suggested that during the period that seals are associated with ice, mortality due to killer whales, polar bears, and sharks only occurs occasionally.

Shustov (1969b) and Fay et al. (1978) both reported seeing ribbon seals with wounds that looked like they were from shark attacks. Harbor seals and other marine mammals have been found in the stomachs of Pacific sleeper sharks (Yang and Page 1999), but it has not been clear whether these were consumed as carrion or live prey. Ringed, bearded, and hooded seals have been found recently with relatively high frequency in the stomachs of the closely related Greenland shark (*Somniosus microcephalus*) near Svalbard (Leclerc et al. 2012), and circumstantial evidence indicates the seals were actively preyed upon. Thus, the role of shark predation in the dynamics of ribbon seal and other arctic marine mammal populations may be underappreciated.

Of the potential predators, polar bears, killer whales, and sharks seem the most likely to encounter ribbon seals in the current sea ice regime. However, there have not been any confirmed predations of ribbon seals by these species and, if predation does occur, it is likely opportunistic. In the Bering Sea, ribbon 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 ribbon 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 ribbon seals. The naiveté of young pups and physiological constraints of molting for older seals would make them vulnerable to opportunistic predation. Burns (1981), however, suggested the general behavior and unwariness of ribbon seals when hauled out on sea ice reflects a lack of consistent predatory pressure from polar bears.

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 ribbon 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. However, during a research cruise in the central Bering Sea in April 2008, a group of transient killer whales was observed, and later confirmed with photo identification, in close proximity to hauled-out ribbon seals (unpubl. data, Peter Boveng, NMML, 7600 Sand Point Way NE, Seattle, WA 98115). 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*; unpubl. data, C. Matkin, North Gulf Oceanic Society, P.O. Box 15244, Homer, AK 99603). The extent of predation on ribbon seals is currently unknown.

Unlike the case with ringed seals and polar bears, ribbon 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 seals are pelagic and widely distributed as well as during the whelping, weaning and molting period when seals are associated with the sea-ice edge zone. 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. Because ribbon seals are highly dispersed and perhaps solitary during the pelagic phase, they would not represent a concentrated source of prey, and any killer whale predation would likely occur only during occasional chance encounters; exceptions could occur in geographically restricted zones of migration such as Bering Strait and perhaps the Kurile Straits.

4.2.3.3.2 Future scenarios

With scarce information on the degree of interaction between ribbon 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 ribbon seals to predation. It has been speculated that with decreased sea ice extent and seasonal duration, ribbon seals would become more susceptible to predation by polar bears (Center for Biological Diversity 2007). In a scenario of reduced sea ice and faster spring melting, ribbon 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, 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. The range of plausible scenarios is large, making it impossible to predict the direction or magnitude of the net impact on ribbon seal mortality.

The threat of walrus predation on ribbon seals may increase as all the pagophilic species are forced to share less ice as their distributions are compressed. Lowry and Fay (1984) documented walrus predation on ringed, spotted and bearded seals in the Bering Sea and noted increased consumption of seals by walrus during a low ice year. The potential exists for some increased predation of ribbon seals by walrus as the sea ice changes. However, 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 may be higher. A more diffuse distribution of sea ice would likely decrease the potential interaction between walrus and ribbon seals.

Reduced availability of sea ice may lead to increased time spent by ribbon seals in the water earlier in the spring and 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 and sharks. Killer whales are highly adaptable and mobile, so a reduced sea ice scenario might facilitate greater access to ribbon 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). It may also be noteworthy that some killer whales are apparently selective about which seal species they prey upon (Pitman and Durban 2012). As ribbon seals have not been observed to be common prey of killer whales in the recent past, they may not be at risk of increased killer whale predation in future novel encounter scenarios.

4.2.3.4 Summary of risks posed by diseases, parasites, and predation

A variety of pathogens (or antibodies), diseases, helminthes, cestodes, and nematodes, have been found in ribbon seals. The prevalence of these agents is not unusual among seals, but population impacts are 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 ribbon seals and they are not thought to be a primary prey of any predators. Polar bears and killer whales may be the most likely opportunistic predators in the current sea ice regime, but walruses and sharks could pose a potentially greater risk if reduced sea ice conditions force these species into closer proximity in the future.

4.2.4 Inadequacy of Existing Regulatory Mechanisms

Because the evaluation of existing regulatory mechanisms requires to some extent inherently non-scientific sociological and political considerations, the BRT did not include threats stemming from inadequacy of existing regulatory mechanisms in its threats assessment. However, the human activities that are the subject of any such regulatory measures are included in the suite of threats considered under the other four ESA Section 4(a)(1) factors (Sections 4.2.1, 4.2.2, 4.2.3, and 4.2.5). Therefore, a summary of key regulatory mechanisms identified as potentially affecting the conservation of ribbon seals is presented below for perspective on the related threats.

4.2.4.1 International Agreements

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

CITES is 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 presently, 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. Ribbon seals have no special status under CITES.

4.2.4.1.2 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. It 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. Under the IUCN Red List criteria and categories, ribbon seals are currently considered ”data deficient” because the most recent abundance estimates are more than 20 years old and so the species' current status relative to the IUCN Red List categories cannot be evaluated.

4.2.4.2 United States Regulatory Mechanisms

4.2.4.2.1 Endangered Species Act of 1973, as amended (ESA)

The ESA (16 U.S.C. 1531 et seq.) provides a program for the conservation of imperiled species and the ecosystems upon which they depend. The lead federal agencies for implementing the ESA are the USFWS and the NMFS. Under the ESA, species may be listed as either endangered or threatened. “Endangered” means a species is in danger of extinction throughout all or a significant portion of its range. “Threatened” means a species is likely to become endangered within the foreseeable future throughout all or a significant portion of its range. For the purposes of the ESA, species are defined to include subspecies, varieties, and for vertebrates, distinct population segments.

The ESA requires federal agencies to conduct their activities in such a way as to conserve listed species. Section 7 of the ESA also requires federal agencies, in consultation with the FWS and/or NMFS, to ensure that activities they authorize, fund or carry out are not likely to jeopardize the continued existence of any listed species (or species proposed for listing) or result in the destruction or adverse modification of designated or proposed critical habitat of such species.

The ESA forbids the import, export, or interstate or foreign sale of species listed as endangered without a special permit. It also makes “take” of species listed as endangered illegal—forbidding the killing, harming, harassing, pursuing, or removing the species from the wild. Any or all of these protections may be provided to a species listed as threatened through regulations issued under ESA section 4(d).

4.2.4.2.2 Marine Mammal Protection Act of 1972, as amended (MMPA)

In U.S. waters, ribbon seals are protected 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 lead federal agencies for implementing the MMPA are FWS and NMFS.

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

The MMPA includes a general moratorium on the taking and importing of marine mammals, which is subject to a number of exceptions. Some of these exceptions include take for scientific purposes, public display, subsistence use by Alaska Natives, and unintentional incidental take coincident with 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 the NMFS, 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 five-year (or less) period concerned will have a negligible impact on such species or stock and will not have an unmitigable adverse impact on the availability of such species or stock for taking for subsistence uses.” If the Secretary makes the required findings, the Secretary also prescribes regulations that specify: (1) permissible methods of taking, (2) means of effecting the least practicable adverse impact on the species, their habitat, and their availability for subsistence uses, and (3) requirements for monitoring and reporting. The regulatory process does not authorize the activities themselves, but authorizes the incidental take of the marine mammals in conjunction with otherwise legal activities described within the regulations.

Similar to promulgation of incidental take regulations, the MMPA also established an expedited process by which U.S. citizens 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. NMFS refers to these authorizations as Incidental Harassment Authorizations.

Certain exceptions from the prohibitions on taking are provided. The MMPA exempts coastal-dwelling Alaska Natives from the prohibitions on the taking of marine mammals, including ribbon seals, for subsistence purposes. 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.

4.2.4.2.3 National Environmental Policy Act (NEPA)

The NEPA (42 U.S.C. 4321 et seq.) 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 Statements and Environmental Assessments. The NEPA does not itself regulate ribbon seals, but it does require full evaluation and disclosure of information regarding the effects of contemplated federal actions on ribbon seals and their habitat.

4.2.4.2.4 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 within the Department of Interior to the Bureau of Ocean Energy Management and the Bureau of Safety and Environmental Enforcement (BOEM and BSEE, respectively; formerly, Minerals Management Service [MMS]). 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 ribbon seals, although through consistency determinations it helps to ensure that OCS projects do not adversely impact ribbon seals or their habitats.

4.2.4.2.5 Oil Pollution Act (OPA)

The OPA (33 U.S.C. 2701 et seq.) amends provisions of the Clean Water Act concerning oil spills, and is the primary federal statute that comprehensively addresses oil spill prevention, preparedness, and response in the United States. The OPA requires the U.S. Coast Guard (USCG) and the Environmental Protection Agency (EPA) to prepare oil spill response plans for the inland and coastal zones of each federal government region. Under federal guidelines, the State of Alaska is considered a federal planning “region” for which a regional spill response plan must be developed and maintained. In developing the “Unified Plan” for Alaska, USCG and EPA have joined the Alaska Department of Environmental Conservation in using the 10 geographic regions (“subareas”) that Alaska Statute 46.04 divides the state into for oil and hazardous substance discharge response and preparedness planning (see below). The Unified Plan contains information applicable to spill response within the entire State of Alaska; whereas, the each subarea contingency plan focuses on issues and provisions specific to the particular subarea.

4.2.4.2.6 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. On July 1, 2011, the federally approved Alaska Coastal Management Program expired, resulting in the state of Alaska’s withdrawal from participation in the CZMA’s National Coastal Management Program.

4.2.4.2.7 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 ribbon seals, although it operates to protect the quality of marine habitats that ribbon seals rely upon.

4.2.4.2.8 Clean Air Act (CAA)

In the United States, the Environmental Protection Agency (EPA) is the primary regulatory agency responsible for issuing and implementing federal regulations to address climate change, in particular under the CAA (42 U.S.C. 7401 et seq.). In 2007, the U.S. Supreme Court ruled that carbon dioxide and other greenhouse gases (GHGs) are covered under the CAA's definition of air pollutants, and that they can then be regulated by the EPA under this Act if the EPA has found that these gases pose a risk to public health or welfare (Supreme Court of the United States 2007). The EPA subsequently published a final finding that six GHGs taken in combination constitute a threat to public health and welfare, and that the combined emissions from motor vehicles contribute to this threat (Environmental Protection Agency and Department of Transportation 2010). The U.S. Court of Appeals for the District of Columbia Circuit upheld the EPA's endangerment finding in June 2012.

The EPA and the Department of Transportation's National Highway Traffic Safety Administration (NHTSA) issued the first national rule to establish GHG emissions and fuel economy standards for model year 2012-2016 passenger cars and light trucks (Environmental Protection Agency and Department of Transportation 2010) in 2010. In 2012, the EPA and the NHTSA finalized a rule that extends these standards to model year 2017-2025 cars and light trucks (Environmental Protection Agency and Department of Transportation 2012). The EPA and the NHTSA also issued a final rule to establish GHG emissions and fuel efficiency standards for model year 2014-2018 medium- and heavy-duty engines and vehicles in 2011 (Environmental Protection Agency and Department of Transportation 2011).

In 2010, the EPA issued the "Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule" (GHG Tailoring Rule) to address GHG emissions from large stationary sources. This rule set thresholds for GHG emissions that define when permits are required under the CAA's New Source Review Prevention of Significant Deterioration (PSD) and Title V Operating Permit programs (Environmental Protection Agency 2010). The PSD program is a preconstruction review and permitting program applicable to new major stationary sources as well as to major modifications at existing major stationary sources. A principal requirement of the PSD program is the application of "best available control technology". The Title V program requires major sources of GHGs and certain other sources to apply for operating permits. Title V operating permits consolidate all applicable air pollution control requirements into a single comprehensive permit that covers all aspects of the source's operations.

The GHG Tailoring Rule specified a phased-in approach to implementing the permit requirements under the PSD and Title V programs, focusing on the largest emitters, and promulgated Steps 1 and 2 of the phase-in program. Under Step 1, no sources were subject to CAA permitting requirements solely due to GHG emissions. The Step 1 PSD permitting requirements for GHG emissions applied only to new or modified facilities that triggered permitting for emissions of other pollutants and that also had GHG emissions of at least 75,000 tons per year. Similarly under the Operating Permit program, during Step 1 only new or existing major sources for pollutants other than GHGs were subject to the Title V requirements for GHGs. Step 2, which came into effect in 2011, phased in additional large sources of GHG emissions. The Step 2 PSD permitting requirements apply to: (a) newly constructed facilities with GHG emissions of at least 100,000 tons per year (tpy), regardless of whether permitting requirements for any other pollutant are triggered; and (b) modifications at existing facilities that have GHG emissions of at least 100,000 tpy, when those modifications increase GHG emissions by at least 75,000 tpy. Also under Step 2, Title V permitting requirements apply to facilities that emit at least 100,000 tons per year of GHGs, regardless of whether the permitting requirements apply for any other pollutant. EPA issued a final rule In June 2012 that maintains the Step 2 thresholds for GHG permitting requirements, rather than implementing a third step described in the GHG Tailoring Rule that would have lowered the thresholds for PSD and Title V permit applicability (Environmental Protection Agency 2012a).

According to the EPA, power plants are the largest individual sources of carbon pollution in the United States (Environmental Protection Agency 2012b). EPA issued a proposed rule in March 2012 that would set national limits on the amount of carbon pollution fossil-fuel-fired power plants that are built in the future can emit (Environmental Protection Agency 2012b). The proposed rule does not apply to existing power plants that are already operating or to those that begin construction within 12 months of the proposed rule.

4.2.4.2.9 State of Alaska Regulations

A number of State of Alaska regulatory programs contribute to conservation of ribbon seals and their habitats. For example, Alaska Statute 46.04 requires the Alaska Department of Conservation to develop response plans for oil and hazardous substance discharges for the 10 geographic subareas that comprise the State of Alaska and also requires industry to develop and maintain state-approved oil spill response and contingency plans. There are also state regulatory programs governing solid waste management, water quality, wastewater, air quality, and cleanup of contaminated sites, among others.

4.2.4.3 Russian Federation Regulatory Mechanisms

Both subsistence and commercial hunting of ribbon seals occur in Russia. The Russian Federation government approves limits of total allowable catch (TACs) that are assigned by species and geographical region (COWI 2008, Marine Mammal Council 2008). During 2000-2005, the annual quotas for harvest of ribbons seals in Russian waters were high—ranging between 16,700 and 21,000 individuals. As discussed in Section 4.2.2.1 , despite the high quotas, harvest levels currently remain very low, likely ranging in the tens to few hundreds per year (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, August 20, 2008, pers. comm.) This is likely because following the collapse of the Soviet Union in 1991, commercial sealing became less economically viable (Grachev 2006). If economic conditions were to change in Russia so that commercial sealing was once again profitable, it is possible that harvest could increase to levels that adversely affect the species, as has occurred historically (see Section 4.2.2.1). 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 to ensure that potential commercial harvests remain within sustainable levels in Russian waters.

4.2.4.4 International Regulatory Mechanisms Addressing GHG Emissions

The primary international regulatory mechanism addressing GHG emissions and global warming is the United Nations Framework Convention on Climate Change (UNFCCC), an international treaty aimed at addressing climate change by reducing GHG emissions. The UNFCCC established a framework for negotiating international treaties ("protocols") that may set binding limits on GHG emissions. Parties to the UNFCCC meet annually in Conferences of the Parties (COP). The Kyoto Protocol to the UNFCCC, negotiated in 1997 at COP3 and entered into force in 2005, was the first legally binding agreement to establish GHG emissions reduction targets for developed countries ("Annex I" countries); however mandates were not imposed for countries in transition to a market economy, such as India and China. As of September 2011, 192 parties had signed and ratified the agreement. The United States is the only Annex I country that did not ratify the agreement; and Canada withdrew from the agreement in December 2011 (effective 15 December 2012).

With the approaching expiration of the first Kyoto commitment period at the end of 2012, the goal of COP15 in 2009 was to produce a new protocol to address global climate change; however, a binding agreement was not reached. Instead, the primary outcome of COP15 was the Copenhagen Accord, which recognizes the scientific basis for taking actions to keep any further global temperature increase during this century to below 2°C, but does not include commitments for reduced GHG emissions necessary to meet this objective. Rather, participating countries have established pledges for emissions reductions by 2020. For example, the United States has pledged a 17% reduction in GHG emissions from a 2005 baseline by 2020. However, it appears that even if country pledges are fully implemented, the reduction in GHG emissions will fall well short of reductions considered consistent with likely meeting the 2°C target, which will make limiting emissions beyond 2020 consistent with the 2°C target less feasible (Rogelj et al. 2010, United Nations Environment Programme 2012).

At the 2012 COP18 in Doha, parties to the Kyoto Protocol agreed to a second period of emissions reductions from 2013 to 2020, and set a target date of 2015 (COP21) for development of a successor agreement to be implemented in 2020. As noted above, the United States has not ratified the agreement, and several parties that participated in the first Kyoto commitment period (e.g., Canada, Russia, Japan, and New Zealand) have not committed to new targets in the second commitment period.

The United Nations Environment Programme (2012) noted that global emissions continue to rise, and its findings show that "the range of 2020 emission levels implied by current pledges is most consistent with pathways limiting global temperature increase (with a "likely" (>66%) chance) to 3 to 5°C above pre-industrial levels during the 21st century." A recent review of existing domestic regulatory mechanisms to address GHG emissions for the top 25 GHG-emitting countries, as well as their respective commitments via the Kyoto and Copenhagen agreements, can be found in National Marine Fisheries Service (2012). This review did not reveal any information indicating that current national regulatory measures addressing GHG emissions are ambitious enough to effectively address the threats posed to ribbon seals by related changes in ribbon seal habitat from sea ice loss or from ocean acidification.

The BRT did not attempt to separate the risk posed by the lack of regulatory mechanisms 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 ribbon 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 ribbon seal habitat. 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 Section 4.2.1 on present or threatened destruction of habitat.

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 phocids (Kelly 1988). Levels of cadmium and zinc found in the liver tissue of ribbon seals of the Sea of Okhotsk in the 1970s were higher than levels found in ringed seals and harbor seals (presumed to be spotted seals) during the same study (Hamanaka et al. 1977). Quakenbush and Sheffield (2007) also found that ribbon seals have the highest levels of cadmium among ice-associated seals in Alaska, though there does not appear to be an increase in mean liver cadmium levels over time. Additional work is needed to determine the bioavailability of cadmium in the liver and the magnitude of toxic effects on this species (Quakenbush and Sheffield 2007).

Research has also found persistent organochlorine pollutants, including flame retardant compounds like PBDEs (polybrominated diphenyl ethers; Quakenbush 2007), as well as DDTs (dichloro-diphenyl-trichloroethanes) and PCBs (polychlorinated biphenyls; Quakenbush and Sheffield 2007) in ribbon, spotted, bearded, and ringed seals, in addition to PFCs (perfluorinated contaminants; Quakenbush and Citta 2008). In pinnipeds specifically, DDT and PCB exposure has been linked to endocrine disruption, reproductive disorders, and reproductive failure (reviewed by Gregory and Cyr 2002). Less is known about the toxicology of flame retardants but they are widely used in carpets, upholstery, and plastics. 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). Ribbon seals were found to have higher levels of most metals, organochlorine pollutants, and other contaminants such as PBDEs and PFCs than other ice-associated seal species in Alaska; however, their levels were not higher than ringed seals in the Arctic in most cases (Quakenbush and Citta 2008). The spatial distribution of organochlorines in pinnipeds appears to be consistent with levels found in the environment as 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) as concentrations in surrounding Arctic regions continue to rise (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) induction has been demonstrated in harbor seals after exposure to an organochlorine compound (Miller et al. 2005). The CYP1A gene has been identified in ribbon seals (CYP1A1) and was found to be identical to that in spotted seals (CYP1A1; Teramitsu et al. 2000). Future research is likely to utilize this approach to evaluate effects of contaminant exposure in ribbon and other ice-associated seals.

In summary, although some pollutants are elevated in ribbon seals, there is no conspicuous evidence of toxicity or other significant impacts to the species. Continued and expanded monitoring would be prudent to document any trends in the contaminants of greatest concern.

4.2.5.2 Oil and Gas Exploration, Development, and Production

4.2.5.2.1 Overview

4.2.5.2.1.1 The Arctic

Commercial oil and gas activities began in the Arctic in the 1920s in Canada's Northwest Territories, and greatly expanded during the 1970s, particularly in Alaska, Russia, and Norway (AMAP 2007). By the 1980s and early 1990s, oil and gas activities had extended farther into the Arctic with several fields being explored and developed offshore. To date, cumulative production from the Arctic is in the billions of cubic meters for both oil and gas, and the Arctic is currently producing about a tenth of the world's oil and a quarter of its gas (AMAP 2007). In 2008, the U.S. Geological Survey (USGS) completed an assessment of undiscovered conventional oil and gas resources in all areas north of the Arctic Circle. Using a geology-based probabilistic method, the USGS estimated that 90 billion barrels of oil, 1,669 trillion cubic feet of natural gas, and 44 billion barrels of natural gas liquids may remain to be found in the Arctic, of which approximately 84% is expected to occur in offshore areas (U.S. Geological Survey 2008). These reserves may represent as much as a quarter of the world's undiscovered oil and gas (AMAP 2007). Such extensive reserves coupled with rising global demand make it very likely that oil and gas activity will increase in the Arctic in the future. According to the *Arctic Oil and Gas 2007* assessment (AMAP 2007):

> *"More activity is expected in the next two decades, however projections father into the future become increasingly speculative since the pace of activity is affected by a number of factors including economic conditions, societal considerations, regulatory processes, and technological advances. Global climate change may introduce additional factors that need to be taken into account."*

Climate change is expected to enhance marine access to offshore oil and gas reserves by reducing sea-ice extent, thickness, and seasonal duration, thereby improving ship accessibility to these resources around the margins of the Arctic Basin (ACIA 2004, AMAP 2007). Reduced sea-ice extent and thickness is also likely to allow construction and operation of more economical offshore platforms since the ice forces these structures must withstand may also be reduced (ACIA 2005, AMAP 2007). Conversely, land-based infrastructure such as ice roads, pipelines, artificial islands, and coastal installations will likely be negatively impacted by climate change due to thawing of permafrost, increased storm surges, and coastal erosion (ACIA 2005, AMAP 2007). These effects may make future development on land more complicated and expensive, providing further incentive for the development of marine-based production and transportation infrastructure (AMAP 2007).

4.2.5.2.1.1.1 United States (Alaska)

The United States schedules oil and gas lease sales on its outer continental shelf (OCS) regions in 5-year programs that indicate the size, timing, and location of proposed leasing activity for each 5-year period. In June 2007, the Secretary of the Interior approved the 2007-2012 OCS Oil and Gas Leasing Program. Lease sales were planned in the Chukchi Sea in 2008, 2010, and 2012; in the Beaufort Sea in 2009 and 2011; and in the North Aleutian Basin of the southeastern Bering Sea in 2011 (Minerals Management Service 2007b). Two lawsuits were filed against the lease program in 2007, and in April 2009, the U.S. Court of Appeals for the District of Columbia vacated and remanded the program and required the Department of the Interior to “conduct a more complete comparative analysis of the environmental sensitivity of different areas” (Minerals Management Service 2010a). In March 2010, the MMS announced that the Preliminary Revised 2007-2012 OCS Oil and Gas Leasing Program retains the Chukchi Sea lease sale from 2008 and allows proposed exploratory activities on leases in the Chukchi and Beaufort Seas to proceed, but removes the five remaining lease sales in the North Aleutian Basin and Beaufort and Chukchi Seas from the program (Minerals Management Service 2010b). The Final Revised 2007-2012 leasing program became effective on December 23, 2010.

On 16 January 2009, the MMS announced the release of a 5-year Draft Proposed Program (DPP) for offshore oil and gas lease sales for 2010-2015 (Minerals Management Service 2009b), 2 years earlier than the usual schedule. The DPP called for lease sales in the Chukchi Sea in 2010, 2012, and 2014; in the Beaufort Sea in 2013 and 2015; and in the North Aleutian Basin in 2011 and 2014. On 10 February 2009, the Secretary of the Interior extended 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 2009c).

The 20 April 2010 explosion of the *Deepwater Horizon* drilling platform in the Gulf of Mexico and the catastrophic oil blowout that resulted (estimated to be 4.9 million barrels total, Deepwater Horizon Response 2010) had, and will likely continue to have, significant impact on oil and gas activities in the United States, including Alaska. In response to the *Deepwater Horizon* blowout, the MMS was renamed the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) in June 2010 and in October 2011, BOEMRE was reorganized into the Bureau of Ocean Energy Management (BOEM) and the Bureau of Safety and Environmental Enforcement (BSEE). In November 2011, the 2010-2015 DPP was restructured to form the 2012-2017 Outer Continental Shelf Oil and Gas Leasing Program, which included a Draft EIS. This program includes the Chukchi and Beaufort Seas and Cook Inlet as potential leasing locations for the 2012-2017, but does not include the North Aleutian Basin.

The State of Alaska also conducts lease sales and licensing for the exploration of oil and gas on state lands and in state waters. At least 20 lease sales have been made in state waters of the Beaufort Sea since 1979, and new lease sales are scheduled to occur annually according to the 5-year leasing program for 2010-2014 (Alaska Department of Natural Resources 2010b). The petroleum potential in these coastal waters is considered to be moderate to high.

4.2.5.2.1.1.1.1 Beaufort and Chukchi Seas

Oil and gas activities have been conducted off the coast of Alaska since the 1970s, with most of the activity occurring in the Beaufort Sea. Between 1976 and 2003, 31 offshore exploratory wells were drilled in the Beaufort Sea, 30 were drilled in the Bering Sea (including 6 deep stratigraphic test wells), and 5 were drilled in the Chukchi Sea (Minerals Management Service 2009a). The MMS (now BOEM) has conducted 10 offshore lease sales in federal waters of the Beaufort Sea since 1979, and seven oil companies had active leases there as of January 2009 (Figure 21). The Alaska Department of Natural Resources has conducted an additional 20 lease sales in state waters of the Beaufort Sea since 1979 (Alaska Department of Natural Resources 2009) and many exploration and development activities are ongoing there (Alaska Department of Natural Resources 2010a). Three oil fields are currently in production in the Beaufort Sea where drilling is being conducted from artificial islands in state waters: Endicott field has been in production since October 1987, Northstar field since October 2001, and Oooguruk field since June 2008. By 2009, these three fields had produced nearly 600 million barrels of oil (Alaska Department of Natural Resources 2009). Development of the Nikaitchuq and Liberty oil fields began in 2008 (Lee 2008). Though the Nikaitchuq oil field began producing oil in 2011 (Alaska Department of Natural Resources 2011), development at the Liberty oil fields was indefinitely suspended in 2012 due to cost overruns and technical setbacks (Alaska Department of Natural Resources 2012). Several other oil fields on Alaska’s North Slope (e.g., Point Thompson, Badami, Dewline, and Beechey Point) had development wells drilled near the coast of the Beaufort Sea in recent years (Alaska Department of Natural Resources 2010a).

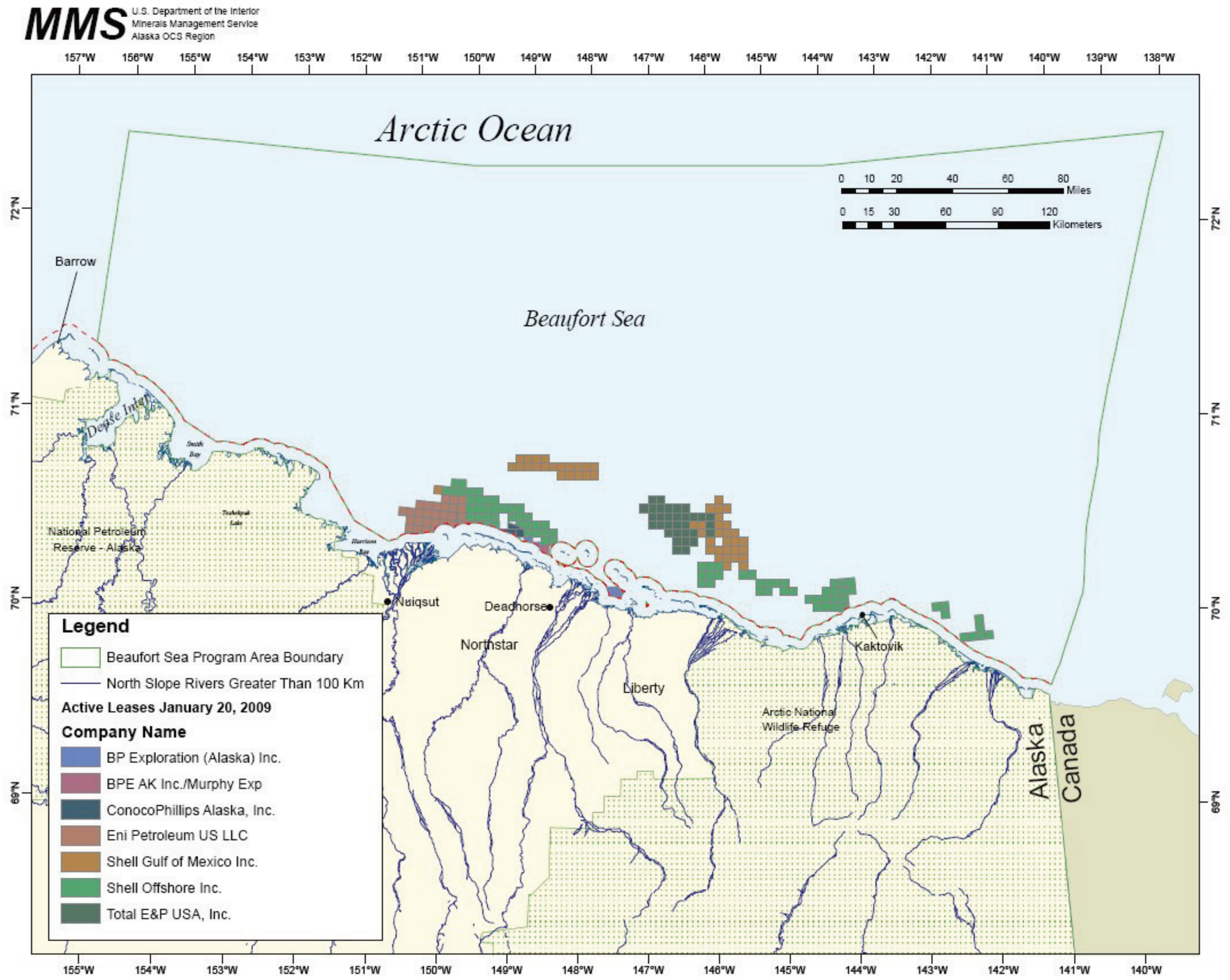


Figure 21. -- Active offshore oil and gas leases in the Beaufort Sea program area (Source: Minerals Management Service 2009a).

Although five exploratory wells were drilled in the past, no oil fields have been developed or brought into production in the Chukchi Sea to date. The MMS has conducted three offshore lease sales in the Chukchi Sea since 1988, with the latest (Sale 193 in 2008) being the most profitable ever in the offshore waters of Alaska (Minerals Management Service 2008b). In December 2009, the MMS approved Shell Gulf of Mexico Inc.'s (2009) exploration plan for drilling at five potential sites within three prospects known as Burger, Crackerjack, and Southwest Shoebill in the Chukchi Sea during 2010 (Figure 22). Following the *Deepwater Horizon* blowout in the Gulf of Mexico, the Secretary of the Interior announced on 27 May 2010, that Shell would not be permitted to drill five exploratory wells in their Beaufort and Chukchi Sea leases, pending further review by the MMS (U.S. Department of the Interior 2010). In August 2011, Shell was awarded the appropriate permits to drill four shallow-water wells in the Beaufort and Chukchi Seas. Drilling was initiated in the summer of 2012, however mechanical, safety, and logistical setbacks led Shell to announce that they would suspend plans for Arctic drilling in 2013.

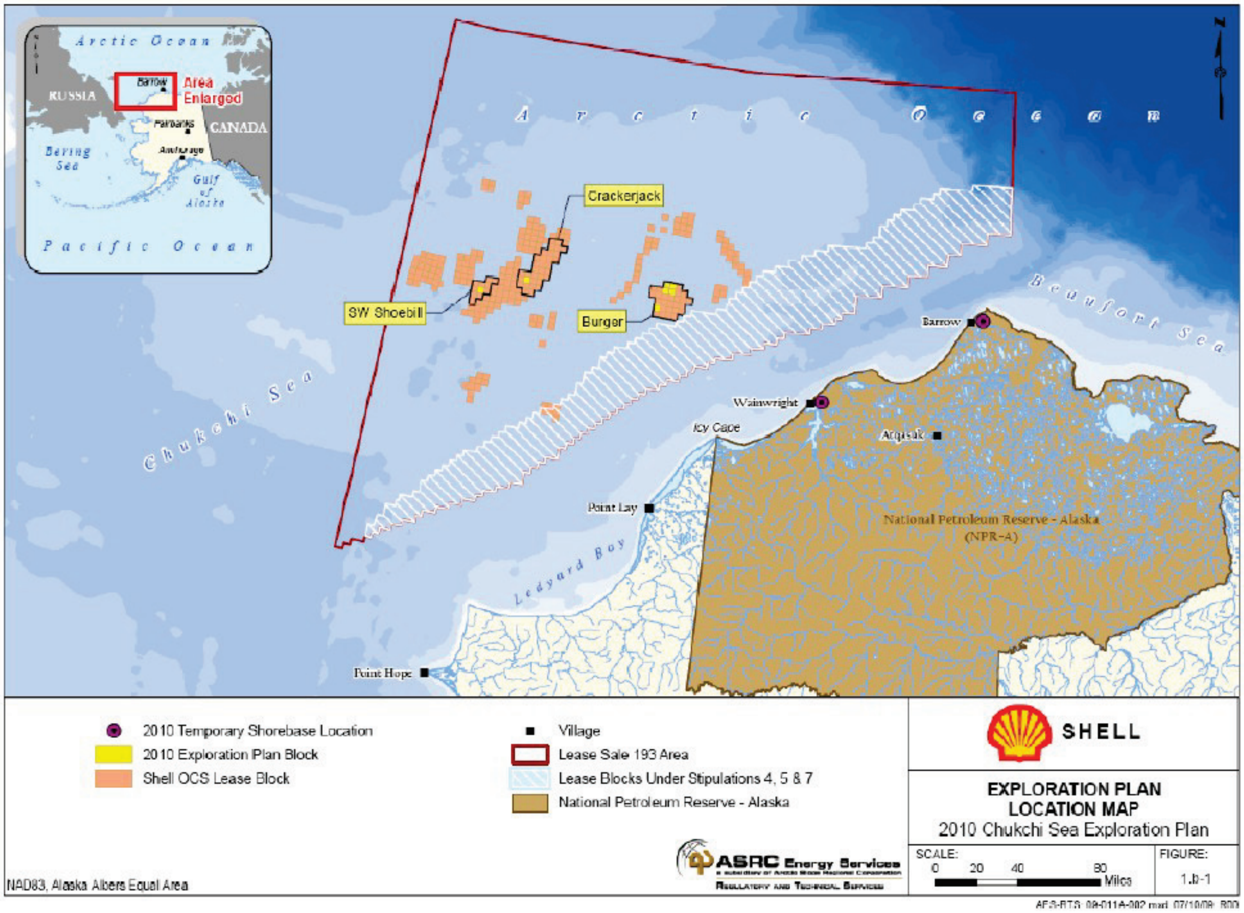


Figure 22. -- Locations of three prospects (Burger, Crackerjack, and Southwest Shoebill) identified as potential drilling sites by Shell in their 2010 exploration plan (Source: Shell Gulf of Mexico Inc. 2009).

There are no offshore oil or gas fields in development or production in the Bering Sea, and all previous lease sales have expired (Minerals Management Service 2009a).

4.2.5.2.1.1.2 Russian Federation (East Siberian, Chukchi and Bering Seas)

The continental shelves of Russia’s East Siberian, Chukchi, and Bering Seas have excellent prospects for large-scale and long-term developments of offshore oil and gas with potential recoverable reserves estimated in the billions of tons of conventional fuel (Patin 1999). Waters offshore of eastern Russia are thought to contain more than one-third of the recoverable offshore oil reserves and more than 10% of recoverable gas reserves in the Russian Arctic (Frantzen 2007). Recently, there has been renewed interest in the Russian sector of the Chukchi Sea as new evidence emerges to support the notion that the region may contain world-class oil and gas reserves. Global oil and gas exploration companies are becoming more interested in the Russian Arctic offshore, because it is one of the world’s few remaining petroleum frontiers with significant resource potential. In 2006, 3,700 km of seismic surveys were conducted in Russia’s North and South Chukchi Basins to explore for economically viable oil and gas reserves. Preliminary results were described as “very encouraging” (Frantzen 2007).

4.2.5.2.1.2 Sea of Okhotsk

In the Sea of Okhotsk, oil and natural gas operations are active off the northeastern coast of Sakhalin Island and future developments are planned in the Magadan and western Kamchatka regions (Figure 23). The project referred to as *Salkhain-1* is focused on three deposits with extraction capability up to 10 billion cubic meters per year, and *Salkhalin-2* is one of the world's largest integrated oil and gas projects with annual production of liquefied gas at nearly 20 billion cubic meters (Chernenko 2007). 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). Initial work and seismic exploration for the projects *Salkahin-3,4,5* and *6* has also begun (Chernenko 2007). In 1999, oil and gas development off Sakhalin Island resulted in an oil spill that released about 3.5 tons of oil (Lapko and Radchenko 2000).

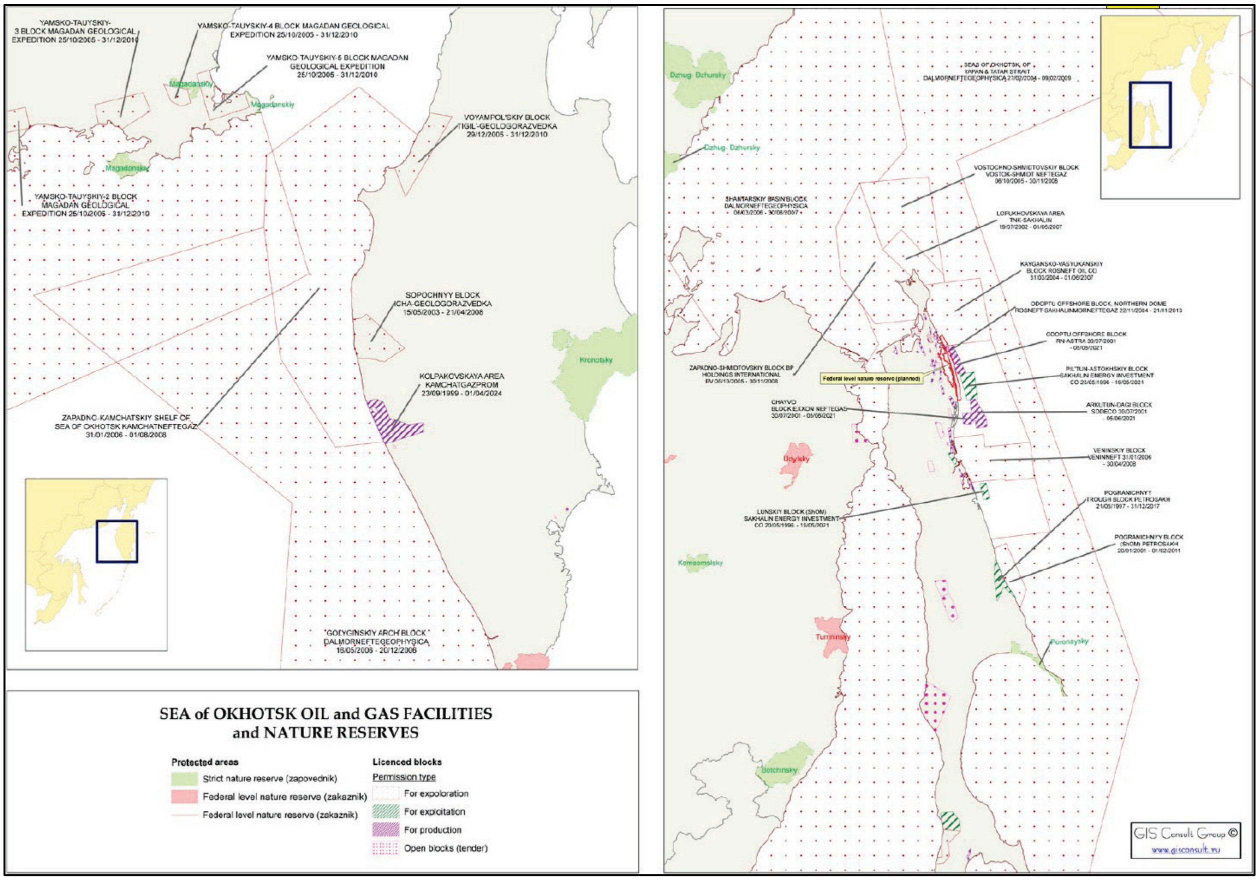


Figure 23. -- Oil and gas fields, areas of exploration, and nature reserves on or around the Kamchatka Peninsula (left panel) and Sakhalin Island (right panel) in the Sea of Okhotsk (Source: Chernenko 2007).

An oil and gas project is also planned in the Magadan region of the northern Sea of Okhotsk (Chernenko 2007). The project is also proposed for integrated extraction of oil and natural gas (15-20 million tons of oil and 35-50 billion cubic meters of gas). 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).

4.2.5.2.2 Potential threats to ribbon seals from offshore oil and gas exploration, development, and production

Potentially harmful activities of oil and gas exploration, development, and production include seismic surveys; exploratory, delineation, and production drilling; construction of artificial-islands, causeways, ice roads, shore-based facilities, pipelines; and vessel and aircraft operations. These activities have the potential to impact ribbon seals, primarily through the noise, physical disturbance, and pollution they cause, particularly in the event of a large oil spill or blowout.

4.2.5.2.2.1 Noise and physical disturbance

Noise and physical disturbances associated with oil and gas exploration, drilling, construction, and support activities could potentially interfere with ribbon seals' ability to function normally and so impact their health. The 'noisiest' and 'busiest' periods of offshore oil and gas operations occur during exploration and site establishment (Richardson et al. 1995). Conversely, production activities are generally quieter and require fewer support operations. To varying degrees, drilling operations produce low-frequency sounds with strong tonal components.

Air and vessel traffic are needed to support offshore oil and gas exploration and development. Low-flying aircraft may cause seals resting on ice to enter the water (Burns and Harbo 1972), however, most of these disturbances will likely be minor, highly variable, and brief in nature. The effects of noise and physical disturbance from ships are discussed in Section 4.2.5.4.2.1.2.

4.2.5.2.2.1.1 Seismic surveys

Seismic surveys are a particularly intense source of noise and, thus, warrant further consideration as a potential threat. 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. 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 ice-associated seals. The consequences might be more serious in areas where many surveys are occurring simultaneously. Underwater audiograms of 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.

There is no specific evidence that exposure to pulses of airgun sound can cause permanent threshold shifts 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 pinnipeds exposed to a single pulse of sound at 218 dB re: 1 micropascal in water and 143 dB re: 20 micropascals in air. Although it is unlikely that airgun operations during most seismic surveys would cause permanent threshold shifts in ribbon seals, caution is warranted given the limited knowledge about noise-induced hearing damage in this species.

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 harbor seals and gray seals (*Halichoerus grypus*) exhibit strong avoidance behavior of small seismic airgun arrays, including swimming rapidly away from seismic sources, ceasing feeding activities, and exiting the water, 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. Based on tagging studies conducted in 2001, Cott et al. (2003) reported that Canadian marine seismic surveys in the Beaufort Sea did not appear to affect the timing or route of the western fall migration of ringed seals, a sympatric ice-associated seal species. Comparison of ringed seal densities in areas of shorefast ice with seismic activity (using explosive charges) vs. undisturbed areas indicated that ringed seals were not appreciably displaced by even intensive seismic activity; however, this analysis was conducted immediately offshore of the Prudhoe Bay oil fields where ringed seals were said to “normally occur at very low densities” over the entire region (Burns and Harbo 1972). Similar studies have not been conducted on ribbon seals.

4.2.5.2.2.2 Oil spills

Large oil spills or blowouts are generally considered to be the greatest threat of oil and gas activities in marine environments (AMAP 2007). In contrast to spills on land, large spills at sea are difficult to contain and may spread over hundreds or thousands of kilometers. Responding to a spill in the Arctic environment would be particularly challenging. Many oil and gas activities occur in locations far from population centers, where spill response resources are typically located. Reaching a spill site and responding effectively would be especially difficult in winter, when weather can be severe and daylight extremely limited. Oil spills under ice or in ice-covered waters are the most challenging to deal with, simply because they cannot be contained or recovered effectively with current technology. Current techniques, such as use of dispersants and in-situ burning, may be attempted, however, both techniques have drawbacks that may be made worse in Arctic conditions (AMAP 2007). New techniques, such as the use of ice rather than booms to contain and concentrate oil until it can be recovered by skimmers, have shown some promise, but most response techniques require rapid action to be effective, which may not be possible in remote areas without prior staging of equipment and personnel (AMAP 2007). The difficulties experienced in stopping and containing the oil blowout at the *Deepwater Horizon* well in the Gulf of Mexico, where environmental conditions and response preparedness are comparatively good, point towards even greater challenges of attempting a similar feat in a much more severe and remote Arctic location. Prince William Sound, Alaska has advanced spill containment and clean-up capabilities, yet a recent report indicated that an appropriate response would not be feasible 38% of the time due to environmental factors (Robertson 2007). The presence of sea ice will delay, limit, or preclude access to areas of contamination (Minerals Management Service 2008a). Clean up efforts themselves are also likely to cause disturbance which, if they occurred during breeding, could interfere with nursing and further impact pup survival (St. Aubin 1988).

Although planning, management, and use of best practices can help reduce risks and impacts, the history of oil and gas activities, including recent events, indicates that accidents cannot be eliminated (AMAP 2007). Tanker spills, pipeline leaks, and oil blowouts are likely to occur in the future, even under the most stringent regulatory and safety systems. According to a figure in AMAP's (2007) report, one oil tanker spill of 35,000 cubic meters or greater is estimated to occur each year, and an oil blowout of 2,000 cubic meters or greater is estimated to occur every 10 years. And according to the MMS (2007a), the probability of one or more large oil spills (≥ 1,000 barrels) occurring over the production life of a new development in the Chukchi Sea was estimated to be 35-40%. To date, there have been no large spills in the Arctic marine environment from oil and gas activities, however, based on experiences of spills in sub-Arctic regions (e.g., Prince William Sound, Alaska; the North Sea in Europe; and the Gulf of St. Lawrence, Canada), the potential impacts of a spill in the Arctic are likely to be severe for Arctic species and ecosystems (AMAP 2007).

Researchers have suggested that pups of ice-associated seals may be particularly vulnerable to fouling because of their dense lanugo coat (Johnson 1983, St. Aubin 1990, Jenssen 1996). Fouled pelage of neonates would have a lower insulative value, putting them at greater risk of low-temperature stress when out of the water (Kooyman et al. 1977, St. Aubin 1990), lower mass at weaning (Davis and Anderson 1976), and lower survival (Harding et al. 2005). Ribbon seals pups rely on their lanugo for insulation and typically retain this coat for 4-6 weeks after birth. During this time, they would be particularly prone to the physical impacts of contacting oil. Energetic costs may be compounded if mothers attempted to move their pups out of the affected area. The increased time spent swimming in water could lead to hypothermia and increased mortality in pups (Smith 1987). Adults, juveniles, and weaned young-of-the-year rely on blubber for insulation, so effects on their thermoregulation are expected to be minimal (Jenssen 1996).

Other acute effects of oil exposure, which have been shown to reduce seals' health and possibly survival, include skin irritation, disorientation, lethargy, conjunctivitis, corneal ulcers, and liver legions (Geraci and Smith 1976, St. Aubin 1988). Many of these effects are thought to be largely reversible, but others such as brain lesions and nerve damage may be fatal (Engelhardt 1983, Frost and Lowry 1994, Frost et al. 1994b, Lowry et al. 1994, Spraker et al. 1994, Salazar 2003).

Direct ingestion of oil, ingestion of contaminated prey, or inhalation of volatile hydrocarbons transfers toxins to body fluids, muscle, liver, and blubber, causing effects that may lead to death, as suspected in dead gray and harbor seals found with oil in their stomachs (Engelhardt et al. 1977, Engelhardt 1982, St. Aubin 1990, Frost et al. 1994b, Lowry et al. 1994, Spraker et al. 1994, Jenssen 1996). Furthermore, ingestion of hydrocarbons irritates and destroys epithelial cells of the stomach and intestine, affecting motility, digestion, and absorption, which can result in death or reproductive failure (St. Aubin 1990).

Freshly spilled oil contains high levels of toxic aromatic compounds that, if inhaled, could cause serious health effects or death in ribbon 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). Oil that disperses from a spill site may still have high levels of toxic aromatic compounds, depending on the temperature and whether the oil becomes frozen into ice (St. Aubin 1990). Pinnipeds stressed by parasitism or other metabolic disorders may be susceptible to injury or death from even brief exposure to low concentrations of hydrocarbon vapors (St. Aubin 1990). For example, parasitized lungs—common in pinnipeds—can exacerbate the effects of even mild irritation of respiratory tissues (St. Aubin 1990). Toxicity of oil is generally greater in younger animals so exposure to oil contamination during the breeding season would likely cause higher mortality among pups (Jenssen 1996, Jenssen et al. 1996).

4.2.5.2.3 Oil and gas activity threat assessment

Although the probability of an oil spill affecting a substantial portion of a ribbon seal population is likely low because of the dispersed nature of this species' distribution, the potential impacts from such a spill could be significant for some individuals, particularly if subsequent clean-up efforts were ineffective. Because toxicity varies widely across oil types and with exposure, it is difficult to generalize about the toxicological impacts on ribbon seals that come in contact with oil. Based on the documented exposures of other phocid species to oil, however, significant effects on health and survival would be expected for any seal that is immersed or coated in oil during the days and weeks following a spill (St. Aubin 1990).

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 population size, it is difficult to predict the impacts of an oil spill on ribbon 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 determine the magnitude of potential effects (Frost et al. 2004). In summary, the threats to ribbon seals from oil and gas activities are greatest where these activities converge with breeding aggregations or in migration corridors such as in Bering Strait, primarily due to potential impacts from oil spills.

4.2.5.3 Commercial fisheries interactions and by-catch

Commercial fisheries may impact ribbon seals through direct interactions (i.e., incidental take or by-catch) and indirectly through competition for prey resources (Lowry et al. 1996). During 1990-2007, a total of six observed direct fishery interactions have occurred within the U.S. Exclusive Economic Zone (EEZ), based on 1.16 million observed fishing operations (Alaska Fisheries Science Center 1990-2007). This suggests that one ribbon seal suffers direct mortality on average for every 193,000 federally managed groundfish-fishing operations (of which about 30% are fixed gear (longline and traps) and 70% are trawl). Many state-managed fisheries, including groundfish fisheries, are not observed, and estimates of by-catch are not available. If one took a conservative estimate that only one-third of all fishing operations were observed, then this would bring the total on the order of approximately 18 incidental takes within the U.S. EEZ during this 18-year period, or approximately 1 per year. Between 2007 and 2009, the estimated minimum mortality rate incidental to commercial fisheries in Alaska was 2.25 (CV = 0.22) ribbon seals per year, based exclusively on observer data (Allen and Angliss 2012).

Many coastal fisheries rely on gill nets, which are the most common type of gear involved in by-catch of marine mammals (Read 2008). Woodley and Lavigne (1991) summarized reported catches of ribbon seals in these types of fisheries around Japan, comprising from a few to as many as 14 per year. Burkanov and Nikulin (2001) estimated that, within the Russian EEZ, the incidental take of ribbon seals by the Japanese salmon gill-net fishery was 1,079 (±238) seals over the 7-year period from 1993-1999, or approximately 154 ribbon seals per year. Nikulin and Burkanov (2002) reported that a total of seven ribbon seals were taken by the Japanese salmon drift-net fishery within the Russian EEZ in 1999 and 2001. The authors indicated that there was also by-catch in the Russian salmon and halibut gill-net fisheries, but no estimates were produced (Burkanov and Nikulin 2001). No by-catch of ribbon seals was observed in gill-net fisheries in the coastal waters of Alaska, which have been subject to observer programs, with the exception of the 1990 Alaska Peninsula/Aleutian Islands salmon drift gill-net fishery. Coastal gill-net fisheries in other countries are mostly not subject to by-catch observer programs, so the numbers reported above, which total less than 200 ribbon seals per year, are certainly underestimates of the total take. However, even if this under-reporting is an order of magnitude low, the total incidental take of ribbon seals range-wide would not in itself constitute a major threat to the population.

For indirect interactions, it is important to note that commercial fisheries target a number of known ribbon seal prey species, such as walleye pollock, Pacific cod, herring, and capelin. These fisheries may affect ribbon 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 by-catch 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 ribbon seal populations is unknown. In the U.S. 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). In 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 ribbon seals.

On finer geographic and temporal scales, fishing can reduce the local abundance of fish that might otherwise be available for prey, where operations overlap with actively feeding ribbon seals. The fact that relatively few direct interactions with fishing gear have occurred suggests that the overlap in distributions may be relatively minor. This is further corroborated by ribbon seal telemetry data which shows a low level of overlap with fishing areas and seasons. The ribbon seals that have been tracked by satellite revealed that they spend a large proportion of time dispersed throughout the North Pacific

Ocean, Bering Sea, and Arctic Ocean (Boveng et al. 2007), often in pelagic regions where active commercial fishing is non-existent (Alaska Fisheries Science Center 1990-2007).

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 ribbon 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, ribbon seals dependence on different size composition for groundfish species would seem to be fairly adaptable. In addition, ribbon seals are likely to prey mostly on younger, smaller classes of fish than those harvested commercially, so this aspect of indirect fishery impacts is not likely to be significant.

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. However, 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 2009). 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 improving ice conditions (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, September 19, 2008, pers. comm.).

4.2.5.4 Shipping and transportation

4.2.5.4.1 Bering and Chukchi Seas

The substantial 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). Decreases 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. 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 begin freezing later in the fall, resulting in an expansion of potential shipping routes and lengthening of the potential navigation season (ACIA 2004, Khon et al. 2010). This reduction in sea ice “is very likely to increase marine transport and access to resources” in the Arctic during this century (ACIA 2004).

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). Both the NWP and NSR pass through the Chukchi and northern Bering Seas at the Pacific Ocean end of the routes (Figure 24). 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. 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 2004). The annual number of days with navigable conditions for the NSR is projected to increase from about 35 to 120 days for non-ice-reinforced ships (<50% ice concentration) and from about 80 to 165 days for ice-reinforced ships (<75% ice concentration) by 2100 (ACIA 2004).

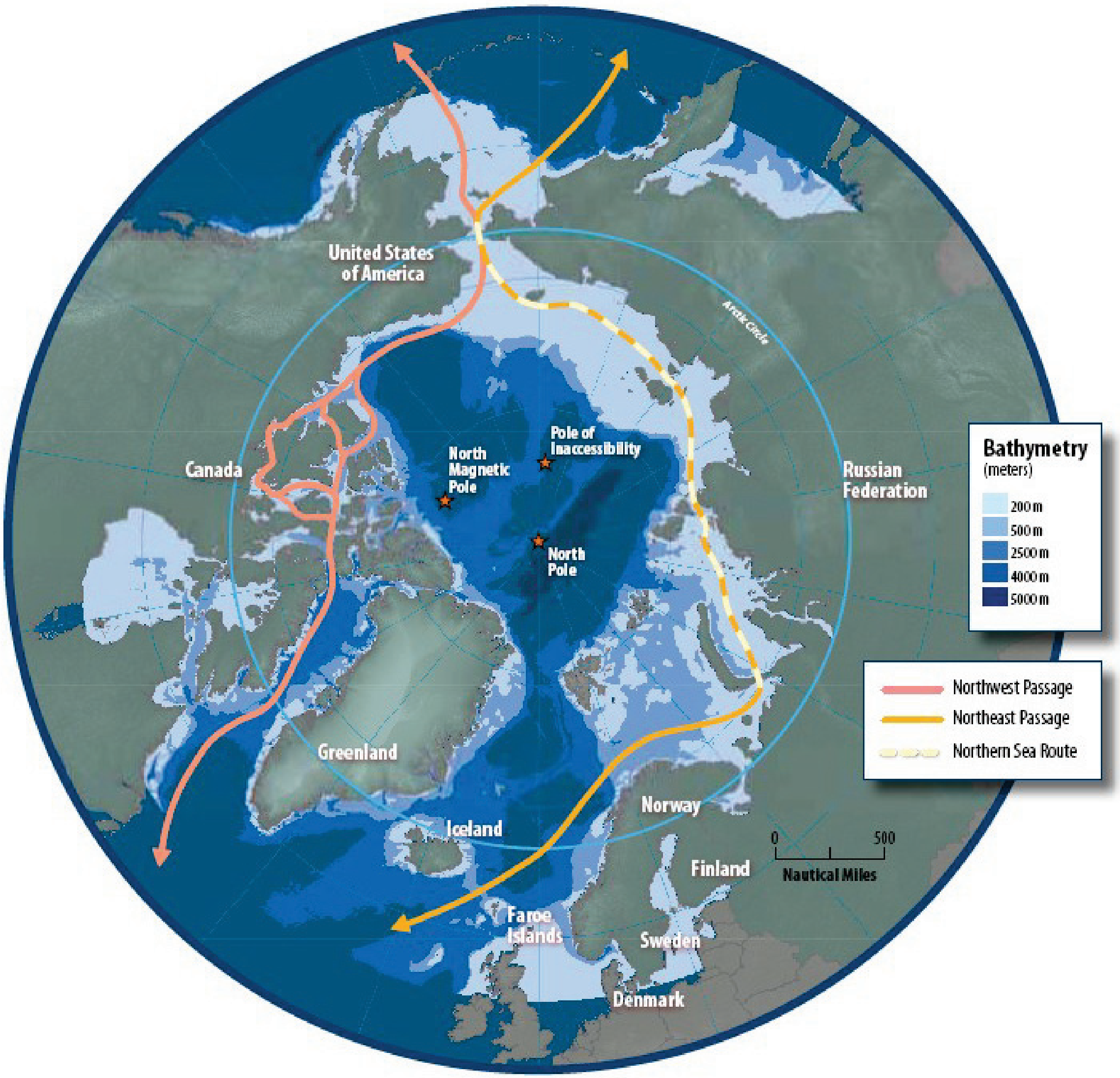


Figure 24 -- Major shipping routes and bathymetry of the Arctic Ocean (Source: Arctic Council 2009).

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. The operating season along the NWP is short—generally from late July to mid-October—and depends on the ice conditions in any given year (Arctic Council 2009). 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). However, 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 2004, Howell and Yackel 2004). 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 2004). These larger, denser ice features could present serious navigational hazards along this route.

According to the *Arctic Marine Shipping Assessment 2009 Report* (Arctic Council 2009), the eastern Bering Sea and Aleutian Islands (defined by the U.S. as part of the Arctic) are currently among the Arctic regions with the highest concentrations of ship traffic. Nearly half of the 6,000 vessels reported in the Arctic in 2004 (the study's baseline year) travelled along the Great Circle Route connecting Asia and North America through the Aleutian Island Archipelago. Most other ship traffic in the eastern Bering Sea consisted of bulk cargo carriers serving the Red Dog mine in northwest Alaska, fishing vessels, and ships resupplying coastal communities during summer (Arctic Council 2009). There was much less ship traffic reported in the western Bering Sea and Chukchi Sea in 2004, but this may be partially due to underreporting. Nearly all types of shipping activity are expected to increase in the Arctic in the future, including petroleum exploration and development; bulk transport of ore, oil, and gas; community resupply; government and research vessel operations; and cruise tourism (Arctic Council 2009).

4.2.5.4.2 Sea of Okhotsk

Though few details are available regarding actual shipping levels in the Sea of Okhotsk, resource development over the last decade stands out as a likely significant contributor (Reeves et al. 2005). It is clear that considerable ship traffic is needed to support present oil and gas operations, primarily off the northeastern coast of Sakhalin Island and the western coast of the Kamchatka Peninsula (Lapko and Radchenko 2000, Dulepova and Radchencko 2004), with future developments pointing to an ever-growing shipping industry to support the area's energy and minerals commerce (United Nations Environment Programme 2006). Large-scale commercial fishing occurs in many parts of the sea, accounting for half of the total Russian fish harvest from the Pacific Ocean (Dulepova and Radchencko 2004). Recent analyses of satellite imagery revealed fairly regular, large offshore oil slicks in the Sea of Okhotsk (Ivanov and Zatyagalova 2008). Sources of the oil could not be identified, but many of the largest slicks were linear in form and believed to have been left by passing ships. Fairly regular dumping of engine room and bilge water by fishing and factory processor ships is also believed to be a significant source of pollution (Ivanov and Zatyagalova 2008).

The Russian government and international companies have focused primarily on developing oil and gas fields near Sakhalin and less on developing the resources and technical expertise to respond adequately to large or remote oil spills. For example, many oil tankers operating in the region do not have double hulls (Lawn et al. 1999, United Nations Environment Programme 2006). Although Russian waters are covered by the MARPOL treaty, inadequate port reception facilities, high costs of waste disposal, inaction against violators, and an inability to detect illegal dumping are believed to result in significant waste discharges at sea (Schei and Brubaker 2006, Ivanov and Zatyagalova 2008). An accident at an oil production complex near Sakhalin Island resulted in a large (3.5 ton) spill in 1999 (Lapko and Radchenko 2000). In winter 2009, an unknown quantity of oil associated with a tanker fouled 3 km of coastline and hundreds of birds in Aniva Bay (Associated Foreign Press 2009). Navigation in this sea is reported to be very difficult during winter due to heavy ice conditions, yet shipping still occurs year-round at the largest ports with the help of icebreakers (Kommersant 2004). Winter shipping activities in the southern Sea of Okhotsk are expected to increase considerably as oil and gas production pushes the development and use of new classes of icebreaking ships, thereby increasing the potential for shipping accidents and spills in the ice-covered regions of this sea (Shumei et al. 2001, Choi 2008).

4.2.5.4.2.1 Potential threats to ribbon seals from shipping activities

4.2.5.4.2.1.1 Oil spills and toxic pollution

The most significant threat to ribbon seals posed by shipping activities is the accidental or illegal discharge of oil or other toxic substances from ships due to their immediate and potentially long-term effects on individual animals, populations, food webs, and the environment (Arctic Council 2009). This threat is magnified by the lack of accident response resources in the Arctic, the lack of effective techniques for containing or cleaning up spilled oil under ice or in broken ice, and the challenges of conducting a rapid, effective spill response in regions where weather is often severe, daylight may be limited, and accidents may happen in very remote locations (AMAP 2007). The potential threat of oil spills to ribbon seals was previously reviewed in the section on oil and gas exploration, development, and production (Section 4.2.5.2). The regular and legal discharge of oily sludge, garbage, and other debris from ships also poses significant risks to ribbon seals since these types of pollutants are more common and widespread than accidents or illegal discharges and can have similar immediate and long-term impacts on individuals, communities, and the environment (Arctic Council 2009).

4.2.5.4.2.1.2 Noise and physical disturbance

All vessels produce sound during operation, which when propagated at certain frequencies and intensities can alter the normal behavior of marine mammals, mask their underwater communications and other uses of sound, cause them to avoid noisy areas, and in extreme cases (e.g., high-powered sonar), damage their auditory systems and even cause death (Marine Mammal Commission 2007, Arctic Council 2009, OSPAR Commission 2009). The mere presence and movements of ships in the vicinity of seals can cause disturbance of their normal behaviors (Jansen et al. 2010) and potentially cause ribbon seals to abandon their preferred breeding habitats in areas with high traffic (Mansfield 1983). Pups have a greater potential for heat loss than adults, thus, would be more prone to incur energetic costs of increased time in the water if vessel disturbance became a frequent event. Ribbon seal pups may also be at risk of abandonment by their mothers as a result of disturbance by icebreakers (Smiley and Milne 1979). Vessel strikes are probably not a threat to ribbon seals except in the case of icebreakers, which could potentially crush individuals (particularly young pups and perhaps their protective mothers) that are hauled out on sea ice in the springtime.

4.2.5.4.2.1.3 Indirect effects

Ships contribute significantly to global climate change and air pollution through their emissions of GHGs, aerosols, nitrogen and sulfur oxides, carbon monoxide, and particulate matter. The release and deposition of black carbon in the Arctic is of particular concern because of the effect it has on reducing the albedo of sea ice and snow cover, which in turn significantly increases the rate of melting (ACIA 2005, Arctic Council 2009). The introduction of exotic species into the Arctic by ships could also affect ribbon seals, although likely in a more indirect manner, such as through changes in the lower trophic levels of their food webs (Arctic Council 2009).

4.2.5.4.2.2 Shipping threat assessment

Current and future shipping activities in the Arctic pose varying levels of threat to ribbon seals depending on the type and intensity of the shipping activity and its degree of spatial and temporal overlap with the seals. These factors are inherently difficult to know or predict. There is no one scenario of global supply and demand that seems most likely (ECON 2007), and knowledge about present impacts is even limited because few are witnessed, documented, or studied. Nonetheless, based on our knowledge of ribbon seals and shipping activity within their range, some general assessments can be made.

Ribbon seals are typically widely distributed in low densities on sea ice during the spring reproductive season, and are likely even more dispersed while pelagic during the summer and fall open-water seasons. They are not known to congregate in large numbers as many other pinniped species do. Their highly dispersed distribution may help mitigate the risks of localized shipping threats, such as oil spills or physical disturbance, since the impacts from such events would be less likely to affect large numbers of seals. The fact that nearly all shipping activity in the Arctic purposefully avoids areas of ice and primarily occurs during the ice-free or low-ice seasons (Arctic Council 2009) may also help mitigate the threats of shipping to ribbon seals since this species is closely associated with ice mainly during the whelping, nursing, and molting periods when the seals (especially young pups) may be most vulnerable to shipping impacts.

Icebreakers may pose special risks to ribbon seals since they are capable of operating year-round in all but the heaviest ice conditions and are sometimes used to escort other types of vessels (e.g., tankers and bulk carriers) through ice-covered areas. Furthermore, new classes of ships are being designed that serve the dual roles of both tanker/carrier and icebreaker (Arctic Council 2009). Therefore, if icebreaking activities increase in the Arctic in the future as expected, the likelihood of negative impacts (e.g., oil spills, pollution, noise, and disturbance) occurring in ice-covered areas where ribbon seals reside will likely also increase.

Spatially, ribbon seals may be at the greatest risk from shipping threats in areas where geographic constriction concentrates seals and shipping activity into confined areas, such as Bering Strait, where a substantial fraction of the Bering Sea population passes through in relatively short seasonal periods during migrations north and south. Effective governance and regulations will be necessary to mitigate the threats of shipping to ribbon seals, especially in areas and during periods of high risk (Arctic Council 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. Indeed, shipping impacts alone may comprise a low risk to entire populations, but when combined with the effects related to diminishing ice cover, such as increasingly denser aggregations, the impacts may be magnified and play an important role in affecting the future health of populations.

4.2.6 Threats Assessment

A structured approach was used to elicit BRT members' expert judgment about the significance or potential significance of threats facing ribbon seals. The threats were grouped by ESA Section 4(a)(1) factors (excluding Inadequacy of Existing Regulatory Mechanisms), and each individual threat was scored for its significance, in two components: extent and likelihood. Extent was defined as the portion of the population that would experience reduced survival or reproductive success if the threat condition or event were to occur. Judging the extent of a threat required considerations such as the geographic scope, the age classes of ribbon seals affected, and the duration of that threat. Likelihood was defined as the probability that the threat will occur within a specified time period in the foreseeable future.

BRT members noted that for some threats, such as those associated with loss of sea ice, future projections are readily available that assist in judgment about the most plausible scenario that will occur in the future, thereby helping to establish an extent as a basis for assigning a likelihood. For many threats, however, such as oil spills or commercial harvests, there are broad ranges of plausible extents with little or no consensus about what scenarios are most plausible. In those cases, it was necessary first to judge what extent of a threat was most plausible—a choice that includes an element of likelihood. In other words, the process of judging the significance of a threat was often an iterative process in which extent was not always judged before likelihood, and vice-versa.

BRT members were asked to score the extent and likelihood of each threat on 5-level scales (Table 6), separately for the Bering Sea and the Sea of Okhotsk. The scores were assigned in consideration of two time intervals: from now to the year 2050, and from now to the year 2100. The former interval was included to provide a sense of how some of the threats are anticipated to change, and to provide a reference similar to the time frame used in the previous assessment of ribbon seal status (Boveng et al. 2008). The latter interval corresponds to the foreseeable future for the primary threats related to climate disruption by greenhouse gas emissions. For the scores ascribed to the period from now to 2100, BRT members were asked to express their confidence in their scores, on a scale of low, medium, or high. As guidance, high confidence would be justified if there is *definitive* published and unpublished data to support the extent and likelihood ascribed to a threat, medium confidence would justified if there is *some* published and unpublished data to support the extent and likelihood ascribed to a threat, and low confidence would justified if there is *little* published and unpublished data to support the extent and likelihood ascribed to a threat.

Table 6. -- Five-level scales used to score the significance of threats facing ribbon seals, based on the extent and likelihood of each threat.

Score	Extent	Likelihood (that the threat will occur)
1	**Minor**: the threat would reduce the survival or reproductive success of a minor portion (<10%) of the population	**Remote** (<=1%)
2	**Moderate**: the threat would reduce the survival or reproductive success of a moderate portion (10%-30%) of the population	**Unlikely** (2%-20%)
3	**Substantial**: the threat would reduce the survival of a substantial portion (31%-50%) of the population	**Possible** (21%-79%)
4	**Major**: the threat would reduce the survival or reproductive success of a major portion (51%-80%) of the population	**Likely** (80%-98%)
5	**Widespread**: the threat would reduce the survival or reproductive success of all or nearly all (>80%) of the population	**Almost certain** (>=99%)

To provide an illustrative example of the scoring process, one BRT member described the rationale used to arrive at a judgment about the threat of a decrease in sea ice habitat for whelping and nursing, in the Bering Sea:

> “For the period from now to 2050, an extent score of 1 (‘minor’) was chosen. Whelping and nursing primarily occurs in April and early May. Although sea ice varies, and decreases overall by 2050, there still appears to be suitable habitat for most seals over this time period and even during the last decade. Therefore, the extent chosen is 1, which equates to ‘minor’—that survival or reproductive success would be reduced in <10% of the population. A likelihood score of 3, equating to ‘possible’ (21-79%), was chosen. The reduction of survival or reproductive success is possible but the connection between a small reduction in suitable habitat and an actual negative impact on vital rates is uncertain and therefore doesn’t warrant a likelihood of greater than 80%.
>
> For the period from now to 2100, an extent score of 3 (‘substantial’) was chosen. Whelping and nursing primarily occurs in April and early May. By 2100, sea ice will be diminished during these months and the average ice edge will be far away from the shelf break, which may reduce feeding efficiency for adults. However, there will still be occasional or even frequent years with ice that may be suitable habitat, given that the effects on the ecosystem and resultant effects on feeding during this period are uncertain. Therefore, the extent chosen was ‘substantial’—that survival or reproductive success is reduced in 31-50% of the population. A likelihood score 4 (‘likely’, 80-98%) was chosen. Given the greatly reduced extent of sea ice by 2100 (e.g., >10% chance of no ice in April in the Eastern Bering) it is very likely that 31-50% of the population would have reduced vital rates. The likelihood is enhanced by the possibility that the location of available ice will not be optimal feeding habitat, reducing the condition of nursing females. One factor that keeps the likelihood from being certain is that changes in arctic ecology may result in habitat becoming suitable in the Chukchi.

> Uncertainty in both the amount of sea ice available over the period and in the makeup of suitable habitat for ribbon seal survival and reproduction supports ‘medium’ confidence in both the extent and likelihood scores for the period from now to 2100. These scores could plausibly over- or under-estimate this threat.”

The extent and likelihood scores for the period from now to 2100 were combined as a product to yield a threat score that could range from low to extreme (numerically from 1-25) (Table 7). These individual threat scores were then considered in a judgment about the overall score, using the same scale, for all the threats included in each ESA Section 4(a)(1) factor. In assigning an overall factor score, BRT members considered that a factor score should typically be at least as high as the individual threat scores within that factor, and in some cases higher because multiple threats may have cumulative effects that sum or magnify the overall threat for the factor.

Table 7. -- Threat significance scores were obtained as the product of extent and likelihood for the period from now to 2100. The range of these scores was divided into categories of low (1-4), moderate (5-10), high (11-15), very high (16-20), and extreme (21-25), which are shown as different shades.

		Extent				
		Minor	**Moderate**	**Substantial**	**Major**	**Widespread**
Likelihood	**Remote**	**1**	**2**	**3**	**4**	**5**
	Unlikely	**2**	**4**	**6**	**8**	**10**
	Possible	**3**	**6**	**9**	**12**	**15**
	Likely	**4**	**8**	**12**	**16**	**20**
	Almost Certain	**5**	**10**	**15**	**20**	**25**

The BRT members scored the threats individually, then met as a group to discuss the threats for which there were extreme ranges in scores. The discussion was aimed at ensuring that a consistent approach was used for scoring, rather than at achieving consensus opinion on the significance of threats. A final round of scoring was completed after this discussion. The average score and the range of scores among BRT members are presented for each threat and ESA Section 4(a)(1) factor, separately for the Bering Sea and the Sea of Okhotsk in Table 8 and Table 9, respectively.

For ribbon seals in both the Bering Sea and Sea of Okhotsk, the BRT judged the threats of destruction or modification of habitat to be of greater significance than the threats from the other factors. In the Bering Sea, loss of suitable ice for molting and pup maturation, and diminished prey from effects of ocean acidification were judged to be the greatest threats to habitat, although confidence about the score for the latter threat was low (Table 8). In the Sea of Okhotsk, losses of ice suitable for whelping, nursing, mating, and molting were judged to pose the greatest threats (Table 9). Threats of overutilization were judged to be of low significance and threats from disease, parasites, and predation were judged to be of moderate significance in both regions. Threats from other natural or man-made factors were judged to be of moderate significance in both regions. Across all four factors, the threats were judged to be more significant in the Sea of Okhotsk than the Bering Sea, reflecting greater concern about ice loss and regulation of petroleum development in the Sea of Okhotsk. There was substantial variability in the threat scores and factor scores among the BRT members (Table 10 and Table 11), with strong consensus only in the factor comprising threats of overutilization in the Bering Sea.

Table 8. -- Threats assessment table for the Bering Sea. BRT members judged the extent and likelihood (on a scale from 1 to 5) of each threat to the persistence of ribbon seals from now until 2050 and until 2100. BRT members also indicated their confidence (on a scale of 1-3) in their scores for the period from now to 2100. The product extent and likelihood scores is reported as a threat score for each threat, again relating to the period from now to 2100. BRT members used the threat scores (on a scale of 1-25) to assign a score to each overall ESA Section 4(a)(1) factor. The averages and ranges of scores are given in parentheses.

ESA Section 4(a)(1) Factor	Threats	Now to 2050		Now to 2100				Factor Score
		Extent	Likelihood	Extent	Likelihood	Confidence	Threat Score	
Habitat destruction, modification, or curtailment	Decrease in sea ice habitat suitable for whelping and nursing	1.7 (1-3)	2.7 (1-4)	2.7 (2-4)	3.2 (2-4)	2.1 (2-3)	8.9 (4-12)	13.2 (4-18)
	Decrease in sea ice habitat suitable for pup maturation	1.9 (1-3)	2.7 (1-4)	2.8 (2-4)	3.5 (2-4)	2.0 (2-2)	9.9 (4-16)	
	Decrease in sea ice habitat suitable for mating	1.6 (1-3)	2.5 (1-3)	2.4 (1-4)	3.0 (2-4)	2.0 (1-3)	7.2 (3-12)	
	Decrease in sea ice habitat suitable for molting	2.4 (1-3)	2.9 (2-4)	3.3 (2-4)	3.5 (2-4)	2.0 (2-2)	11.7(6-16)	
	Decrease in prey density and/or availability due to changes in ice cover and ocean warming	1.9 (1-3)	2.5 (1-3)	2.5 (1-3)	2.9 (2-4)	1.2 (1-2)	7.4 (2-12)	
	Decoupling of sea ice resting areas from deep-water foraging habitat	1.6 (1-3)	2.6 (1-3)	2.5 (1-3)	3.4 (3-4)	1.5 (1-3)	8.4 (3-12)	
	Decrease in prey density and/or availability due new competitive relationships or other changes in community structure	2.0 (1-3)	2.6 (2-3)	2.4 (1-3)	2.9 (2-4)	1.1 (1-2)	7.1 (2-12)	
	Decrease in prey density and/or availability due to changes in ocean acidification	2.4 (1-4)	2.5 (1-3)	3.1 (1-4)	3.2 (2-4)	1.4 (1-2)	10.3(2-16)	
Over-utilization	Excessive subsistence harvest	1.0 (1-1)	1.0 (1-1)	1.1 (1-2)	1.3 (1-2)	2.5 (1-3)	1.5 (1-4)	2.3 (1-4)
	Illegal harvest	1.0 (1-1)	1.2 (1-3)	1.1 (1-2)	1.3 (1-3)	2.5 (1-3)	1.5 (1-4)	
	Excessive sport and/or commercial harvest	1.3 (1-2)	1.4 (1-2)	1.2 (1-2)	1.5 (1-3)	2.5 (1-3)	1.8 (1-4)	
	Excessive scientific take	1.0 (1-1)	1.0 (1-1)	1.0 (1-1)	1.1 (1-2)	2.8 (2-3)	1.1 (1-2)	
Disease, parasites and predation	Increased infection or disease	1.8 (1-2)	2.4 (1-3)	2.0 (1-3)	2.5 (1-3)	1.5 (1-3)	5.2 (1-9)	5.9 (1-9)
	Increased predation associated with changes in sea ice cover	1.3 (1-2)	1.7 (1-3)	1.4 (1-2)	2.1 (1-3)	1.5 (1-3)	2.9 (1-6)	
	Increase in parasites	1.6 (1-2)	2.0 (1-3)	1.6 (1-2)	2.1 (1-3)	1.3 (1-3)	3.5 (1-6)	
Other natural or man-made factors	Increased impairment (e.g., reproductive, metabolic) from contaminants	1.4 (1-2)	1.6 (1-3)	1.5 (1-3)	1.9 (1-3)	1.5 (1-3)	3.1 (1-6)	7.5 (5-12)
	Physical disturbance, injury or mortality from oil and gas development, shipping or commercial fisheries	1.4 (1-2)	2.2 (1-3)	1.9 (1-3)	2.6 (1-3)	1.5 (1-2)	5.3 (1-9)	
	Noise pollution from oil and gas development, shipping or commercial fisheries and ocean acidification	1.6 (1-4)	2.1 (1-3)	1.9 (1-4)	2.6 (2-3)	1.5 (1-2)	5.2 (2-12)	
	Disturbance, injury or mortality from oil spills and other discharge	1.7 (1-3)	2.3 (2-3)	2.1 (1-3)	2.7 (2-3)	1.5 (1-3)	5.8 (2-9)	

Table 9. -- Threats assessment table for the Sea of Okhotsk. BRT members judged the extent and likelihood (on a scale from 1 to 5) of each threat to the persistence of ribbon seals from now until 2050 and until 2100. BRT members also indicated their confidence (on a scale of 1-3) in their scores for the period from now to 2100. The product extent and likelihood scores is reported as a threat score for each threat, again relating to the period from now to 2100. BRT members used the threat scores (on a scale of 1-25) to assign a score to each overall ESA Section 4(a)(1) factor. The averages and ranges of scores are given in parentheses.

ESA Section 4(a)(1) Factor	Threats	Now to 2050		Now to 2100				Factor Score
		Extent	Likelihood	Extent	Likelihood	Confidence	Threat Score	
Habitat destruction, modification, or curtailment	Decrease in sea ice habitat suitable for whelping and nursing	2.4 (1-4)	2.8 (1-4)	3.5 (2-4)	3.5 (3-5)	1.9 (1-3)	12.5(6-20)	16.8 (12-20)
	Decrease in sea ice habitat suitable for pup maturation	2.5 (1-4)	3.1 (2-4)	3.5 (2-4)	3.9 (3-5)	1.9 (1-3)	13.6(6-20)	
	Decrease in sea ice habitat suitable for mating	2.2 (1-4)	2.7 (1-4)	3.0 (2-4)	3.5 (3-5)	1.8 (1-3)	10.8(6-20)	
	Decrease in sea ice habitat suitable for molting	3.0 (2-4)	3.1 (2-4)	3.8 (3-4)	3.9 (3-5)	2.1 (1-3)	15.1(9-20)	
	Decrease in prey density and/or availability due to changes in ice cover and ocean warming	2.0 (1-3)	2.6 (2-3)	2.7 (1-4)	3.2 (2-4)	1.2 (1-3)	9.1 (2-16)	
	Decoupling of sea ice resting areas from deep-water foraging habitat	1.7 (1-3)	2.6 (1-4)	2.4 (1-4)	3.3 (2-4)	1.2 (1-3)	8.0 (3-16)	
	Decrease in prey density and/or availability due new competitive relationships or other changes in community structure	2.1 (1-3)	2.6 (2-3)	2.5 (1-3)	3.0 (2-4)	1.0 (1-1)	7.7 (3-12)	
	Decrease in prey density and/or availability due to changes in ocean acidification	2.3 (1-4)	2.5 (1-3)	3.0 (1-4)	2.9 (2-4)	1.4 (1-3)	8.9 (2-16)	
Over-utilization	Excessive subsistence harvest	1.1 (1-2)	1.4 (1-4)	1.2 (1-2)	1.5 (1-4)	2.2 (1-3)	2.0 (1-6)	4.3 (2-6)
	Illegal harvest	1.4 (1-2)	1.7 (1-3)	1.4 (1-2)	2.0 (1-3)	2.0 (1-3)	2.5 (1-4)	
	Excessive sport and/or commercial harvest	1.8 (1-2)	2.0 (1-3)	1.8 (1-3)	2.2 (1-3)	1.7 (1-3)	4.0 (1-6)	
	Excessive scientific take	1.0 (1-1)	1.3 (1-4)	1.1 (1-2)	1.5 (1-4)	2.6 (1-3)	1.7 (1-4)	
Disease, parasites and predation	Increased infection or disease	1.8 (1-2)	2.4 (1-3)	2.2 (1-3)	2.4 (1-3)	1.3 (1-3)	5.5 (1-9)	6.3 (1-10)
	Increased predation associated with changes in sea ice cover	1.2 (1-2)	1.7 (1-3)	1.4 (1-2)	2.4 (1-3)	1.3 (1-3)	3.3 (1-6)	
	Increase in parasites	1.6 (1-2)	2.0 (1-3)	1.6 (1-2)	2.2 (1-3)	1.2 (1-3)	3.7 (1-6)	
Other natural or man-made factors	Increased impairment (e.g., reproductive, metabolic) from contaminants	1.5 (1-2)	2.1 (1-3)	1.6 (1-2)	2.4 (1-3)	1.4 (1-3)	4.1 (1-6)	8.6 (4-12)
	Physical disturbance, injury or mortality from oil and gas development, shipping or commercial fisheries	1.5 (1-2)	2.5 (1-4)	1.8 (1-3)	3.0 (1-5)	1.5 (1-2)	5.6 (1-10)	
	Noise pollution from oil and gas development, shipping or commercial fisheries and ocean acidification	1.8 (1-4)	2.0 (1-4)	1.9 (1-4)	2.5 (2-4)	1.5 (1-2)	5.1 (2-12)	
	Disturbance, injury or mortality from oil spills and other discharge	1.8 (1-3)	2.5 (2-4)	2.1 (1-3)	3.1 (2-4)	1.5 (1-3)	6.9 (2-12)	

Table 10. -- Distribution of threat scores for the Bering Sea assigned by the 11 BRT members. Warmer colors indicate greater consensus.

ESA Section 4(a)(1) Factor	Threats	Threat Scores													
		1	2	3	4	5	6	8	9	10	12	15	16	20	25
Habitat destruction, modification or curtailment	Decrease in sea ice habitat suitable for whelping and nursing				2		2		2		5				
	Decrease in sea ice habitat suitable for pup maturation				1		2	1	1		5		1		
	Decrease in sea ice habitat suitable for mating			2	1		3		3		2				
	Decrease in sea ice habitat suitable for molting						2		1		5		3		
	Decrease in prey density and/or availability due to changes in ice cover and ocean warming		1	1	1		1		6		1				
	Decoupling of sea ice resting areas from deep-water foraging habitat			1			3	1	3		3				
	Decrease in prey density and/or availability due new competitive relationships or other changes in community structure		1	1	1		2		5		1				
	Decrease in prey density and/or availability due to changes in ocean acidification		1		1		1		1		5		2		
Over-utilization	Excessive subsistence harvest	8	2		1										
	Illegal harvest	9		1	1										
	Excessive sport and/or commercial harvest	5	4	1	1										
	Excessive scientific take	10	1												
Disease, parasites predation	Increased infection or disease	1	1		3		4		2						
	Increased predation associated with changes in sea ice cover	3	1	3	3		1								
	Increase in parasites	2	1	1	5		2								
Other natural or man-made factors	Increased impairment (e.g., reproductive, metabolic) from contaminants	4		2	3		2								
	Physical disturbance, injury or mortality from oil and gas development, shipping or commercial fisheries	1	1	3	1		1		4						
	Noise pollution from oil and gas development, shipping or commercial fisheries and ocean acidification		3	2			4		1		1				
	Disturbance, injury or mortality from oil spills and other discharge		1	1	2		4		3						

Table 11. -- Distribution of threat scores for the Sea of Okhotsk assigned by the 11 BRT members. Warmer colors indicate greater consensus.

ESA Section 4(a)(1) Factor	Threats	Threat Scores													
		1	2	3	4	5	6	8	9	10	12	15	16	20	25
Habitat destruction, modification or curtailment	Decrease in sea ice habitat suitable for whelping and nursing						2		2		2		4	1	
	Decrease in sea ice habitat suitable for pup maturation						1				5		4	1	
	Decrease in sea ice habitat suitable for mating						3	1	1		4		1	1	
	Decrease in sea ice habitat suitable for molting								2		1		6	2	
	Decrease in prey density and/or availability due to changes in ice cover and ocean warming		1	1			1		5		1		2		
	Decoupling of sea ice resting areas from deep-water foraging habitat			2	1		2	1	2		2		1		
	Decrease in prey density and/or availability due new competitive relationships or other changes in community structure			1	1		2		6		1				
	Decrease in prey density and/or availability due to changes in ocean acidification		1				2	1	4		2		1		
Over-utilization	Excessive subsistence harvest	6	3		1		1								
	Illegal harvest	2	4	1	3										
	Excessive sport and/or commercial harvest	1	2	1	3		4								
	Excessive scientific take	8		1	2										
Disease, parasites predation	Increased infection or disease	1	2		2		2		4						
	Increased predation associated with changes in sea ice cover	2	1	4	2		2								
	Increase in parasites	2	1	1	4		3								
Other natural or man-made factors	Increased impairment (e.g., reproductive, metabolic) from contaminants	2	1	1	2		5								
	Physical disturbance, injury or mortality from oil and gas development, shipping or commercial fisheries	1		3	1		2	1	2	1					
	Noise pollution from oil and gas development, shipping or commercial fisheries and ocean acidification		2	2	4		1				2				
	Disturbance, injury or mortality from oil spills and other discharge		2		1		4	1			3				

4.3 Analysis of Demographic Risks

Threats to a species' long-term persistence are manifested demographically as risks from low abundance, poor productivity, disrupted spatial structure and connectivity, and reduced genetic and ecological diversity. These demographic risks thus provide the most direct indices or proxies of extinction risk. In this section, the current and foreseeable status of each of these risks is assessed in turn by responding to a set of questions adapted from guidelines posed by McElhany et al. (2000) for determining the conservation status of populations. Although the guidelines were developed in consideration of viable salmonid populations, they 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 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)?

With a population of around 200,000-300,000 or more individuals, spread over the entire known historical range, ribbon seals are not at risk from typical year-to-year variation nor to episodic perturbations such as El Niño and related oceanographic shifts that have occurred numerous times in the species' past. The primary anthropogenic perturbation expected in the foreseeable future is of a different nature, namely low frequency (i.e., long-term trend) variation. Although the trajectory of ribbon seal abundance is impossible to project with any certainty, it is likely that the combined effects of diminished sea ice habitat and disrupted prey communities will reduce ribbon seals' vital rates of survival and reproduction gradually throughout the foreseeable future. Whether the abundance might become low enough to pose serious risk of extinction due to interannual or episodic variability is considered further in 4.3.2.1 .

4.3.1.2 Is the species' abundance so low, or variability in abundance so high, that it is at 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 ribbon seals 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 ribbon seals are not subject to extreme fluctuations leading to risk of depensation. The species also does not appear to rely upon social structures, foraging groups, or group predation defenses. The mating system is poorly understood, but does not involve groups or dense aggregation areas. The species' use of vocalizations may support finding mates in low-density distributions that seem to be characteristic. Depensatory processes are unlikely to play a significant role in ribbon seal demography within the foreseeable future.

4.3.1.3 Is the species' abundance so low that its genetic diversity is at 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 ribbon seals (Quakenbush and Citta 2008), though the current sample is too small for adequate assessment. In any case, genetic risks associated with abundance are typically confined to very small populations of tens to hundreds of individuals (e.g., studies reviewed by Frankham 2005), again indicating that these risks are not currently a concern for ribbon seals.

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

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 ribbon 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 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 ribbon seal, demographic stochasticity would be unlikely to be a concern for populations with greater than several tens to hundreds of individuals. Clearly, for the ribbon seal population, which currently comprises hundreds of thousands of individuals, demographic stochasticity is highly unlikely to be an imminent risk. Whether ribbon seal numbers could plausibly reach low enough levels for demographic stochasticity to become important for extinction risk within the foreseeable future could be addressed by modeling, but there is currently not enough reliable information available for setting bounds on the parameters required for such a population viability analysis model.

4.3.2 Productivity

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

The current net productivity (population trend) of ribbon seals is unknown, due to the imprecision of available abundance estimates. Hypothetically, if the current population size is 267,000 individuals, ribbon seals could sustain about 100 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.

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?

The average productivity is not known to be below replacement, and the species is thought to occupy all of its historically observed range and habitats. Depensatory risks were considered in Section 4.3.1.2 .

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 risk of satisfying any of the preceding conditions?

The only trends in abundance or shifts in demographic traits (e.g., age structure and reproductive rates) that are supported by data are those associated with Soviet overharvest in the 1950s and 1960s (Fedoseev 1973, Fedoseev 2000). The population decline apparently reversed when harvest levels were reduced through the 1980s (Fedoseev 2000). A possible signal of this shift has been detected in growth rates and a condition index examined by Quakenbush and Citta (2008) using samples from ribbon seals collected in the Bering Sea. Seals from the 1970s, when population densities were reported to be the lowest, had greater age-specific body length (i.e., faster growth) than seals harvested in the 1960s and 2000s. Body condition assessed by a blubber volume index was suggestive of the same pattern, but condition in the 1970s was not significantly different than in the 2000s. Although the implication is that productivity may have been higher in the 1970s than in recent years, the low age at maturity and high pregnancy rates that Quakenbush and Citta (2008) measured in samples from the 2000s were still indicative of high potential for productivity.

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 ribbon seal population trends restricts the overall confidence in assessing the species' long-term risks. Unfortunately, a reliable trend estimate for ribbon 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.

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 risk of extinction due to environmental and anthropogenic perturbations or catastrophic events?

This question is explored in detail under Section 4.2.1.

4.3.3.2 Are natural rates of dispersal among populations, metapopulations, or habitat patches so low that the species is at 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 given the relative absence of physical barriers in the marine environment (compared with terrestrial or river systems) and the ribbon seal's proven ability to move long distances, as shown by satellite-tracked individuals (Figure 5). Furthermore, genetic analysis of 24 skin samples (22 from Little Diomede Island and two from Hooper Bay, Alaska) revealed that ribbon seals possess very high levels of nucleotide and haplotype diversity, with many individuals possessing unique haplotypes (Quakenbush and Citta 2008). Genetic population structure was also not detected. This is not surprising, however, given the small samples sizes, small number of sample locations, and the timing of sample collections during the pelagic (i.e., potentially mixed) portion of the year (Quakenbush and Citta 2008). Future genetic analyses that address these issues are a high priority.

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

No populations, subpopulations, or habitat patches for ribbon seals are known to have been lost. Concern about future loss of habitat was the primary motivation for this ESA status review; the threats to ribbon seal habitat are considered explicitly in Section 4.2.1.

Because of potential differences in the strength of threats between the Bering Sea and Sea of Okhotsk, the threats were scored separately for these two portions of the ribbon seal's range. Indeed, as shown in and, all of the ESA threat factors were judged to be higher in the Sea of Okhotsk than in the Bering Sea. Naturally, this difference raises the question of whether loss of the portion of the species residing in the Sea of Okhotsk would place the entire species at risk of extinction.

At present, the numbers of ribbon seals in both portions of the range are large, on the order of 100,000 or more in each sea basin. As discussed above, populations or sub-populations of this magnitude and with the life history characteristics of the ribbon seal are typically immune to demographic risks that are associated with or exacerbated by low abundance, such as year-to-year environmental fluctuations, loss of diversity, failure of breeding systems, and lack of potential for productivity. Thus, at least in the near term, loss of the Sea of Okhotsk portion of the ribbon seal population would not place the remainder, the Bering Sea portion, in danger of extinction.

The climate related threats facing ribbon seals are expected to increase more or less in parallel between the Bering Sea and Sea of Okhotsk, albeit more quickly in the latter. If ribbon seal numbers in the Bering Sea decrease in the future to levels at which the demographic risks considered in this section (4.3), become significant, then the loss of either the Sea of Okhotsk or the Bering Sea portions would likely place the entire species in danger of extinction.

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

The distribution of ribbon seal breeding areas in the past few decades is relatively well known, though it is not known whether there have been recent changes, owing to lack of recent surveys with sufficient coverage. Also, the relative importance of the Chukchi Sea is not currently known, though initial results suggest that about one-third of ribbon seals from the eastern and central Bering Sea breeding area use the Chukchi Sea in summer and autumn. Recent satellite-tracking studies have produced substantial new spatial data on movements and habitat use, for both the ice-associated and pelagic periods of the ribbon seal's annual cycle; analysis and publication of these results can be expected to reduce uncertainty about spatial processes for future ribbon 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?

None of these changes or losses is known to have occurred.

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

No information about rates of dispersal or gene flow is available.

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

Ribbon seals, as wide-ranging sub-Arctic and Arctic inhabitants, continue to be exposed to substantial ecological variation at a broad range of time scales. Thus, from the standpoint of concern about lack of ecological variation leading to lack of genetic diversity, this is not a threat for ribbon seals. The broader issue of whether other impacts have occurred or are anticipated in response to alteration of natural processes is the subject of Section 4.2.1.

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

Recognition of the uncertainty about requisite levels of diversity has been factored into the BRT's assessment of risks.

4.3.5 Relevant Modifying or Mitigating Factors

4.3.5.1 Life-history characteristics

Ribbon 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 ribbon seals if a large decline were to occur.

4.3.5.2 Population characteristics

Ribbon seals tend to be highly dispersed, particularly during the ice-free, pelagic season. Even during the ice-associated breeding season, ribbon seals are relatively more dispersed than most other pinnipeds. This trait should reduce demographic risks associated with localized threats, such as oil spills or a fishery with concentrations of gear that is prone to by-catch of seals.

4.3.5.3 Habitat constraints or benefits

The marine habits of ribbon seals and the capability of individuals to undertake large seasonal movements and shifts between pelagic 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 ribbon seal habitat within the current range is reduced by climate change, it is plausible that the population will adjust by shifting its range to include new habitat made suitable by, for example, a northward shift of the typical spring ice edge. Such changes may involve demographic impacts to the population, though the present level of quantitative understanding is insufficient to assess the magnitude of these impacts.

4.3.6 Demographic Risks Assessment

The BRT members' assessments of the significance of demographic risks to the persistence of ribbon seals were summarized in numerical scores. Scoring was modeled on similar approaches used in other ESA status reviews (e.g., Atlantic Wolffish Biological Review Team 2009, Butler et al. 2009). The system was designed to elicit expert judgment about the likelihood that the known and potential threats will impact a species' persistence. Specifically, each BRT member considered the risk that the population may be placed in danger of extinction by demographic problems with abundance, productivity, spatial structure, or diversity, and then assigned a score to each of these demographic categories as follows: 1 = very low or zero risk, 2 = low risk, 3 = medium risk, 4 = high risk, and 5 = very high risk. The questions posed in 4.3.1 - 4.3.4 and used to guide consideration of each demographic category emphasized the present risks of extinction. To assess future risks of extinction, the BRT members also scored the risks that problems associated with those demographic categories will—between now and 2050, and between now and 2100—place the species in danger of extinction. The average score and the range of scores among BRT members are presented in Table 12.

Table 12. -- Demographic risks assessment table for ribbon seals. BRT members judged the risks that threats to the persistence of the species would be manifested as demographic problems associated with abundance, productivity, spatial structure, or diversity. The significance of the risk that the population may be placed in danger of extinction by these demographic problems—both from Present to 2050 and Present to 2100—was given a score as follows: 1 = very low or zero risk, 2 = low risk, 3 = medium risk, 4 = high risk, or 5 = very high risk. The averages and ranges (in parentheses) of these scores are presented.

Demographic Risks	Present to 2050	Present to 2100
Abundance	1.1 (1-2)	1.7 (1-3)
Productivity	1.1 (1-2)	1.9 (1-3)
Spatial Structure	2.0 (1-3)	2.8 (1-4)
Diversity	1.3 (1-2)	1.6 (1-2)

For the period from now to 2050, demographic risks were judged to be very low to low (1.1 to 2.0). With a population likely comprising at least 200,000-300,000 individuals, ribbon seals are not currently at risk from the demographic issues of low abundance commonly associated with ESA listing decisions, such as demographic stochasticity, inbreeding, loss of genetic diversity, and depensatory effects. The current population trend is unknown, but observations by hunters and a recent estimate of 61,100 ribbon seals in the eastern and central Bering Sea are consistent enough with historical accounts to suggest that no major or catastrophic change has occurred in recent decades. The species is thought to occupy its entire historically-observed range; there are no portions of the range in which ribbon seals have been reported to have disappeared or become extinct.

For the longer time frame, from now to 2100, a recognition of the increasing significance of diminished sea ice and increased prevalence of ocean acidification was reflected in risk scores that ranged from low to medium (1.6 to 2.8). The greatest risks perceived by the BRT were in the category of spatial structure, stemming from loss of habitat patches and connectivity that is anticipated to become significant in the latter half of this century.

To supplement the demographic risks assessment and express a single, summarized judgment about extinction risk, each BRT member allocated 10 likelihood points among five time intervals, indicating his or her judgment about the time until ribbon seals would reach a population level of 5,000 individuals, representing a hypothetical minimum viable population (MVP). A MVP can be thought of as the smallest population that has a high probability (say, 90-95%) of persisting in the wild on its own for a long time (say, 100-1,000 years). The time intervals were ‘now to 2025’, ‘2026 to 2050’, ‘2051 to 2075’, ‘2076 to 2100’, and ‘>2100’. The degree of uncertainty in this judgment is expressed by spreading the points across the time interval categories. In other words, if a member believed that ribbon seals will never decline to 5,000 individuals, or at least not for a very long time, all 10 likelihood points would be allocated to the interval '>2100'. Or, if the member believed strongly that ribbon seals will reach that level in the latter half of this century, and it is equally likely to happen in either 2051-2075 or 2076-2100, 5 likelihood points would be allocated to each of those intervals. The level of 5,000 individuals was selected without regard to specific aspects of ribbon seal life history that would determine the species' MVP size (which are largely unknown). Rather, it was chosen as a value that has been asserted to be useful because of its derivation as the approximate median from a meta-analysis of MVPs for many species (Traill et al. 2007, Traill et al. 2010). We note, however, that some have cautioned about placing confidence in this value (Flather et al. 2011).

The BRT members assigned all their likelihood points to the three time intervals beyond 2050 (Table 13). Amongst the eleven BRT members, 0 percent of the likelihood points was ascribed to the combined intervals from now to 2050, four percent was ascribed to the interval 2051 to 2075, 13 percent was ascribed to 2076 to 2100, and 83 percent was ascribed to the period beyond 2100. In other words, the BRT's collective distribution of points among time intervals indicating when the ribbon seal population may decline to a hypothetical MVP was concentrated in the time interval beyond the end of the current century. The range among BRT members in the percentage of likelihood points assigned to the combined time interval categories from now to 2100 was 0 percent (five BRT members) to 50 percent (one BRT member), reflecting the variation in this judgment that results from sparse and uncertain information underlying this assessment. The BRT's scoring was of course subjective, but it offers an indication of the BRT members' professional judgment that there is a low near-term extinction risk. In that respect the scoring was consistent with the results of the demographic risks assessment and our evaluation of the ESA section 4(a)(1) factors above.

Table 13. -- Average number of likelihood points out of 10 that were assigned by BRT members for the likelihood that the ribbon seal population would reach a level of 5,000 individuals in a specified time interval. The ranges of likelihood points assigned are shown in parentheses.

	Time interval				
	Now to 2025	**2026-2050**	**2051-2075**	**2076-2100**	**>2100**
Average likelihood points, out of 10	0	0	0.4 (0-2)	1.3 (0-4)	8.3 (5-10)

4.4 Conclusions of the Extinction Risk Assessment

Present or threatened destruction of habitat or range: Sea-ice cover during late winter and spring in the northern Bering Sea and Sea of Okhotsk will continue to be dominated by large interannual variability as in the past. The foremost of the anticipated changes with potential to cause negative effects on ribbon seals is a reduction in the frequency of years with sea ice that persists through April, May, and June in the Bering Sea and Sea of Okhotsk. Condition of breeding adults and survival of pups may be reduced as the average distance from the ice edge to preferred foraging areas along the continental shelf break increases with diminished ice extent. Condition and survival of adults, which molt later than subadults, may be impacted if seals cannot access ice of sufficient quality and stability to ensure completion of their annual pelage molt in May and June. Weaned ribbon seal pups are also likely dependent on sea ice for a 2-3 week period in May for maturation as they develop capabilities to forage on their own. The magnitude of these anticipated impacts is uncertain, in part because the relevant physiological and life history parameters have not been measured. There is evidence from occasional extreme years in the recent past that ribbon seals may compensate by moving to areas with better ice, at least in the Bering Sea. This may not be possible in the Sea of Okhotsk, where there is no northern access to higher-latitude ice-covered seas as there is from the northern Bering Sea to the Chukchi Sea. The coarse spatial resolution of models used to predict sea-ice coverage may render them inaccurate or imprecise for predicting impacts on ribbon seals, particularly in June when in most years ice remains only in patches that are below the resolution of the models but possibly still suitable habitat for ribbon seal molting.

Ocean acidification may impact ribbon seal survival and recruitment through disruption of trophic regimes. The nature and timing of such impacts are extremely uncertain, but many studies published since the previous status review of ribbon seals indicate that the effects will extend well beyond the groups of organisms that have calcifying forms or life stages. Ribbon seals’ apparent dietary flexibility may provide some resilience to the expected changes, but major or rapid shifts in community composition could be difficult to overcome if they persist for several successive years.

Changes in ribbon seal prey, anticipated in response to ocean warming and loss of sea ice are likely to have negative impacts, but the possibilities 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 ribbon seals. For example, several fish species, including walleye pollock (a common ribbon 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. The flexibility in ribbon seal foraging may make these threats of lower concern than more direct impacts from changes in sea ice.

The paleoclimatic history experienced by ribbon seals as a species has included strong and perhaps rapid warming events, possibly indicative of resilience to the present climate disruption. However, those past events may not have been accompanied by such rapid increases in atmospheric $C0_2$: the current levels are estimated to be the highest in 2-3 million years, approximately the time since ribbon seals diverged from their common ancestor with harp seals. Thus, the cumulative direct and indirect effects of ice loss and ocean acidification likely present novel threat scenarios for the species.

Overutilization: There is currently low risk to the ribbon seal population from commercial, subsistence, or other human utilization. The main uncertainty, for now and the foreseeable future, is the magnitude of commercial harvest in Russia, which could increase if market conditions become favorable.

Diseases, parasites, and predation: A variety of pathogens (or antibodies), diseases, helminthes, cestodes, and nematodes have been found in ribbon seals. The prevalence of these agents is not unusual among seals, but the population impact is unknown. A sparsely documented instance of mass mortality (~100 ribbon seals) that may have been disease-related occurred on the sea ice in Russian waters of the northern Bering Sea in 2004, but no major disease outbreaks, such as those that have occurred sporadically in European harbor seals, have been described. 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, perhaps evident in the recent Unusual Mortality Event declared for Arctic pinnipeds, in which no previously known infectious agent has yet been implicated. There is little or no direct evidence of significant predation on ribbon seals and they are not thought to be a primary prey of any predators. Polar bears and killer whales may be the most likely opportunistic predators in the current sea ice regime, but sharks may be underestimated as ribbon seal predators, and walruses could pose a potentially greater risk if reduced sea ice conditions force these species into closer proximity in the future.

Inadequacy of existing regulatory mechanisms: Our review of the regulatory mechanisms in place at the national and international level demonstrates that the short-term, site-specific threats to ribbon seals from direct take, disturbance by humans, and incidental or harassment take are, for the most part, adequately addressed through existing regulatory mechanisms. The primary threat likely to cause negative effects on ribbon seals is the anticipated reduction in the frequency of years with sea ice in the Bering Sea and Sea of Okhotsk that persists through May and June. However, there are no known regulatory mechanisms currently in place at the national or international level that effectively address reductions in sea ice habitat. It is also unclear whether regulatory mechanisms are in place to ensure that potential commercial harvests in Russia are conducted in a sustainable fashion.

Other natural or human factors affecting the species' continued existence: Although some pollutants are elevated in ribbon seals, there is no conspicuous evidence of toxicity or other significant impacts to the species. Continued and expanded monitoring would be prudent, to document any trends in the contaminants of greatest concern.

Oil and gas exploration and development activities may include 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 ribbon seals are the effects of noise, disturbance, and potential oil spills produced from these activities. Any negative effects on ribbon seals from noise and disturbance associated with development activities are likely to be minor and localized. Ribbon seals are also highly dispersed during the summer and autumn open-water season, so the rate of interactions with seismic surveys would likely be low. There have been no studies to determine whether ribbon seals would be affected by oil and gas seismic surveys. The threat posed to ribbon seals by oil spills will increase if offshore oil and gas development and shipping activities increase across their range as predicted. The potential impacts would be greatest during April-June when the seals are relatively aggregated, and substantially lower during the remainder of the year when they are dispersed in the open water throughout the North Pacific Ocean and Bering and Chukchi Seas.

Estimates from observed by-catch in commercial fisheries imply that less than 200 ribbon seals per year are taken, though mortalities are certainly under-reported in some fisheries. Because there is little or no fishery activity near aggregations of ribbon seals when they are associated with ice, and they are highly dispersed in the remainder of the year, by-catch is unlikely to be a significant threat to ribbon seal populations. For the same reason, competition from fisheries that reduce local abundance of ribbon seal prey is unlikely to be significant. Broad-scale reduction in a commercially-fished, primary prey species could have a significant impact, but the large groundfish fisheries in Alaskan waters, at least, are well managed to prevent depletion of the stocks. Fisheries can also cause perturbations in age structure of prey, though unfished populations also exhibit fluctuations, and ribbon seals are probably able to adjust, as evidenced by the diversity of their diet.

The extraordinary reduction in Arctic sea ice that has occurred in recent years has renewed interest in trans-Arctic navigation routes connecting the Atlantic and Pacific Oceans via the NWP and the NSR. The Chukchi Sea and Bering Strait would be the most likely areas for increased exposure of pelagic ribbon seals to ship traffic, because of the geographic constriction and the seasonal migration of part of the ribbon seal population around the beginning and end of the ice-free season. There is currently little or no information about direct impacts from shipping on seals in open water. Ribbon seals hauled out on sea ice may also be at risk from increased ship traffic, but likely only during spring and early summer, and then only by ice-reinforced ships. Assessing risk from increases in shipping and transportation is difficult because projections about future shipping trends within the ribbon seal's range are currently unavailable, and the degree to which ribbon seals may be affected by ship traffic has not been determined.

Demographic factors: With a population likely comprising 200,000-300,000 individuals, ribbon seals are not currently at risk from the demographic issues of low abundance commonly associated with ESA listing decisions, such as demographic stochasticity, inbreeding, loss of genetic diversity, and depensatory effects. The current population trend is unknown, but observations by Alaska Native hunters, and a recent estimate of 61,100 ribbon seals in the eastern and central Bering Sea are consistent enough with historical accounts to suggest that no major or catastrophic change has occurred in recent decades. The species is thought to occupy its entire historically-observed range; there are no portions of the range in which ribbon seals have been reported to have disappeared or become extinct.

For the longer time frame, from now to 2100, a recognition of the increasing significance of diminished sea ice and increased prevalence of ocean acidification was reflected in risk scores ranging from low to medium. The greatest risks perceived by the BRT were in the category of spatial structure, stemming from loss of habitat patches and connectivity that is anticipated to become significant in the latter half of this century. The BRT's collective judgment was that there is a 17% (range of 0% to 50% among BRT members) chance that the ribbon seal population will decline to a hypothetical minimum viable population threshold of 5,000 individuals before the end of the current century.

5 ACKNOWLEDGMENTS

The 2013 Ribbon Seal Biological Review Team is grateful to the following people for their contributions and assistance with producing this status review. Muyin Wang provided graphical results of IPCC climate model output for sea ice projections. Lori Quakenbush provided unpublished results from recent Alaska Department of Fish and Game ribbon seal research that significantly strengthened this review. Three peer-reviewers generously provided thoughtful comments and helpful suggestions. Erin Richmond maintained the electronic bibliographic library that was used while writing this document. We gratefully acknowledge the modeling groups, the Program for Climate Model Diagnosis and Intercomparison (PCMDI) and the World Climate Research Programme’s (WCRP's) Working Group on Coupled Modeling (WGCM) for their roles in making available the WCRP CMIP3 multi-model dataset. Support of this dataset is provided by the Office of Science, U.S. Department of Energy.

6 CITATIONS

Abe, H., Y. Hasegawa, and K. Wada. 1977. A note on the air-sac of ribbon seal. Scientific Reports of the Whales Research Institute 29:129-135.

ACIA. 2004. Impacts of a warming Arctic: Arctic climate impact assessment. Cambridge University Press, New York. 144 p. Accessed at http://www.acia.uaf.edu.

ACIA. 2005. Arctic Climate Impact Assessment. Cambridge University Press, Cambridge, UK. 1042 p. Accessed September 2008 at http://www.acia.uaf.edu.

Alaska Department of Natural Resources. 2009. Alaska oil and gas report November 2009. Alaska DNR, Division of Oil and Gas, Anchorage, AK. 63 p. Accessed at http://www.dog.dnr.state.ak.us/oil/products/publications/annual/2009_annual_report/updated_2009_annual_report/Annual Report 2009 Updated 5-18-10.pdf.

Alaska Department of Natural Resources. 2010a. Historic oil and gas activity maps. Alaska DNR, Division of Oil and Gas, Anchorage, AK. Accessed June 2010 at http://www.dog.dnr.state.ak.us/oil/products/maps/historic_activity_maps.htm.

Alaska Department of Natural Resources. 2010b. State of Alaska five-year program of proposed oil and gas lease sales. Alaska DNR, Division of Oil and Gas, Anchorage, AK. 56 p. Accessed at http://www.dog.dnr.alaska.gov/oil/products/publications/otherreports/5_year_reports/5_year_report.html.

Alaska Department of Natural Resources. 2011. Historic oil and gas activity maps. Alaska DNR, Division of Oil and Gas, Anchorage, AK. Accessed May 2013 at http://dog.dnr.alaska.gov/GIS/Data/ActivityMaps/NorthSlope/North_Slope_Oil_and_Gas_Activity_Map_20111201.pdf.

Alaska Department of Natural Resources. 2012. Historic oil and gas activity maps. Alaska DNR, Division of Oil and Gas, Anchorage, AK. Accessed May 2013 at http://dog.dnr.alaska.gov/GIS/Data/ActivityMaps/NorthSlope/North_Slope_Oil_and_Gas_Activity_Map_20120724.pdf.

Alaska Fisheries Science Center. 1990-2007. North Pacific groundfish observer database. North Pacific Groundfish Observer Program, Fisheries Monitoring and Analysis Division, AFSC, National Marine Fisheries Service, NOAA, 7600 Sand Point Way NE, Seattle, WA 98115.

Allen, B. M., and R. P. Angliss. 2012. Alaska Marine Mammal Stock Assessments, 2011. U.S. Department of Commerce, NOAA Technical Memporandum NMFS-AFSC-234. 288 p.

Allen, J. A. 1880. History of North American pinnipeds: a monograph of the walruses, sea-lions, sea-bears and seals of North America. U.S. Department of the Interior, U.S. Government Printing Office, Washington, D.C. 785 p.

Alley, R. B. 2000. The Younger Dryas cold interval as viewed from central Greenland. Quaternary Science Reviews 19:213-226.

Alley, R. B., D. A. Meese, C. A. Shuman, A. J. Gow, K. C. Taylor, P. M. Grootes, J. W. C. White, M. Ram, E. D. Waddington, P. A. Mayewski, and G. A. Zielinski. 1993. Abrupt increase in Greenland snow accumulation at the end of the Younger Dryas event. Nature 362:527-529.

AMAP. 2007. Arctic oil and gas 2007. Arctic Monitoring and Assessment Programme, Oslo, Norway. 70 p. Accessed at http://www.amap.no/oga/.

Anderson, L. G., and S. Kaltin. 2001. Carbon fluxes in the Arctic Ocean -- potential impact by climate change. Polar Research 20:225-232.

Anderson, P. J., and J. F. Piatt. 1999. Community reorganization in the Gulf of Alaska following ocean climate regime shift. Marine Ecology Progress Series 189:117-123.

Andreev, A., C. Chen, and S. Watanabe. 2009. Calculation methods and the distribution of anthropogenic variations of pH values in the Pacific Subarctic. Oceanology 49:418-428.

Angliss, R. P., and R. B. Outlaw. 2008. Alaska marine mammal stock assessments, 2007. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-180. 252 p.

Anthony, S. J., J. A. St Leger, K. Pugliares, H. S. Ip, J. M. Chan, Z. W. Carpenter, I. Navarrete-Macias, M. Sanchez-Leon, J. T. Saliki, J. Pedersen, W. Karesh, P. Daszak, R. Rabadan, T. Rowles, and W. I. Lipkin. 2012. Emergence of fatal avian influenza in New England harbor seals. mBio 3:e00166-00112.

Arctic Council. 2009. Arctic marine shipping assessment 2009 report. Arctic Council, Tromsø, Norway. 187 p. Accessed at http://www.pame.is/amsa/amsa-2009-report.

Árnason, U., A. Gullberg, A. Janke, M. Kullberg, N. Lehman, E. A. Petrov, and R. Väinölä. 2006. Pinniped phylogeny and a new hypothesis for their origin and dispersal. Molecular Phylogenetics and Evolution 41:345-354.

Arsen'ev, V. A. 1941. Feeding of the ribbon seal. Pages 365-372 *in* Environmental Assessment of the Alaskan Continental Shelf. Annual Reports of Principal Investigators for the year ending March 1977. Volume 1. Receptors--Mammals. U.S. Department of Commerce, NOAA, Environmental Research Laboratory and U.S. Department of the Interior, Bureau of Land Management, Boulder, CO.

Associated Foreign Press. 2009. Oil spill in Russian Far East kills hundreds of birds: reports. Associated Foreign Press, Moscow, Russia. Accessed June 2010 at http://www.google.com/hostednews/afp/article/ALeqM5g1LeTJjXj2LGoogMI331NPFt5oQA.

Atlantic Wolffish Biological Review Team. 2009. Status review of Atlantic wolffish (*Anarhichas lupus*). Report to National Marine Fisheries Service, Northeast Regional Office. September 30, 2009. 149 p.

Aydin, K. Y., V. V. Lapko, V. I. Radchenko, and P. A. Livingston. 2002. Comparison of the eastern Bering and western Bering Sea shelf and slope ecosystems through the use of mass-balance food web models. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-130. 92 p.

Bacastow, R., and C. D. Keeling. 1973. Atmospheric carbon-dioxide and radiocarbon in the natural carbon cycle: II. Changes from A.D. 1700 to 2070 as deduced from a geochemical model. Brookhaven Symposia in Biology 30:86-135.

Bailey, A. M. 1928. An unusual migration of the spotted and ribbon seals. Journal of Mammalogy 9:250-251.

Bailey, A. M., and R. W. Hendee. 1926. Notes on the mammals of northwestern Alaska. Journal of Mammalogy 7:9-28.

Bakun, A. 1990. Global climate change and intensification of coastal ocean upwelling. Science 247:198-201.

Barlough, J. E., E. S. Berry, A. W. Smith, and D. E. Skilling. 1987. Prevalence and distribution of serum neutralizing antibodies to Tillamook (bovine) calicivirus in selected populations of marine mammals. Journal of Wildlife Diseases 23:45-51.

Bates, N. R. 2007. Interannual variability of the oceanic CO_2 sink in the subtropical gyre of the North Atlantic Ocean over the last 2 decades. Journal of Geophysical Research 112:C09013.

Bates, N. R., and J. T. Mathis. 2009. The Arctic Ocean marine carbon cycle: evaluation of air-sea CO_2 exchanges, ocean acidification impacts and potential feedbacks. Biogeosciences Discussions 6:6695-6747.

Bates, N. R., J. T. Mathis, and L. W. Cooper. 2009. Ocean acidification and biologically induced seasonality of carbonate mineral saturation states in the western Arctic Ocean. Journal of Geophysical Research 114:C11007.

Bates, N. R., and A. J. Peters. 2007. The contribution of atmospheric acid deposition to ocean acidification in the subtropical North Atlantic Ocean. Marine Chemistry 107:547-558.

Beaugrand, G., K. M. Brander, J. A. Lindley, S. Souissi, and P. C. Reid. 2003. Plankton effect on cod recruitment in the North Sea. Nature 426:661-664.

Ben-David, M. 1997. Timing of reproduction in wild mink: the influence of spawning Pacific salmon. Canadian Journal of Zoology 75:376-382.

Bengtson, J. L., P. Boveng, U. Franzen, P. Have, M. P. Heide-Jørgensen, and T. J. Härkönen. 1991. Antibodies to canine distemper virus in Antarctic seals. Marine Mammal Science 7:85-87.

Berzin, A. A., A. S. Perlov, and G. S. Avkhutskaya. 1990. Ways of improving the rational exploitation of marine mammals. Pages 5-10 *in* A. A. Berzin, editor. Questions relating to the rational exploitation of marine mammals in the far eastern seas. Bulletin of the Pacific Research Institute of Fisheries and Oceanography (TINRO). TINRO, Vladivostok, USSR. (Translated from Russian by Environment Canada, Translation Bureau Number 4083779/6, 10 p.).

Bluhm, B. A., and R. Gradinger. 2008. Regional variability in food availability for Arctic marine mammals. Ecological Applications 18:S77-S96.

Boily, P. 1995. Theoretical heat flux in water and habitat selection of phocid seals and beluga whales during the annual molt. Journal of Theoretical Biology 172:235-244.

Boldt, J. L., and L. J. Haldorson. 2003. Seasonal and geographical variation in juvenile pink salmon diets in the Northern Gulf of Alaska and Prince William Sound. Transactions of the American Fisheries Society 132:1035-1052.

Boveng, P. L., J. L. Bengtson, T. W. Buckley, M. F. Cameron, S. P. Dahle, B. P. Kelly, B. A. Megrey, J. E. Overland, and N. J. Williamson. 2009. Status review of the spotted seal (*Phoca largha*). U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-200. 153 p.

Boveng, P. L., J. L. Bengtson, T. W. Buckley, M. F. Cameron, S. P. Dahle, B. A. Megrey, J. E. Overland, and N. J. Williamson. 2008. Status review of the ribbon seal (*Histriophoca fasciata*). U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-191. 115 p.

Boveng, P. L., J. M. London, and M. F. Cameron. 2007. Telemetry of ice seals captured during the USCG *Healy* and *Oscar Dyson* research cruises in the eastern Bering Sea. Alaska Fisheries Science Center Quarterly Report, April-May-June 2007:14-16.

Bowman, T. E. 1960. The pelagic amphipod genus *Parathemisto* (Hyperiidea: Hyperiidae) in the North Pacific Ocean and adjacent Arctic Ocean. Proceedings of the United States National Museum 12:343-392.

Bowyer, R. T. 1991. Timing of parturition and lactation in southern mule deer. Journal of Mammalogy 72:138-145.

Boyce, D. G., M. R. Lewis, and B. Worm. 2010. Global phytoplankton decline over the past century. Nature 466:591-596.

Boyd, I. L. 1984. The relationship between body condition and the timing of implantation in pregnant grey seals (*Halichoerus grypus*). Journal of Zoology 203:113-123.

Boyd, I. L. 1996. Individual variation in the duration of pregnancy and birth date in Antarctic fur seals: the role of environment, age, and sex of fetus. Journal of Mammalogy 77:124-133.

Bradstreet, M. S. W., and W. E. Cross. 1982. Trophic relationships at high Arctic ice edges. Arctic 35:1-12.

Bradstreet, M. S. W., K. J. Finley, A. D. Sekerak, W. B. Griffiths, C. R. Evans, M. F. Fabijan, and H. E. Stallard. 1986. Aspects of the biology of arctic cod (*Boreogadus saida*) and its importance in arctic marine food chains. Department of Fisheries and Oceans, Canadian Technical Report of Fisheries and Aquatic Sciences, No. 1491. 193 p.

Braham, H. W., J. J. Burns, G. A. Fedoseev, and B. D. Krogman. 1984. Habitat partitioning by ice-associated pinnipeds: distribution and density of seals and walruses in the Bering Sea, April 1976 Pages 25-47 *in* F. H. Fay and G. A. Fedoseev, editors. Soviet-American Cooperative Research on Marine Mammals. Volume 1 - Pinnipeds. NOAA Technical Report NMFS 12. U.S. Department of Commerce, NOAA, Washington, DC.

Brander, K. M. 1995. The effect of temperature on growth of Atlantic cod (*Gadus morhua* L.). ICES Journal of Marine Science 52:1-10.

Brander, K. M. 2007. The role of growth changes in the decline and recovery of North Atlantic cod stocks since 1970. ICES Journal of Marine Science 64:211-217.

Brewer, P. G., and K. Hester. 2009. Ocean acidification and the increasing transparency of the ocean to low-frequency sound. Oceanography 22:86-93.

Brigham, L., and B. Ellis, editors. 2004. Arctic marine transport workshop. Final Report, 28-30 September 2004. Institute of the North, U.S. Arctic Research Commission, and International Arctic Science Committee, Cambridge, UK. 56 p. Accessed September 2008 at http://www.institutenorth.org/servlet/content/reports.html.

Brodeur, R. D., M. T. Wilson, G. E. Walters, and I. V. Melnikov. 1999. Forage fishes in the Bering Sea: distribution, species associations, and biomass trends. Pages 509-536 *in* T. R. Loughlin and K. Ohtani, editors. Dynamics of the Bering Sea. AK-SG-99-03. University of Alaska Sea Grant, Fairbanks, AK.

Brodziak, J., and L. O'Brien. 2005. Do environmental factors affect recruits per spawner anomalies of New England groundfish? ICES Journal of Marine Science 62:1394-1407.

Broecker, W. S., Y. H. Li, and T. H. Peng. 1971. Carbon dioxide -- man's unseen artifact. Pages 287-324 *in* D. W. Hood, editor. Impingement of man on the oceans. John Wiley and Sons, Inc., New York, NY.

Broecker, W. S., and T. Takahashi. 1966. Calcium carbonate precipitation on Bahama Banks. Journal of Geophysical Research 71:1575-1602.

Brueggeman, J. J., D. P. Volsen, R. A. Grotefendt, G. A. Green, J. J. Burns, and D. K. Ljungblad. 1991. 1990 walrus monitoring program: the popcorn, burger, and crackerjack prospects in the Chukchi Sea. Report from EBASCO Environmental, Bellevue, WA, for Shell Western E&P Inc. and Chevron USA Inc. Shell Western E&P Inc., Houston, TX. 53 p.

Bukhtiyarov, Y. A. 1990. Food habits of seals in the southern Sea of Okhotsk. Pages 96-102 *in* A. A. Berzin, editor. Questions Relating to the Rational Exploitation of Marine Mammals in the Far Eastern Seas. TINRO, Vladivostok, Russia. (Translated from Russian by Environment Canada Library, Vancouver, Canada, 8 p.).

Burek, K. A., F. M. D. Gulland, and T. M. O'Hara. 2008. Effects of climate change on Arctic marine mammal health. Ecological Applications 18:S126-S134.

Burek, K. A., F. M. D. Gulland, G. Sheffield, K. B. Beckmen, E. Keyes, T. R. Spraker, A. W. Smith, D. E. Skilling, J. F. Evermann, J. L. Stott, J. T. Saliki, and A. W. Trites. 2005. Infectious disease and the decline of Steller sea lions (*Eumetopias jubatus*) in Alaska, USA: insights from serologic data. Journal of Wildlife Diseases 41:512-524.

Burkanov, V. N., and V. S. Nikulin. 2001. Estimates of marine mammal incidental mortality at Japanese salmon driftnet fisheries in the Russian economical zone in 1993-1999. Pages 222-230 *in* Results of the Far East Marine Mammal Researchers in 1991-2000, Moscow, Russia. (In Russian) VINRO Publishing. (In Russian).

Burns, J. J. 1969. Marine mammal report. Volume X, Project W-14-R-3 & W-17-1, Work Plan F, Job No. 3, 25 p. Alaska Department of Fish and Game, Juneau, AK.

Burns, J. J. 1970. Remarks on the distribution and natural history of pagophilic pinnipeds in the Bering and Chukchi Seas. Journal of Mammalogy 51:445-454.

Burns, J. J. 1971. Biology of the ribbon seal, *Histriophoca fasciata*, in the Bering Sea (Abstract). Page 135 *in* Proceedings of the Twenty-second Alaska Science Conference, College, AK. Alaska Division of the American Association for the Advancement of Science.

Burns, J. J. 1981. Ribbon seal *Phoca fasciata* Zimmermann, 1783. Pages 89-109 *in* S. H. Ridgway and R. J. Harrison, editors. Handbook of Marine Mammals. Volume 2: Seals. Academic Press, New York, NY.

Burns, J. J. 1994. Ribbon seal. Alaska Department of Fish and Game, Juneau, AK. Accessed July 2008 at http://www.adfg.state.ak.us/pubs/notebook/marine/rib-seal.php.

Burns, J. J., and F. H. Fay. 1970. Comparative morphology of the skull of the ribbon seal, *Histriophoca fasciata*, with remarks on systematics of Phocidae. Journal of Zoology 161:363-394.

Burns, J. J., and S. J. Harbo. 1972. An aerial census of ringed seals, northern coast of Alaska. Arctic 25:179-290.

Butler, J., A. DeVogelaere, R. Gustafson, C. Mobley, M. Neuman, D. Richards, S. Rumsey, B. Taylor, and G. VanBlaricom. 2009. Status review report for black abalone. National Marine Fisheries Service, Southwest Region, Long Beach, CA. 135 p.

Butler, T. H. 1980. Shrimps of the Pacific coast of Canada. Bulletin 202. Department of Fisheries and Oceans, Ottawa, Canada. 280 p.

Byrne, R. H., J. G. Acker, P. R. Betzer, R. A. Feely, and M. H. Cates. 1984. Water column dissolution of aragonite in the Pacific Ocean. Nature 312:321-326.

Caldeira, K., and M. E. Wickett. 2003. Anthropogenic carbon and ocean pH. Nature 425:365.

Caldeira, K., and M. E. Wickett. 2005. Ocean model predictions of chemistry changes from carbon dioxide emissions to the atmosphere and ocean. Journal of Geophysical Research 110:C09S04.

Callan, R. J., G. Early, H. Kida, and V. S. Hinshaw. 1995. The appearance of H3 influenza viruses in seals. Journal of General Virology 76:199-203.

Cameron, M., and P. Boveng. 2007. Abundance and distribution surveys for ice seals aboard USCG *Healy* and the *Oscar Dyson,* April 10-June 18, 2007. Alaska Fisheries Science Center Quarterly Report, April-May-June 2007:12-14.

Cameron, M., E. Moreland, and P. Boveng. 2008. Abundance and distribution surveys for ice seals conducted from the USCG icebreaker *Polar Sea,* April 6-April 27, 2008. Alaska Fisheries Science Center Quarterly Report, April-May-June 2008:20-21.

Canadell, J. G., C. Le Quere, M. R. Raupach, C. B. Field, E. T. Buitenhuis, P. Ciais, T. J. Conway, N. P. Gillett, R. A. Houghton, and G. Marland. 2007. Contributions to accelerating atmospheric CO_2 growth from economic activity, carbon intensity, and efficiency of natural sinks. Proceedings of the National Academy of Sciences of the United States of America 104:18866-18870.

Cao, L., and K. Caldeira. 2008. Atmospheric CO_2 stabilization and ocean acidification. Geophysical Research Letters 35:L19609.

CAPE Last Interglacial Project Members. 2006. Last Interglacial arctic warmth confirms polar amplification of climate change. Quaternary Science Reviews 25:1383-1400.

Carey, A. G. 1992. The ice fauna in the shallow southwestern Beaufort Sea, Arctic Ocean. Journal of Marine Systems 3:225-236.

Cavalieri, D., T. Markus, and J. Comiso. 2004, updated daily. AMSR-E/Aqua Daily L3 12.5 km Brightness Temperature, Sea Ice Conentration, & Snow Depth Polar Grids V002. Digital media. National Snow and Ice Data Center, Boulder, CO. Accessed June 28 2008 at http://nsidc.org/data/ae_si12.html.

Center for Biological Diversity. 2007. Petition to list the ribbon seal (*Histriophoca fasciata*) as a threatened or endangered species under the Endangered Species Act. Center for Biological Diversity. 90 p.

Chapskii, K. K. 1955. An attempt at revision of the systematics and diagnostics of seals in the subfamily Phocinae. Trudy Zoologicheskovo Instituta Akademii Nauk SSSR 17:160-199. (Translated from Russian by T.F. Jeletzky, Fisheries Research Board of Canada, Montreal, Canada, Translation Series No. 114, 57 p.).

Chernenko, T. 2007. Appendix 1. The status of the yellow-billed loon in Russia: a summary of Russian language information. Comments submitted by Center for Biological Diversity, Pacific Environmental, and Natural Resources Defence Council on August 6, 2007, to the U.S. Fish and Wildlife Service on the 90-day Finding and Status Review of the Yellow-billed Loon. 16 p.

Choi, K. 2008. Recent trend in design parameters of ice-transiting vessels. International Journal of Offshore and Polar Engineering 18:282-287. (Abstract online; Accessed May 2010 at http://www.isope.org/publications/journals/ijope-18-4/abst-18-4-p282-RF-40-Choi.pdf).

Cohen, D. M., T. Inada, T. Iwamoto, and N. Scialabba. 1990. FAO species catalogue. Vol. 10. Gadiform fishes of the world (Order Gadiformes). An annotated and illustrated catalogue of cods, hakes, grenadiers and other gadiform fishes known to date. Food and Agriculture Organization of the United Nations, FAO Fisheries Synopsis No. 125. 442 p.

Colton, J. B., Jr. 1972. Temperature trends and distribution of groundfish in continental shelf waters, Nova Scotia to Long Island. Fishery Bulletin 70:637-657.

Comeau, S., G. Gorsky, R. Jeffree, J. L. Teyssié, and J. P. Gattuso. 2009. Key Arctic pelagic mollusc (*Limacina helicina*) threatened by ocean acidification. Biogeosciences Discussions 6:2523-2537.

Comeau, S., R. Jeffree, J. L. Teyssie, and J. P. Gattuso. 2010. Response of the Arctic pteropod *Limacina helicina* to projected future environmental conditions. PLoS ONE 5

Cott, P. A., B. W. Hanna, and J. A. Dahl. 2003. Discussion on seismic exploration in the Northwest Territories 2000-2003. Canadian Manuscript Report for Fisheries and Aquatic Sciences 2648. 36 p.

COWI. 2008. Assessment of the potential impact of a ban of products derived from seal species. European Commission Direcorate-General Environment. 45 p.

Craig, P. C. 1984. Fish use of coastal waters of the Alaska Beaufort Sea: a review. Transactions of the American Fisheries Society 113:265-282.

Crocker, C. E., and J. J. Cech. 1996. The effects of hypercapnia on the growth of juvenile white sturgeon, *Acipenser transmontanus*. Aquaculture 147:293-299.

Dalpadado, P. 2002. Inter-specific variations in distribution, abundance and possible life-cycle patterns of *Themisto* spp. (Amphipoda) in the Barents Sea. Polar Biology 25:656-666.

Dalpadado, P., N. Borkner, B. Bogstad, and S. Mehl. 2001. Distribution of *Themisto* (Amphipoda) spp. in the Barents Sea and predator-prey interactions. ICES Journal of Marine Science 58:876-895.

Dalpadado, P., R. Ingvaldsen, and A. Hassel. 2003. Zooplankton biomass variation in relation to climatic conditions in the Barents Sea. Polar Biology 36:233-241.

Danner, G. R., M. W. McGregor, R. L. Zarnke, and C. W. Olsen. 1998. Serologic evidence of influenza virus infection in a ringed seal (Phoca hispida) from Alaska. Marine Mammal Science 14:380-384.

Darnerud, P. O. 2003. Toxic effects of brominated flame retardants in man and in wildlife. Environment International 29:841-853.

Davis, C. S., I. Stirling, C. Strobeck, and D. W. Coltman. 2008. Population structure of ice-breeding seals. Molecular Biology 17:3078-3094.

Davis, J. E., and S. S. Anderson. 1976. Effects of oil pollution on breeding grey seals. Marine Pollution Bulletin 7:115-118.

de Wit, C. A., M. Alaee, and D. C. G. Muir. 2006. Levels and trends of brominated flame retardants in the Arctic. Chemosphere 64:209-233.

DeAngelis, D. L., and R. M. Cushman. 1990. Potential application of models in forecasting the effects of climate changes on fisheries. Transactions of the American Fisheries Society 119:224-239.

Deepwater Horizon Response. 2010. August 2, 2010 news release: U.S. scientific teams refine estimates of oil flow from BP's well prior to capping. Unified Command, Joint Information Center, Accessed September 2010 at http://www.restorethegulf.gov/release/2010/08/02/us-scientific-teams-refine-estimates-oil-flow-bps-well-prior-capping.

Deguchi, T., Y. Goto, and Y. Sakurai. 2004. Importance of walleye pollock (*Theragra chalcogramma*) to wintering ribbon seals (*Phoca fasciata*) in Nemuro Strait, Hokkaido Japan. Mammal Study 29:55-63.

Dehn, L.-A., G. Sheffield, E. Follmann, L. Duffy, D. Thomas, and T. O'Hara. 2007. Feeding ecology of phocid seals and some walrus in the Alaskan and Canadian Arctic as determined by stomach contents and stable isotope analysis. Polar Biology 30:167-181.

Delamure, S. L., and M. V. Yurakhno. 1974. The helminth fauna of the banded seal in the Bering Sea. Izvestiya TINRO 88:27-35. (In Russian).

Delyamure, S. L., M. V. Yurakhno, and V. N. Popov. 1976. On the helminth fauna of pinnipeds from the Karaginsk Gulf (the Bering Sea). Parazitologiya 10:325-332. (In Russian, English Summary).

DeMaster, D. P., A. W. Trites, P. Clapham, S. Mizroch, P. Wade, R. J. Small, and J. Ver Hoef. 2006. The sequential megafaunal collapse hypothesis: testing with existing data. Progress in Oceanography 68:329-342.

Derocher, A. E., N. J. Lunn, and I. Stirling. 2004. Polar bears in a warming climate. Integrative and Comparative Biology 44:163-176.

Doney, S. C., V. J. Fabry, R. A. Feely, and J. A. Kleypas. 2009. Ocean acidification: the other CO_2 problem. Annual Review of Marine Science 1:169-192.

Drinkwater, K. F. 2005. The response of Atlantic cod (*Gadus morhua*) to future climate change. ICES Journal of Marine Science 62:1327-1337.

Dubey, J. P., R. Zarnke, N. J. Thomas, S. K. Wong, W. Van Bonn, M. Briggs, J. W. Davis, R. Ewing, M. Mense, O. C. H. Kwok, S. Romand, and P. Thulliez. 2003. *Toxoplasma gondii, Neospora caninum, Sarcocystis neurona*, and *Sarcocystis canis*-like infections in marine mammals. Veterinary Parasitology 116:275-296.

Duck, C. D. 1990. Annual variation in the timing of reproduction in Antarctic fur seals, *Arctocephalus gazella*, at Bird Island, South Georgia. Journal of Zoology 222:103-116.

Dulepova, E., and V. Radchencko. 2004. Okhotsk Sea. Pages 95-111 *in* PICES Special Publication: Marine Ecosystems of the North Pacific. North Pacific Marine Science Organization, Sidney, Canada.

Dulepova, E. P., and L. B. Klyashtorin. 2008. Russia. Pages 137-162 *in* R. J. Beamish, editor. Impacts of climate and climate change on the key species in the fisheries in the North Pacific. PICES Scientific Report, No. 35. North Pacific Marine Science Organization, Sidney, Canada.

ECON. 2007. Arctic shipping 2030: from Russia with oil, stormy passage, or Arctic great game? Norshipping, ECON Report No. 2007-070, Project No. 50450. 45 p.

Eley, T. J. 1981. *Dipetalonema spirocauda* in Alaskan marine mammals. Journal of Wildlife Diseases 17:65-67.

Engelhardt, F. R. 1982. Hydrocarbon metabolism and cortisol balance in oil-exposed ringed seals, *Phoca hispida*. Comparative Biochemistry and Physiology C 72:133-136.

Engelhardt, F. R. 1983. Petroleum effects on marine mammals. Aquatic Toxicology 4:199-217.

Engelhardt, F. R., J. R. Geraci, and T. G. Smith. 1977. Uptake and clearance of petroleum hydrocarbons in the ringed seal, *Phoca hispida*. Journal of the Fisheries Research Board of Canada 34:1143-1147.

Environmental Protection Agency. 2010. Prevention of significant deterioration and title V greenhouse gas tailoring rule; Final Rule. Federal Register 75:106 (June 3, 2010) p. 31514-31606.

Environmental Protection Agency. 2012a. Prevention of significant deterioration and title V greenhouse gas tailoring step 3 GHG plantwide applicability limits. Federal Register 77:134 (July 12, 2012) p. 41051-41075.

Environmental Protection Agency. 2012b. Standards of performance for greenhouse gas emissions for new stationary sources: electric utility generating units. Federal Register 77:72 (April 13, 2012) p. 22392-22441.

Environmental Protection Agency, and Department of Transportation. 2010. Light-duty vehicle greenhouse gas emission standards and corporate average fuel economy standards. Federal Register 75:88 (May 7, 2010) p. 25324-25372.

Environmental Protection Agency, and Department of Transportation. 2011. Greenhouse gas emissions standards and fuel efficiency standards for medium- and heavy-duty engines and vehicles. Federal Register 76:179 p. 57106-57513.

Environmental Protection Agency, and Department of Transportation. 2012. 2017 and later model year light-duty vehicle greenhouse gas emissions and corporate average fuel economy standards. Federal Register 77:199 (October 15, 2012) p. 62624-63200.

Fabry, V. J. 2008. Ocean science: marine calcifiers in a high-CO_2 ocean. Science 320:1020-1022.

Fabry, V. J., J. B. McClintock, J. T. Mathis, and J. M. Grebmeier. 2009. Ocean acidification at high latitudes: the bellwether. Oceanography 22:160-171.

Fabry, V. J., B. A. Seibel, R. A. Feely, and J. C. Orr. 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. ICES Journal of Marine Science 65:414-432.

Farley, E. V., and W. Strasburger. 2012. Forage fish CPUE - Bering Aleutian Salmon International Survey - BASIS. Pages 129-133 *in* S. Zador, editor. Ecosystem Considerations 2012, Stock Assessment and Fishery Evaluation Report. North Pacific Fishery Management Council, Anchorage, AK.

Fay, F. H. 1974. The role of ice in the ecology of marine mammals of the Bering Sea. Pages 383-399 *in* D. W. Hood and E. J. Kelley, editors. Oceanography of the Bering Sea. Institute of Marine Science, Hakodate, Japan.

Fay, F. H., R. A. Dieterich, L. M. Shults, and B. P. Kelly. 1978. Morbidity and mortality of marine mammals. Pages 39-79 *in* Environmental Assessment of the Alaskan Continental Shelf. Annual Reports of Principal Investigators for the Year Ending March 1978. Volume 1. Receptors--Mammals-Birds. U.S. Department of Commerce, NOAA and U.S. Department of the Interior, Bureau of Land Management, Boulder, CO.

Fay, F. H., R. A. Dieterich, L. M. Shults, N. K. Murray, A. Hoover, and B. P. Kelly. 1979. Morbidity and mortality of marine mammals. Pages 1-34 *in* Environmental Assessment of the Alaskan Continental Shelf. Annual Reports of Principal Investigators for the Year Ending March 1979. Volume 1. Receptors--Mammals-Birds. U.S. Department of Commerce, NOAA and U.S. Department of the Interior, Bureau of Land Management, Boulder, CO.

Fay, F. H., and D. P. Furman. 1982. Nasal mites (Acari: Halarachnidae) in the spotted seal, *Phoca largha* Pallas, and other pinnipeds of Alaskan waters. Journal of Wildlife Diseases 18:63-68.

Fedoseev, G. A. 1973. Morphological-ecological characteristics of ribbon seal populations and factors affecting the conservation of usable stocks. Izvestiya TINRO 86:158-177. (Translated from Russian by Translation Bureau, Department of the Secretary of State of Canada, 50 p.).

Fedoseev, G. A. 1984. Use of nonmetrical characters of skulls of Bering Sea seals in a study of the phenotypic structure of their populations. Pages 49-54 *in* F. H. Fay and G. A. Fedoseev, editors. Soviet-American Cooperative Research on Marine Mammals. Volume 1 - Pinnipeds. Under Project V.6. Marine Mammals, of the US-USSR Agreement on Cooperation in the Field of Environmental Protection. U.S. Department of Commerce, NOAA Technical Report NMFS 12, Washington, DC.

Fedoseev, G. A. 2000. Population biology of ice-associated forms of seals and their role in the northern Pacific ecosystems. Center for Russian Environmental Policy, Russian Marine Mammal Council, Moscow, Russia. 271 p. (Translated from Russian by I. E. Sidorova, 271 p.).

Fedoseev, G. A. 2002. Ribbon Seal *Hisriophoca fasciata* Pages 1027-1030 *in* W. F. Perrin, B. G. Wursig, and J. G. M. Thewissen, editors. Encyclopedia of Marine Mammals. Academic Press, San Diego, CA.

Fedoseev, G. A., and Y. A. Bukhtiyarov. 1972. The diet of seals of the Okhotsk Sea. Pages 389-390 *in* Environmental Assessment of the Alaskan Continental Shelf. Annual Reports of Principal Investigators for the year ending March 1977. Volume 1. Receptors--Mammals. Theses of Works, 5th All-Union Conf. Studies of Marine Mammals, part 1:110-112 (1972). U.S. Department of Commerce, NOAA, Environmental Research Laboratory and U.S. Department of the Interior, Bureau of Land Management, Boulder, CO. (Translated from Russian by F.H. Fay, University of Alaska, Fairbanks, AK, 2 p.).

Fedoseev, G. A., Y. V. Razlivalov, and G. G. Bobrova. 1988. Distribution and abundance of the ice forms of pinnipeds on the ice of the Bering Sea in April and May 1987. Pages 42-59 *in* N. S. Chernysheva, editor. Scientific Research on Sea Mammals of the Northern Part of the Pacific Ocean in 1986-1987. All-Union Scientific Research Institute of Sea Fisheries and Oceanography (VNIRO), Moscow, Russia. (Translated from Russian by Canada Institute for Scientific and Technical Information, National Research Council, Ottawa, Canada, 189 p.).

Feely, R. A., R. H. Byrne, J. G. Acker, P. R. Betzer, C. T. A. Chen, J. F. Gendron, and M. F. Lamb. 1988. Winter-summer variations of calcite and aragonite saturation in the Northeast Pacific. Marine Chemistry 25:227-241.

Feely, R. A., and C. T. A. Chen. 1982. The effect of excess CO_2 on the calculated calcite and aragonite saturation horizons in the Northeast Pacific. Geophysical Research Letters 9:1294-1297.

Feely, R. A., S. C. Doney, and S. R. Cooley. 2009. Ocean acidification: present conditions and future changes in a high-CO_2 world. Oceanography 22:36-47.

Feely, R. A., C. L. Sabine, J. M. Hernandez-Ayon, D. Ianson, and B. Hales. 2008. Evidence for upwelling of corrosive "acidified" water onto the continental shelf. Science 320:1490-1492.

Feely, R. A., C. L. Sabine, K. Lee, W. Berelson, J. Kleypas, V. J. Fabry, and F. J. Millero. 2004. Impact of anthropogenic CO_2 on the $CaCO_3$ system in the oceans. Science 305:362-366.

Feltz, E. T., and F. H. Fay. 1966. Thermal requirements in vitro of epidermal cells from seals. Cryobiology 3:261-264.

Fiksen, Ø., and A. Slotte. 2002. Stock-environment recruitment models for Norwegian spring spawning herring (*Clupea harengus*). Canadian Journal of Fisheries and Aquatic Sciences 59:211-217.

Flather, C. H., G. D. Hayward, S. R. Beissinger, and P. A. Stephens. 2011. A general target for MVPs: unsupported and unnecessary. Trends in Ecology and Evolution 26:620-622.

Forbes, L. B. 2000. The occurrence and ecology of *Trichinella* in marine mammals. Veterinary Parasitology 93:321-334.

Ford, J. K. B., G. M. Ellis, and K. C. Balcomb. 2000. Killer whales: the natural history and genealogy of *Orcinus orca* in British Columbia and Washington State. 2nd edition. UBC Press, Vancouver, Canada. 104 p.

Ford, J. K. B., G. M. Ellis, L. G. Barrett-Lennard, A. B. Morton, R. S. Palm, and K. C. Balcomb, III. 1998. Dietary specialization in two sympatric populations of killer whales (*Orcinus orca*) in coastal British Columbia and adjacent waters. Canadian Journal of Zoology 76:1456-1471.

Forney, K. A., and P. R. Wade. 2006. Worldwide distribution and abundance of killer whales. Pages 145-163 *in* J. A. Estes, D. P. DeMaster, D. F. Doak, T. M. Williams, and R. L. Brownell, Jr., editors. Whales, Whaling, and Ocean Ecosystems. University of California Press, Berkeley, CA.

Fortunato, E. 1985. The relationship between hostal specificity of parasite and population structure of host species. Zhurnal Obshchei Biologii 46:625-632. (In Russian, English Summary).

Frank, K. T., R. I. Perry, and K. F. Drinkwater. 1990. Predicted response of northwest Atlantic invertebrate and fish stocks to CO_2-induced climate change. Transactions of the American Fisheries Society 119:353-365.

Frankham, R. 2005. Genetics and extinction. Biological Conservation 126:131-140.

Frantzen, E. 2007. From Russia with love. Hart Energy Publishing, LP, Houston, TX. Accessed May 2010 at http://www.epmag.com/archives/features/405.htm.

Froese, R., and D. Pauly. 2008. FishBase (Online database). Accessed September 2008 at http://www.fishbase.org.

Frost, K. J., and L. F. Lowry. 1980. Feeding of ribbon seals (*Phoca fasciata*) in the Bering Sea in spring. Canadian Journal of Zoology 58:1601-1607.

Frost, K. J., and L. F. Lowry. 1984. Trophic relationships of vertebrate consumers in the Alaskan Beaufort Sea. Pages 381-401 *in* P. W. Barnes, D. M. Schell, and E. Reimnitz, editors. The Alaskan Beaufort Sea -- Ecosystems and Environments. Academic Press, Inc., New York, NY.

Frost, K. J., and L. F. Lowry. 1994. Assessment injury to harbor seals in Prince William Sound, Alaska, and adjacent areas following the *Exxon Valdez* oil spill. Alaska Department of Fish and Game, Wildlife Conservation Division, *Exxon Valdez* Oil Spill. State/Federal Natural Resource Damage Assessment Final Report. 157 p.

Frost, K. J., L. F. Lowry, and J. J. Burns. 1977. Spring foods and feeding of phocid seals in the Bering Sea ice front (Abstract). Page 20 *in* The Second Conference on the Biology of Marine Mammals, San Diego, CA. Society for Marine Mammalogy.

Frost, K. J., L. F. Lowry, G. Pendleton, and H. R. Nute. 2004. Factors affecting the observed densities of ringed seals, *Phoca hispida*, in the Alaskan Beaufort Sea, 1996-99. Arctic 57:115-128.

Frost, K. J., L. F. Lowry, E. H. Sinclair, J. Ver Hoef, and D. C. McAllister. 1994a. Impacts on distribution, abundance, and productivity of harbor seals. Pages 97-118 *in* T. R. Loughlin, editor. Marine Mammals and the *Exxon Valdez*. Academic Press, Inc., San Diego, CA.

Frost, K. J., C. A. Manen, and T. L. Wade. 1994b. Petroleum hydrocarbons in tissues of harbor seals from Prince William Sound and the Gulf of Alaska. Pages 331-358 *in* T. R. Loughlin, editor. Marine Mammals and the *Exxon Valdez*. Academic Press, Inc., San Diego, CA.

Frost, K. J., R. B. Russell, and L. F. Lowry. 1992. Killer whales, *Orcinus orca*, in the southeastern Bering Sea: Recent sightings and predation on other marine mammals. Marine Mammal Science 8:110-119.

Fujii, K., C. Kakumoto, M. Kobayashi, S. Saito, T. Kariya, Y. Watanabe, X. N. Xuan, I. Igarashi, and M. Suzuki. 2007. Seroepidemiology of *Toxoplasma gondii* and *Neospora caninum* in seals around Hokkaido, Japan. Journal of Veterinary Medical Science 69:393-398.

Fulton, T. L., and C. Strobeck. 2010a. Multiple fossil calibrations, nuclear loci and mitochondrial genomes provide new insight into biogeography and divergence timing for true seals (Phocidae, Pinnipedia). Journal of Biogeography 37:814-829.

Fulton, T. L., and C. Strobeck. 2010b. Multiple markers and multiple individuals refine true seal phylogeny and bring molecules and morphology back in line. Proceedings of the Royal Society B 277:1065-1070.

Gehlen, M., R. Gangsto, B. Schneider, L. Bopp, O. Aumont, and C. Ethe. 2007. The fate of pelagic $CaCO_3$ production in a high CO_2 ocean: a model study. Biogeosciences 4:505-519.

Geraci, J. R., and T. G. Smith. 1976. Behavior and pathophysiology of seals exposed to crude oil. Pages 447-462 *in* Proceedings of the Symposium American University: Sources, Effects, and Sinks of Hydrocarbons in the Aquatic Environment, Washinton, D.C. The American Institute of Biological Sciences.

Geraci, J. R., D. J. Staubin, I. K. Barker, R. G. Webster, V. S. Hinshaw, W. J. Bean, H. L. Ruhnke, J. H. Prescott, G. Early, A. S. Baker, S. Madoff, and R. T. Schooley. 1982. Mass Mortality of Harbor Seals - Pneumonia Associated with Influenza-a Virus. Science 215:1129-1131.

Gill, T. 1873. The ribbon seal of Alaska. The American Naturalist 7:178-179.

Glantz, M. H., and L. E. Feingold. 1990. Climate variability, climate change and fisheries: a summary. Pages 417-438 *in* M. H. Glantz, editor. Climate Variability, Climate Change and Fisheries. Cambridge University Press, Cambridge, UK.

Gleckler, P. J., K. E. Taylor, and C. Doutriaux. 2008. Performance metrics for climate models. Journal of Geophysical Research 113:D06104.

Goldstein, T., J. A. K. Mazet, V. A. Gill, A. M. Doroff, K. A. Burek, and J. A. Hammond. 2009. Phocine distemper virus in northern sea otters in the Pacific Ocean, Alaska, USA. Emerging Infectious Diseases 15:925-927.

Gordon, J., D. Gillespie, J. Potter, A. Frantzis, M. P. Simmonds, R. Swift, and D. Thompson. 2003. A review of the effects of seismic surveys on marine mammals. Marine Technology Society Journal 37:16-34.

Gosselin, M., M. Lavasseur, P. A. Wheeler, R. A. Horner, and B. C. Booth. 1997. New measurements of phytoplankton and ice algal production in the Arctic Ocean. Deep-Sea Research II 44:1623-1644.

Grachev, A. I. 2006. Analysis of present-day harvest of true seals in the Sea of Okhotsk and its prospects. Pages 155-159 *in* V. M. Belkovich, editor. Marine Mammals of the Holarctic. 2006. Collection of Scientific Papers, St. Petersburg, Russia. Marine Mammal Council.

Grachev, A. M., and J. P. Severinghaus. 2005. A revised +10 +/- 4 degrees C magnitude of the abrupt change in Greenland temperature at the Younger Dryas termination using published GISP2 gas isotope data and air thermal diffusion constants. Quaternary Science Reviews 24:513-519.

Gradinger, R. R., and B. A. Bluhm. 2004. In-situ observations on the distribution and behavior of amphipods and Arctic cod (*Boreogadus saida*) under the sea ice of the High Arctic Canada Basin. Polar Biology 27:595-603.

Grebmeier, J. M., L. W. Cooper, H. M. Feder, and B. I. Sirenko. 2006a. Ecosystem dynamics of the Pacific-influenced Northern Bering and Chukchi Seas in the Amerasian Arctic. Progress in Oceanography 71:331-361.

Grebmeier, J. M., S. E. Moore, J. E. Overland, K. E. Frey, and R. Gradinger. 2010. Biological response to recent Pacific Arctic sea ice retreats. EOS, Transactions American Geophysical Union 91:161-162.

Grebmeier, J. M., J. E. Overland, S. E. Moore, E. V. Farley, E. C. Carmack, L. W. Cooper, K. E. Frey, J. H. Helle, F. A. McLaughlin, and S. L. McNutt. 2006b. A major ecosystem shift in the northern Bering Sea. Science 311:1461-1464.

Gregory, M., and D. G. Cyr. 2002. Effects of environmental contaminants on the endocrine system of marine mammals. Pages 67-81 *in* J. G. Vos, G. Bossart, M. Fournier, and T. O'Shea, editors. Toxicology of Marine Mammals. Routledge, Florence, KY.

Guinotte, J. M., and V. J. Fabry. 2008. Ocean acidification and its potential effects on marine ecosystems. Year in Ecology and Conservation Biology 2008 1134:320-342.

Guppy, M., and P. Withers. 1999. Metabolic depression in animals: physiological perspectives and biochemical generalizations. Biological Review 74:1-40.

Hamanaka, T., H. Kato, and T. Tsujita. 1977. Cadmium and zinc in ribbon seal, *Histriophoca fasciata*, in the Okhotsk Sea. Pages 547-561 *in* Special Volume. Research Institute of North Pacific Fisheries, Hokkaido University, Hokkaido, Japan.

Hammill, M. O., and G. B. Stenson. 2003. Harvest stimulations for 2003-2006 harp seal management plan. Fisheries and Oceans Canada, Canadian Science Advisory Secretariat Research Document 2003/068. 29 p.

Harding, K. C., M. Fujiwara, Y. Axberg, and T. Härkönen. 2005. Mass-dependent energetics and survival in harbour seal pups. Functional Ecology 19:129-135.

Hare, S. R., and N. J. Mantua. 2000. Empirical evidence for North Pacific regime shifts in 1977 and 1989. Progress in Oceanography 47:103-145.

Härkönen, T., R. Dietz, P. Reijnders, J. Teilmann, K. Harding, A. Hall, S. Brasseur, U. Siebert, S. J. Goodman, P. D. Jepson, T. D. Rasmussen, and P. Thompson. 2006. A review of the 1988 and 2002 phocine distemper virus epidemics in European harbour seals. Diseases of Aquatic Organisms 68:115-130.

Harris, R. E., G. W. Miller, and W. J. Richardson. 2001. Seal responses to airgun sounds during summer seismic surveys in the Alaskan Beaufort Sea. Marine Mammal Science 17:795-812.

Harvell, C. D., K. Kim, J. M. Burkholder, R. R. Colwell, P. R. Epstein, D. J. Grimes, E. E. Hofmann, E. K. Lipp, A. D. M. E. Osterhaus, R. M. Overstreet, J. W. Porter, G. W. Smith, and G. R. Vasta. 1999. Emerging marine diseases--climate links and anthropogenic factors. Science 285:1505-1510.

Harvell, C. D., C. E. Mitchell, J. R. Ward, S. Altizer, A. P. Dobson, R. S. Ostfeld, and M. D. Samuel. 2002. Climate warming and disease risks for terrestrial and marine biota. Science 296:2158-2162.

Hawkins, E., and R. Sutton. 2009. The potential to narrow uncertainty in regional climate predictions. Bulletin of the American Meteorological Society 90:1095-1107.

Heptner, L. V. G., K. K. Chapskii, V. A. Arsen'ev, and V. T. Sokolov. 1976. Ribbon (banded) seal. *Phoca (Histriophoca) fasciata* Zimmermann, 1783. Pages 436-452 *in* L. V. G. Heptner, N. P. Naumov, and J. Mead, editors. Mammals of the Soviet Union. Volume II, Part 3--Pinnipeds and Toothed Whales, Pinnipedia and Odontoceti. Vysshaya Shkola Publishers, Moscow, Russia. (Translated from Russian by P. M. Rao, 1996, Science Publishers, Inc., Lebanon, NH).

Herman, D. P., D. G. Burrows, P. R. Wade, J. W. Durban, C. O. Matkin, R. G. LeDuc, L. G. Barrett-Lennard, and M. M. Krahn. 2005. Feeding ecology of eastern North Pacific killer whales *Orcinus orca* from fatty acid, stable isotope, and organochlorine analyses of blubber biopsies. Marine Ecology Progress Series 302:275-291.

Higdon, J. W., O. R. P. Bininda-Emonds, R. M. D. Beck, and S. H. Ferguson. 2007. Phylogeny and divergence of the pinnipeds (Carnivora: Mammalia) assessed using a multigene dataset. BMC Evolutionary Biology 7:216.

Hill, D. K., and J. J. Magnuson. 1990. Potential effects of global climate warming on the growth and prey consumption of Great Lakes fish. Transactions of the American Fisheries Society 119:265-275.

Hinshaw, V. S., W. J. Bean, R. G. Webster, J. E. Rehg, P. Fiorelli, G. Early, J. R. Geraci, and D. J. St. Aubin. 1984. Are seals frequently infected with avian influenza viruses? Journal of Virology 51:863-865.

Hoberg, E. P. 1992. Congruent and synchronic patterns in biogeography and speciation among seabirds, pinnipeds, and cestodes. Journal of Parasitology 78:601-615.

Hollowed, A. B., S. R. Hare, and W. S. Wooster. 2001. Pacific Basin climate variability and patterns of northeast Pacific marine fish production. Progress in Oceanography 49:257-282.

Hopkins, D. M. 1973. Sea level history in Beringia during the past 250,000 years. Quaternary Research 3:520-540.

House, C., A. A. Aguirre, and J. A. House. 2002. Emergence of infectious diseases in marine mammals. Pages 104-117 *in* A. A. Aguirre, R. S. Ostfeld, G. M. Tabor, C. House, and M. C. Pearl, editors. Conservation Medicine: Ecological Health in Practice. Oxford University Press, Inc., New York, NY.

Hovelsrud, G. K., M. McKenna, and H. P. Huntington. 2008. Marine mammal harvests and other interactions with humans. Ecological Applications 18:S135-S147.

Howell, S. E. L., and J. J. Yackel. 2004. A vessel transit assessment of sea ice variability in the Western Arctic, 1969-2002: implications for ship navigation. Canadian Journal of Remote Sensing 30:205-215.

Hunt, G. L., K. O. Coyle, L. B. Eisner, E. V. Farley, R. A. Heintz, F. Mueter, J. M. Napp, J. E. Overland, P. H. Ressler, S. Salo, and P. J. Stabeno. 2011. Climate impacts on eastern Bering Sea foodwebs: a synthesis of new data and an assessment of the Oscillating Control Hypothesis. ICES Journal of Marine Science 68:1230-1243.

Hunt, G. L., Jr., P. Stabeno, G. Walters, E. Sinclair, R. D. Brodeur, J. M. Napp, and N. A. Bond. 2002. Climate change and control of the southeastern Bering Sea pelagic ecosystem. Deep-Sea Research II 49:5821-5853.

Hunt, G. L., Jr., P. J. Stabeno, S. Strom, and J. M. Napp. 2008. Patterns of spatial and temporal variation in the marine ecosystem of the southeastern Bering Sea, with special reference to the Pribilof Domain. Deep-Sea Research II 55:1919-1944.

Huntington, H. P. 2009. A preliminary assessment of threats to arctic marine mammals and their conservation in the coming decades. Marine Policy 33:77-82.

Hurrell, J. W. 1995. Decadal trends in the North Atlantic Oscillation: regional temperatures and precipitation. Science 269:676-679.

Ianelli, J. 2005. Assessment and fisheries management of eastern Bering Sea walleye pollock: is sustainability luck? Bulletin of Marine Science 76:321-335.

Ianelli, J. N., T. Hoknkalehto, S. Barbeaux, S. Kotwicki, K. Aydin, and N. Williamson. 2012. Assessment of the walleye pollock stock in the Eastern Bering Sea. Pages 51-156 *in* S. Zador, editor. Ecosystem Considerations 2012, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, Anchorage, AK.

Iglesias-Rodriguez, M. D., P. R. Halloran, R. E. M. Rickaby, I. R. Hall, E. Colmenero-Hidalgo, J. R. Gittins, D. R. H. Green, T. Tyrrell, S. J. Gibbs, P. von Dassow, E. Rehm, E. V. Armbrust, and K. P. Boessenkool. 2008. Phytoplankton calcification in a high-CO_2 world. Science 320:336-340.

IPCC. 2000. Summary for policymakers. Pages 1-20 *in* Emissions Scenarios. A Special Report of the Intergovernmental Panel on Climate Change Working Group III. IPCC, Geneva, Switzerland.

IPCC. 2007a. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland. 104 p.

IPCC. 2007b. Summary for policymakers. Pages 1-22 *in* Core Writing Team, R. K. Pachauri, and A. Reisinger, editors. Climate Change 2007: Synthesis Report. IPCC, Geneva, Switzerland.

IPCC. 2007c. Summary for policymakers. Pages 1-18 *in* S. Solomon, D. Qin, M. Manning, M. Marquis, K. Averyt, M. M. B. Tignor, H. L. Miller, Jr., and Z. Chen, editors. Climate Change 2007: The Physical Science Basis. Cambridge University Press, Cambridge, UK and New York, NY.

IPCC. 2008. About IPCC (Website). Intergovernmental Panel on Climate Change, Geneva, Switzerland. Accessed August 22, 2008 at http://www.ipcc.ch/about/index.htm.

Ishimatsu, A., M. Hayashi, K. S. Lee, T. Kikkawa, and J. Kita. 2005. Physiological effects on fishes in a high-CO_2 world. Journal of Geophysical Research 110:C09209.

Ivanov, A. Y., and V. V. Zatyagalova. 2008. A GIS approach to mapping oil spills in a marine environment. International Journal of Remote Sensing 29:6297-6313.

Jansen, E., J. Overpeck, K. R. Briffa, J.-C. Duplessy, F. Joos, V. Masson-Delmotte, D. Olago, B. Otto-Bliesner, W. R. Peltier, S. Rahmstorf, R. Ramesh, D. Raynaud, D. Rind, O. Solomina, R. Villalba, and D. Zhang. 2007. Palaeoclimate. Pages 433-497 *in* S. Solomon, D. Qin, M. Manning, M. Marquis, K. Averyt, M. M. B. Tignor, J. Henry LeRoy Miller, and Z. Chen, editors. Climate Change 2007: The Physical Science Basis. Cambridge University Press, Cambridge, UK and New York, NY.

Jansen, J. K., P. L. Boveng, S. P. Dahle, and J. L. Bengtson. 2010. Reaction of harbor seals to cruise ships. Journal of Wildlife Management 74:1186-1194.

Jemison, L. A., and B. P. Kelly. 2001. Pupping phenology and demography of harbor seals (*Phoca vitulina richardsi*) on Tugidak Island, Alaska. Marine Mammal Science 17:585-600.

Jenssen, B. M. 1996. An overview of exposure to, and effects of, petroleum oil and organochlorine pollution in grey seals (*Halichoerus grypus*). Science of the Total Environment 186:109-118.

Jenssen, B. M., J. U. Skaare, M. Ekker, D. Vongraven, and S. H. Lorentsen. 1996. Organochlorine compounds in blubber, liver and brain in neonatal grey seal pups. Chemosphere 32:2115-2125.

Johnson, L. 1983. Assessment of the effects of oil on Arctic marine fish and marine mammals. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1200. 15 p.

Jun, M., R. Knutti, and D. W. Nychka. 2008. Spatial analysis to quantify numerical model bias and dependence: how many climate models are there? Journal of the American Statistical Association 103:934-947.

Kathman, R. D., W. C. Austin, J. C. Saltman, and J. D. Fulton. 1986. Identification manual to the Mysidacea and Euphausiacea of the northeast Pacific. Department of Fisheries and Oceans, Ottawa, Canada. 411 p.

Kavra, V. 2004. Mass mortality event of ribbon seal in Kresta Bay. Marine Mammal Council, Chukotka, Russia. Accessed March 12, 2008 at http://www.2mn.org/ru/info/krylatka2004.htm.

Kelly, B. P. 1988. Ribbon seal, *Phoca fasciata*. Pages 95-106 *in* J. W. Lentfer, editor. Selected Marine Mammal Species of Alaska: Species Accounts with Research and Managment Recommendations. Marine Mammal Commission, Washington, D.C.

Kennedy-Stoskopf, S. 2001. Viral diseases. Pages 285-308 *in* L. A. Dierauf and F. Gulland, editors. CRC Handbook of Marine Mammal Medicine. CRC Press LLC, Boca Raton, FL.

Khon, V. C., I. I. Mokhov, M. Latif, V. A. Semenov, and W. Park. 2010. Perspectives of Northern Sea Route and Northwest Passage in the twenty-first century. Climatic Change 100:757-768.

King, J. E. 1964. Seals of the world. British Museum (Natural History), London, UK. 240 p.

King, J. E. 1983. Seals of the world. 2nd edition. British Museum (Natural History) and Oxford University Press, London, UK. 240 p.

Knutti, R., M. R. Allen, P. Friedlingstein, J. M. Gregory, G. C. Hegerl, G. A. Meehl, M. Meinshausen, J. M. Murphy, G.-K. Plattner, S. C. B. Raper, T. F. Stocker, P. A. Stott, H. Teng, and T. M. L. Wigley. 2008. A review of uncertainties in global temperature projections over the twenty-first century. Journal of Climate 21:2651-2663.

Knutti, R., and J. Sedláček. 2012. Robustness and uncertainties in the new CMIP5 climate model projections. Nature (Published online 28 October 2012).

Kommersant. 2004. Magadan Region (Online news article). Kommersant Publishing House, Moscow, Russia. Accessed May 2010 at http://www.kommersant.com/p-52/r_396/Magadan_Region/.

Konishi, K., and Y. Sakurai. 2002. Geographical variations in infection by larval *Anisakis simplex* and *Contracaecum osculatum* (Nematoda, Anisakidae) in walleye pollock *Theragra chalcogramma* stocks off Hokkaido, Japan. Fisheries Science 68:534-542.

Kooyman, G. L., R. W. Davis, and M. A. Castellini. 1977. Thermal conductance of immersed pinniped and sea otter pelts before and after oiling with Prudhoe Bay crude. Pages 151-157 *in* D. A. Wolfe, editor. Fate and effects of petroleum hydrocarbons in marine ecosystems and organisms. Pergamon Press, New York, NY.

Kotwicki, S., T. W. Buckley, T. Honkalehto, and G. Walters. 2005. Variation in the distribution of walleye pollock (*Theragra chalcogramma*) with temperature and implications for seasonal migration. Fishery Bulletin 103:574-587.

Kovacs, K. M., and C. Lydersen. 2008. Climate change impacts on seals and whales in the North Atlantic Arctic and adjacent shelf seas. Science Progress 92:117-150.

Krylov, V. I., G. A. Fedoseev, and A. P. Shustov. 1964. Pinnipeds of the Far East. Pischevaya Promyshlennost (Food Industry), Moscow, Russia. 59 p. (Translated from Russian by F. H. Fay and B. A. Fay, University of Alaska, Fairbanks, AK, 47 p.).

Kurihara, H., and A. Ishimatsu. 2008. Effects of high CO_2 seawater on the copepod (*Acartia tsuensis*) through all life stages and subsequent generations. Marine Pollution Bulletin 56:1086-1090.

Laidre, K. L., I. Stirling, L. F. Lowry, Ø. Wiig, M. P. Heide-Jørgensen, and S. H. Ferguson. 2008. Quantifying the sensitivity of Arctic marine mammals to climate-induced habitat change. Ecological Applications 18:S97-S125.

Lalli, C. M., and R. Gilmer. 1989. Pelagic snails: the biology of holoplanktonic gastropod mollusks. Stanford University Press, Stanford, CA. 276 p.

Langenbuch, M., and H. O. Pörtner. 2003. Energy budget of Antarctic fish hepatocytes (*Pachycara brachycephalum* and *Lepidonotohen kempi*) as a function of ambient CO_2: pH dependent limitations of cellular protein biosynthesis? Journal of Experimental Biology 206:3895-3903.

Lapko, V. V., and V. I. Radchenko. 2000. Sea of Okhotsk. Marine Pollution Bulletin 41:179-187.

Lauth, R. 2007. Forage - Eastern Bering Sea. Pages 136-137 *in* J. L. Boldt, editor. Appendix C: Ecosystem Considerations for 2008 of the Bering Sea and Aleutian Islands/Gulf of Alaska Stock Assessment and Fishery Evaluation Reports for 2008. North Pacific Fishery Management Council, Anchorage, AK.

Lauth, R. 2011. Forage species - Eastern Bering Sea. Pages 146-147 *in* S. Zador, editor. Appendix C: Ecosystem Considerations for 2012 of the Bering Sea and Aleutian Islands/Gulf of Alaska Stock Assessment and Fishery Evaluation Reports for 2012. North Pacific Fishery Management Council, Anchorage, AK.

Lawn, D., R. Steiner, and J. Wills. 1999. Sakhalin's oil: doing it right. Applying gold standards to public participation, environmental monitoring, oil spill prevention and response and liability standards in the Sakhalin Oblast of the Russian Federation. Sakhalin Environment Watch and Pacific Environment and Resources Center. 46 p.

Learmonth, J. A., C. D. MacLeod, M. B. Santos, G. J. Pierce, H. Q. P. Crick, and R. A. Robinson. 2006. Potential effects of climate change on marine mammals. Oceanography and Marine Biology: An Annual Review 44:431-464.

Leclerc, L.-M., C. Lydersen, T. Haug, L. Bachmann, A. Fisk, and K. Kovacs. 2012. A missing piece in the Arctic food web puzzle? Stomach contents of Greenland sharks sampled in Svalbard, Norway. Polar Biology DOI: 10.1007/s00300-012-1166-7 (Published online March 9, 2012).

Lee, J. 2008. BP to begin developing Liberty oil field (Online news article). Anchorage Daily News, Anchorage, AK. Accessed June 2010 at http://www.adn.com/2008/07/14/464438/bp-to-begin-developing-liberty.html.

Leidenberger, S., K. Harding, and T. Härkönen. 2007. Phocid seals, seal lice and heartworms: a terrestrial host-parasite system conveyed to the marine environment. Diseases of Aquatic Organisms 77:235-253.

Lenfant, C., K. Johansen, and J. D. Torrance. 1970. Gas transport and oxygen storage capacity in some pinnipeds and the sea otter. Respiration Physiology 9:277-286.

Loeng, H. 1989. The influence of temperature on some fish population parameters in the Barents Sea. Journal of Northwest Atlantic Fisheries Science 9:103-113.

Logerwell, E. A., K. Rand, S. Parker-Stetter, J. K. Horne, T. Weingartner, and B. A. Bluhm. 2010. Beaufort Sea marine fish monitoring 2008: pilot survey and test of hypotheses. Final Report. Minerals Management Service, Anchorage, AK.

Lønne, O. J., and B. Gulliksen. 1989. Size, age and diet of polar cod, *Boreogadus saida* (Lepechin, 1773), in ice covered waters. Polar Biology 9:187-191.

Lønne, O. J., and B. Gulliksen. 1991a. On the distribution of sympagic macro-fauna in the seasonally ice covered Barents Sea. Polar Biology 11:457-469.

Lønne, O. J., and B. Gulliksen. 1991b. Sympagic macro-fauna from multiyear sea-ice near Svalbard. Polar Biology 11:471-477.

Loughlin, T. R., I. N. Sukhanova, and E. H. Sinclair. 1999. Summary of biology and ecosystem dynamics in the Bering Sea. Pages 387-407 *in* T. R. Loughlin and K. Ohtani, editors. Dynamics of the Bering Sea. AK-SG-99-03. University of Alaska Sea Grant, Fairbanks, AK.

Lowry, L., and P. Boveng. 2008. Ribbon seal, *Histriophoca fasciata*. Pages 945-948 *in* W. F. Perrin, J. G. M. Thewissen, and B. Wursig, editors. Encyclopedia of Marine Mammals. MacMillan, New York, NY.

Lowry, L. F. 1985. The ribbon seal (*Phoca fasciata*). Pages 71-78 *in* J. J. Burns, K. J. Frost, and L. F. Lowry, editors. Marine Mammals Species Accounts. Alaska Department Fish and Game, Juneau, AK.

Lowry, L. F. 2000. Marine mammal-sea ice relationships. Pages 91-96 *in* H. P. Huntington, editor. Report of the Marine Mammal Commission Workshop: Impacts of Changes in Sea Ice and Other Environmental Parameters in the Arctic, Girdwood, AK. Marine Mammal Commission.

Lowry, L. F., V. N. Burkanov, and K. J. Frost. 1996. Importance of walleye pollock, *Theragra chalcogramma*, in the diet of phocid seals in the Bering Sea and northwestern Pacific Ocean. Pages 141-151 *in* R. D. Brodeur, P. A. Livingston, T. R. Loughlin, and A. B. Hollowed, editors. Ecology of Juvenile Walleye Pollock, *Theragra chalcogramma*. Papers from the Workshop "The Importance of Prerecruit Walleye Pollock to the Bering Sea and the North Pacific Ecosystems" Seattle, Washington, 28-30 October 1993. U.S. Department of Commerce, NOAA Technical Report NMFS-126, Seattle, WA.

Lowry, L. F., and F. H. Fay. 1984. Seal eating by walruses in the Bering and Chukchi Seas. Polar Biology 3:11-18.

Lowry, L. F., K. J. Frost, and J. J. Burns. 1979. Potential resource competition in the southeastern Bering Sea: fisheries and phocid seals. Pages 287-296 *in* B. R. Melteff, editor. Proceedings of the 29th Alaska Science Conference. Alaska Fisheries: 200 Years and 200 Miles of Change. Sea Grant Report 79-6. University of Alaska Sea Grant, Fairbanks, AK.

Lowry, L. F., K. J. Frost, and K. W. Pitcher. 1994. Observations of oiling of harbor seals in Prince William Sound. Pages 209-225 *in* T. R. Loughlin, editor. Marine Mammals and the *Exxon Valdez*. Academic Press, Inc., San Diego, CA.

Lunn, N. J., and I. L. Boyd. 1993. Effects of maternal age and condition on parturition and the perinatal period of Antarctic fur seals. Journal of the Zoological Society of London 229:55-67.

Lunn, N. J., I. L. Boyd, and J. P. Croxall. 1994. Reproductive performance of female Antarctic fur seals: the influence of age, breeding experience, environmental variation and individual quality. Journal of Animal Ecology 63:827-840.

Lüthi, D., M. Le Floch, B. Bereiter, T. Blunier, J. M. Barnola, U. Siegenthaler, D. Raynaud, J. Jouzel, H. Fischer, K. Kawamura, and T. F. Stocker. 2008. High-resolution carbon dioxide concentration record 650,000-800,000 years before present. Nature 453:379-382.

MacKenzie, B. R., and D. Schiedek. 2007. Daily ocean monitoring since the 1860s shows record warming of northern European seas. Global Change Biology 13:1335-1347.

Mansfield, A. W. 1983. The effects of vessel traffic in the arctic on marine mammals and recommendations for future research. Government of Canada Fisheries and Oceans, Canadian Technical Reports in Fisheries and Aquatic Sciences No. 1186. 97 p.

Marine Mammal Commission. 2007. Marine mammals and noise. A sound approach to research and management. Marine Mammal Commission, Report to Congress. 370 p.

Marine Mammal Council. 2008. Russian Federation Government Decrees #1482-r, #1644-r, #1603-r, and #1551-r. Marine Mammal Council, Moscow, Russia. Accessed February 2010 at http://2mn.org/engl/directory_en.htm.

Maslanik, J. A., C. Fowler, J. Stroeve, S. Drobot, J. Zwally, D. Yi, and W. Emery. 2007. A younger, thinner Arctic ice cover: increased potential for rapid, extensive sea-ice loss. Geophysical Research Letters 34:L24501.

Mathis, J. T., J. N. Cross, and N. R. Bates. 2011a. Coupling primary production and terrestrial runoff to ocean acidification and carbonate mineral suppression in the eastern Bering Sea. Journal of Geophysical Research 116:C02030.

Mathis, J. T., J. N. Cross, and N. R. Bates. 2011b. The role of ocean acidification in systemic carbonate mineral suppression in the Bering Sea. Geophysical Research Letters 38:L19602.

Mathis, J. T., R. S. Pickart, R. H. Byrne, C. L. McNeil, G. W. K. Moore, L. W. Juranek, X. W. Liu, J. Ma, R. A. Easley, M. M. Elliot, J. N. Cross, S. C. Reisdorph, F. Bahr, J. Morison, T. Lichendorf, and R. A. Feely. 2012. Storm-induced upwelling of high *p*CO(2) waters onto the continental shelf of the western Arctic Ocean and implications for carbonate mineral saturation states. Geophysical Research Letters 39:L07606.

Mathis, J. T., R. S. Pickart, D. A. Hansell, D. Kadko, and N. R. Bates. 2007. Eddy transport of organic carbon and nutrients from the Chukchi Shelf: impact on the upper halocline of the western Arctic Ocean. Journal of Geophysical Research 112:C05011.

Matkin, C. O., L. G. Barrett-Lennard, H. Yurk, D. Ellifrit, and A. W. Trites. 2007. Ecotypic variation and predatory behavior among killer whales (*Orcinus orca*) off the eastern Aleutian Islands, Alaska. Fishery Bulletin 105:74-87.

McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-42. 156 p.

Measures, L. N. 2001. Lungworms of marine mammals. Pages 279-300 *in* W. M. Samuel, M. J. Pybus, and A. A. Kocan, editors. Parasitic Diseases of Wild Mammals. Iowa State University Press, Ames, IA.

Measures, L. N., J. F. Gosselin, and E. Bergeron. 1997. Heartworm, *Acanthocheilonema spirocauda* (Leidy, 1858), infections in Canadian phocid seals. Canadian Journal of Fisheries and Aquatic Sciences 54:842-846.

Mecklenberg, C. W., T. A. Mecklenberg, and L. K. Thorsteinson. 2002. Fishes of Alaska. American Fisheries Society, Bethesda, MD. 1037 p.

Meehl, G. A., T. F. Stocker, W. D. Collins, P. Friedlingstein, A. T. Gaye, J. M. Gregory, A. Kitoh, R. Knutti, J. M. Murphy, A. Noda, S. C. B. Raper, I. G. Watterson, A. J. Weaver, and Z.-C. Zhao. 2007. Global climate projections. Pages 747-846 *in* S. Solomon, D. Qin, M. Manning, M. Marquis, K. Averyt, M. M. B. Tignor, J. Henry LeRoy Miller, and Z. Chen, editors. Climate Change 2007: The Physical Science Basis. Cambridge University Press, Cambridge, UK and New York, NY.

Melnikov, I. A., E. G. Kolosova, H. E. Welch, and L. S. Zhitina. 2002. Sea ice biological communities and nutrient dynamics in the Canada Basin of the Arctic Ocean. Deep-Sea Research I 49:1623-1649.

Mertz, G., and R. A. Myers. 1996. Influence of fecundity on recruitment variability of marine fish. Canadian Journal of Fisheries and Aquatic Sciences 53:1618-1625.

Michaelidis, B., A. Spring, and H. O. Pörtner. 2007. Effects of long-term acclimation to environmental hypercapnia on extracellular acid-base status and metabolic capacity in Mediterranean fish *Sparus aurata*. Marine Biology 150:1417-1429.

Miksis-Olds, J. L., and S. E. Parks. 2011. Seasonal trends in acoustic detection of Ribbon seal (*Histriophoca fasciata*) vocalizations in the Bering Sea. Aquatic Mammals 37:464-471.

Miller, G. W., and R. A. Davis. 2002. Marine mammal and acoustical monitoring of Anderson Exploration Limited's open-water seismic program in the southeastern Beaufort Sea, 2001. LGL Ecological Research Associates, Inc., LGL Report TA 2618-1. 199 p.

Miller, K. A., M. G. L. Assunção, N. J. Dangerfield, S. M. Bandiera, and P. S. Ross. 2005. Assessment of cytochrome P450 1A in harbour seals (*Phoca vitulina*) using a minimally-invasive biopsy approach. Marine Environmental Research 60:153-169.

Miller, M. A., I. A. Gardner, A. Packham, J. K. Mazet, K. D. Hanni, D. Jessup, J. Estes, R. Jameson, E. Dodd, B. C. Barr, L. J. Lowenstine, F. M. Gulland, and P. A. Conrad. 2002. Evaluation of an indirect fluorescent antibody test (IFAT) for demonstration of antibodies to *Toxoplasma gondii* in the sea otter (*Enhydra lutris*). Journal of Parasitology 88:594-599.

Miller, M. A., K. Sverlow, P. R. Crosbie, B. C. Barr, L. J. Lowenstine, F. M. Gulland, A. Packham, and P. A. Conrad. 2001. Isolation and characterization of two parasitic protozoa from a Pacific harbor seal (*Phoca vitulina richardsi*) with meningoencephalomyelitis. Journal of Parasitology 87:816-822.

Miller, W. G., L. G. Adams, T. A. Ficht, N. F. Cheville, J. P. Payeur, D. R. Harley, C. House, and S. H. Ridgway. 1999. Brucella-induced abortions and infection in bottlenose dolphins (*Tursiops truncatus*). Journal of Zoo and Wildlife Medicine 30:100-110.

Minerals Management Service. 2007a. Chukchi Sea planning area: oil and gas lease sale 193 and seismic surveying activities in the Chukchi Sea. Final Environmental Impact Statement. U.S. Department of the Interior, Minerals Management Service, Anchorage, AK. 631 p.

Minerals Management Service. 2007b. Proposed final program Outer Continental Shelf oil and gas leasing program 2007-2012, April 2007. U.S. Department of the Interior, Minerals Management Service, Anchorage, AK. 146 p.

Minerals Management Service. 2008a. Arctic oil spill response research and development program: a decade of achievement. U.S. Department of the Interior, Minerals Management Service. 29 p.

Minerals Management Service. 2008b. February 6, 2008 news release: MMS Chukchi Sea lease sale 193 breaks energy records with $2.6 billion in high bids. U.S. Department of the Interior, Minerals Management Service, Accessed August 2008 at http://www.mms.gov/ooc/press/2008/press0206.htm.

Minerals Management Service. 2009a. Alaska OCS Region (Website). Minerals Management Service, Anchorage, AK. Accessed June 2010 at http://www.mms.gov/alaska/fo/index.htm.

Minerals Management Service. 2009b. Draft proposed Outer Continental Shelf (OCS) oil and gas leasing program 2010-2015. Minerals Management Service, Washington, D.C. 140 p. Accessed at http://www.mms.gov/5-year/PDFs/2010-2015/DPP FINAL (HQPrint with landscape maps).pdf.

Minerals Management Service. 2009c. February 10, 2009 news release: Secretary Salazar details strategy for comprehensive energy plan on U.S. Outer Continental Shelf -- provides more time for public comment; incorporates renewable energy. U.S. Department of the Interior, Minerals Management Service, Washington, D.C. Accessed May 2010 at http://www.doi.gov/archive/news/09_News_Releases/021009.html.

Minerals Management Service. 2010a. 2007-2012 5-year program. Minerals Management Service, Washington, D.C. Accessed June 2010 at http://www.mms.gov/5-year/2007-2012FiveYearProgram.htm.

Minerals Management Service. 2010b. Preliminary revised program Outer Continental Shelf oil and gas leasing program 2007-2012. Minerals Management Service, Washington, D.C. 216 p. Accessed at http://www.mms.gov/5-year/PDFs/PRP2007-2012.pdf.

Mizroch, S. A., and D. W. Rice. 2006. Have North Pacific killer whales switched prey species in response to depletion of the great whale populations? Marine Ecology Progress Series 310:235-246.

Mizuno, A. W., A. Wada, T. Ishinazaka, K. Hattori, Y. Watanabe, and N. Ohtaishi. 2002. Distribution and abundance of spotted seals *Phoca largha* and ribbon seals *Phoca fasciata* in the southern Sea of Okhotsk. Ecological Research 17:79-96.

Moeller, R. B., Jr. 2003. Pathology of marine mammals with special reference to infectious disease. Pages 3-37 *in* J. G. Vos, G. Bossart, M. Fournier, and T. O'Shea, editors. Toxicology of Marine Mammals. Routledge, Florence, KY.

Mohr, E. 1951. Zur kenntnis der Bandrobbe, *"Histriophoca" fasciata* (Zimmermann, 1783). Zoologischer Anzeiger 147:187-195. (In German).

Moore, S. E., and H. P. Huntington. 2008. Arctic marine mammals and climate change: impacts and resilience. Ecological Applications 18:S157-S165.

Moore, S. E., K. M. Stafford, H. Melling, C. Berchok, O. Wiig, K. M. Kovacs, C. Lydersen, and J. Richter-Menge. 2012. Comparing marine mammal acoustic habitats in Atlantic and Pacific sectors of the High Arctic: year-long records from Fram Strait and the Chukchi Plateau. Polar Biology 35:475-480.

Moreland, E. E., M. Cameron, and P. Boveng. 2012. Bering Okhotsk seal surveys (BOSS): Joint U.S.-Russian aerial surveys. Alaska Fisheries Science Center Research Report, April-May-June 2012

Moreland, E. E., M. F. Cameron, and P. L. Boveng. 2008. Densities of seals in the pack ice of the Bering Sea (Poster Presentation). Alaska Marine Science Symposium, Anchorage, AK. Accessed at ftp://ftp.afsc.noaa.gov/posters/pMoreland01_bs-seal-pack-ice.pdf.

Mouchaty, S., J. A. Cook, and G. F. Shields. 1995. Phylogenetic analysis of northern hair seals based on nucleotide sequences of the mitochondrial cytochrome {Ib} gene. Journal of Mammalogy 76:1178-1185.

Mouvet, C., and A. C. M. Bourg. 1983. Speciation (including adsorbed species) of copper, lead, nickel and zinc in the Meuse River: observed results compared to values calculated with a chemical equilibrium computer program. Water Research 17:641-649.

Mueter, F. J., N. A. Bond, J. N. Ianelli, and A. B. Hollowed. 2011. Expected declines in recruitment of walleye pollock (*Theragra chalcogramma*) in the eastern Bering Sea under future climate change. ICES Journal of Marine Science 68:1284-1296.

Mueter, F. J., C. Broms, K. F. Drinkwater, K. D. Friedland, J. A. Hare, G. L. Hunt, Jr., W. Melle, and M. Taylor. 2009. Ecosystem response to recent oceanographic variability in high-latitude Northern Hemisphere ecosystems. Progress in Oceanography 81:93-110.

Mueter, F. J., and M. A. Litzow. 2008. Sea ice retreat alters the biogeography of the Bering Sea continental shelf. Ecological Applications 18:309-320.

Mueter, F. J., and B. A. Megrey. 2006. Using multi-species surplus production models to estimate ecosystem-level maximum sustainable yields. Fisheries Research 81:189-201.

Murawski, S. A. 1993. Climate change and marine fish distributions: forecasting from historical analogy. Transactions of the American Fisheries Society 122:647-658.

Murawski, S. A., and J. T. Finn. 1988. Biological bases for mixed-species fisheries: species co-distribution in relation to environmental and biotic variables. Canadian Journal of Fisheries and Aquatic Sciences 45:1720-1735.

Naito, Y., and S. Konno. 1979. The post-breeding distributions of ice-breeding harbour seal (*Phoca largha*) and ribbon seal (*Phoca fasciata*) in the southern Sea of Okhotsk. Scientific Reports of the Whales Research Institute 31:105-119.

Naito, Y., and M. Oshima. 1976. The variation in the development of pelage of the ribbon seal with reference to the systematics. Scientific Reports of the Whales Research Institute 28:187-197.

Nakicenovic, N., and R. Swart, editors. 2000. Special report on emissions scenarios: a special report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK. 612 p.

Napp, J. 2010. The Bering Sea: current status and recent events. PICES Press 18:20-21.

Napp, J., and N. Shiga. 2005. Bering Sea zooplankton. Pages 157-158 *in* J. L. Boldt, editor. Ecosystem Considerations for 2007: Appendix C of the Bering Sea and Aleutian Islands/Gulf of Alaska Stock Assessment and Fishery Evaluation Reports for 2007. North Pacific Fishery Management Council, Anchorage, AK.

Napp, J. M. 2008. The Bering Sea: current status and recent events. PICES Press 16:31-33.

National Marine Fisheries Service. 2008a. Notice of 12-month finding on a petition to list the ribbon seal as a threatened or endangered species. Federal Register 73:250 (December 30, 2008) p. 79822-79828.

National Marine Fisheries Service. 2008b. Notice of 90-day finding on a petition to list the ribbon seal as a threatened or endangered species. Federal Register 73:61 (March 28, 2008) p. 16617-16619.

National Marine Fisheries Service. 2009. Proposed threatened and not warranted status for distinct population segments of the spotted seal. Federal Register 74:201 (October 20, 2009) p. 53683-53696.

National Marine Fisheries Service. 2010. Threatened status for the southern distinct population segment of the spotted seal. Federal Register 75:204 (October 22, 2010) p. 65239-65248.

National Marine Fisheries Service. 2011. Endangered and threatened species; initiation of status review for ribbon seal. Federal Register 76:239 p. 77467-77469.

National Marine Fisheries Service. 2012. Management report for 82 corals status review under the Endangered Species Act: existing regulatory mechanisms and conservation efforts. U.S. Department of Commerce. 152 p.

National Marine Fisheries Service. 2013. Diseased Ice Seals. National Marine Fisheries Service, Alaska Regional Office, Juneau, Alaska. Accessed March 21, 2013 at http://alaskafisheries.noaa.gov/protectedresources/seals/ice/diseased/default.htm.

National Research Council. 2002. Abrupt climate change: Inevitable surprises. National Academy Press, Washington, D.C. 230 p.

National Research Council. 2010. Ocean acidification: a national strategy to meet the challenges of a changing ocean. National Academies Press, Washington, D.C. 175 p.

National Snow and Ice Data Center. 2007. October 1, 2007 press release: Diminished summer sea ice leads to opening of the fabled Northwest Passage. NSIDC, Boulder, CO. Accessed September 30, 2008 at http://www.nsidc.org/news/press/2007_seaiceminimum/20071001_pressrelease.html.

Nesis, K. N. 1982. Cephalopods of the world. VAAP Copyright Agency, Moscow, Russia. 351 p.

Nielsen, O., A. Clavijo, and J. A. Boughen. 2001. Serologic evidence of influenza A infection in marine mammals of Arctic Canada. Journal of Wildlife Diseases 37:820-825.

Nikolaev, A. M., and V. A. Skalkin. 1975. On the food of true seals of the eastern coast of Sakhalin. Pages 384-388 *in* Environmental Assessment of the Alaskan Continental Shelf. Annual Reports of Principal Investigators for the year ending March 1977. Volume 1. Receptors--Mammals. U.S. Department of Commerce, NOAA, Environmental Research Laboratories and U.S. Department of the Interior, Bureau of Land Management, Boulder, CO.

Nikulin, V. S., and V. N. Burkanov. 2002. Some seasonal regularities of marine mammals incidental bycatch at salmon driftnet fisheries in south-west of the Bering Sea (Abstract). Pages 205-208 *in* V. M. Belkovich, editor. Marine Mammals of the Holarctic. 2002. Abstracts of Reports, Baikal, Russia. Marine Mammal Council. (Translated from Russian).

NOAA, and U.S. Fish and Wildlife Service. 2012. Northern pinnipeds (ice seals and walrus). Page 2 Update: Unusual Mortality Event (UME), Investigations and Findings.

Nørgaard-Pedersen, N., N. Mikkelsen, S. J. Lassen, and Y. Kristoffersen. 2007. The last interglacial Arctic Ocean – intrabasinal sediment and faunal records support much reduced sea ice concentrations. Geophysical Research Abstracts 9:7427.

North Pacific Fishery Management Council. 2009. Fishery management plan for fish resources of the Arctic management area. NPFMC, Anchorage, AK. 158 p. Accessed May 2010 at http://www.fakr.noaa.gov/npfmc/fmp/arctic/ArcticFMP.pdf.

O'Brien, C. M., C. J. Fox, B. Planque, and J. Casey. 2000. Fisheries - Climate variability and North Sea cod. Nature 404:142-142.

O'Corry-Crowe, G. 2008. Climate change and the molecular ecology of arctic marine mammals. Ecological Applications 18:S56-S76.

Oppenheimer, M., B. C. O'Neill, M. Webster, and S. Agrawala. 2007. Climate change: the limits of consensus. Science 317:1505-1506.

Oreskes, N. 2004. The scientific consensus on climate change. Science 306:1686.

Ormseth, O. A. 2012. Assessment of the squid stock complex in the Gulf of Alaska. Pages 643-646 *in* S. Zador, editor. Ecosystem Considerations 2012, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, Anchorage, AK.

Ormseth, O. A., and E. Jorgensen. 2007. Bering Sea and Aleutian Island squids. Pages 931-952 *in* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Region. North Pacific Fishery Management Council, Anchorage, AK.

Orr, J. C., V. J. Fabry, O. Aumont, L. Bopp, S. C. Doney, R. A. Feely, A. Gnanadesikan, N. Gruber, A. Ishida, F. Joos, R. M. Key, K. Lindsay, E. Maier-Reimer, R. Matear, P. Monfray, A. Mouchet, R. G. Najjar, G.-K. Plattner, K. B. Rodgers, C. L. Sabine, J. L. Sarmiento, R. Schlitzer, R. D. Slater, I. J. Totterdell, M.-F. Weirig, Y. Yamanaka, and A. Yool. 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. Nature 437:681-686.

Orr, J. C., S. Jutterström, L. Bopp, L. G. Anderson, P. Cadule, V. J. Fabry, T. Frölicher, E. P. Jones, F. Joos, A. Lenton, E. Maier-Reimer, J. Segschneider, M. Steinacher, and D. Swingedouw. 2009. Amplified acidification of the Arctic Ocean (Abstract). IOP Conference Series: Earth and Environmental Science 6:462009.

OSPAR Commission. 2009. Overview of the impacts of anthropogenic underwater sound in the marine environment. OSPAR Commission, Biodiversity Series. 134 p.

Overland, J. E., and P. J. Stabeno. 2004. Is the climate of the Bering Sea warming and affecting the ecosystem? EOS, Transactions of the American Geophysical Union 85:309-316.

Overland, J. E., and M. Wang. 2013. When will the summer Arctic be nearly sea ice free? Geophysical Research Letters

Overland, J. E., M. Wang, N. A. Bond, J. E. Walsh, V. M. Kattsov, and W. L. Chapman. 2011. Considerations in the selection of global climate models for regional climate projections: the Arctic as a case study*. Journal of Climate 24:1583-1597.

Overland, J. E., and M. Y. Wang. 2007. Future regional Arctic sea ice declines. Geophysical Research Letters 34:L17705.

Parmerter, R. R. 1975. A model of simple rafting in sea ice. Journal of Geophysical Research 80:1948-1952.

Parmesan, C., and G. Yohe. 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature 421:37-43.

Patin, S. 1999. Russian oil and gas offshore. EcoMonitor Publishing, East Northport, NY. Accessed April 29, 2010 at http://www.offshore-environment.com/russianoil.html.

Perry, A. L., P. J. Low, J. R. Ellis, and J. D. Reynolds. 2005. Climate change and distribution shifts in marine fishes. Science 308:1912-1915.

PICES. 2005. Report of the study group on fisheries and ecosystem responses to recent regime shifts. North Pacific Marine Science Organization (PICES), PICES Scientific Report No. 28. 162 p.

Pickart, R. S., T. Weingartner, L. J. Pratt, S. T. Zimmerman, and D. J. Torres. 2005. Flow of winter-transformed Pacific water into the western Arctic. Deep-Sea Research II 52:3175-3198.

Pitman, R. L., and J. W. Durban. 2012. Cooperative hunting behavior, prey selectivity and prey handling by pack ice killer whales (*Orcinus orca*), type B, in Antarctic Peninsula waters. Marine Mammal Science 28:16-36.

Polterman, M., H. Hop, and S. Falk-Petersen. 2000. Life under Arctic sea ice -- reproduction strategies of two sympagic (ice-associated) amphipod species, *Gammarus wilkitzkii* and *Apherusa glacialis*. Marine Biology 136:913-920.

Popov, L. A. 1982. Status of the main ice-living seals inhabiting inland waters and coastal marine areas of the USSR. Pages 361-381 *in* FAO Fisheries Series No. 5. Mammals in the Seas. Volume IV--Small

Cetaceans, Seals, Sirenians and Otters. Food and Agriculture Organization of the United Nations, Rome, Italy.

Popov, V. N. 1975. New data on the helminth fauna of the ribbon seal living in the southern part of the Okhotsk Sea. Parazitologiya 9:31-36. (In Russian).

Popov, V. N. 1976. On the helminth fauna of the ribbon seal (*Histriophoca fasciata* Zimmerman) of the northern part of the Okhotsk Sea. Nauchnye Doklday Vysshei Shkoly, Biologicheskie Nauki 1:49-53. (In Russian).

Pörtner, H. 2008. Ecosystem effects of ocean acidification in times of ocean warming: a physiologist's view. Marine Ecology Progress Series 373:203-217.

Pörtner, H. O., M. Langenbuch, and B. Michaelidis. 2005. Synergistic effects of temperature extremes, hypoxia, and increases in CO_2 on marine animals: from Earth history to global change. Journal of Geophysical Research 110:C09S10.

Pörtner, H. O., M. Langenbuch, and A. Reipschläger. 2004. Biological impact of elevated CO_2 concentrations: lessons from animal physiology and earth history. Journal of Oceanography 60:705-718.

Quakenbush, L., and J. Citta. 2008. Biology of the ribbon seal in Alaska. Report to National Marine Fisheries Service. 45 p. Arctic Marine Mammal Program, Alaska Department of Fish and Game, Fairbanks, AK.

Quakenbush, L., and G. Sheffield. 2007. Ice seal bio-monitoring in the Bering-Chukchi Sea region. North Pacific Research Board (NPRB) Project 312 Final Report, 47 p. Alaska Department of Fish and Game, Fairbanks, AK.

Quakenbush, L. T. 2007. Polybrominated diphenyl ether compounds in ringed, bearded, spotted, and ribbon seals from the Alaskan Bering Sea. Marine Pollution Bulletin 54:232-236.

Quinn, T. J., II, and H. J. Niebauer. 1995. Relation of eastern Bering Sea walleye pollock (*Theragra chalcogramma*) recruitment to environmental and oceanographic variables. Pages 497-507 *in* R. J. Beamish, editor. Climate Change and Northern Fish Populations. National Research Council of Canada, Ottawa, Canada.

Rachlow, J. L., and R. T. Bowyer. 1991. Interannual variation in timing and synchrony of parturition in Dall's sheep. Journal of Mammalogy 72:487-492.

Radchenko, V. I., E. P. Dulepova, O. N. Katugin, K. Ohshima, J. Nishioka, S. M. McKinnell, and A. T. Tsoy. 2010. Status and trends of the Sea of Okhotsk region, 2003-2008. Pages 268-299 *in* S. M. McKinnell and M. J. Dagg, editors. Marine Ecosystems of the North Pacific Ocean, 2003-2008. PICES Special Publication 4

Räisänen, J. 2007. How reliable are climate models? Tellus 59A:2-29.

Räisänen, J., L. Ruokolainen, and J. Ylhäisi. 2010. Weighting of model results for improving best estimates of climate change. Climate Dynamics 35:407-422.

Randall, D. A., R. A. Wood, S. Bony, R. Colman, T. Fichefet, J. Fyfe, V. Kattsov, A. Pitman, J. Shukla, J. Srinivasan, R. J. Stouffer, A. Sumi, and K. E. Taylor. 2007. Climate models and their evaluation. Pages 589-662 *in* S. Solomon, D. Qin, M. Manning, M. Marquis, K. Averyt, M. M. B. Tignor, J. Henry LeRoy Miller, and Z. Chen, editors. Climate Change 2007: The Physical Science Basis. Cambridge University Press, Cambridge, UK and New York, NY.

Rausch, R., B. B. Babero, R. V. Rausch, and E. L. Schiller. 1956. Studies on the helminth fauna of Alaska. XXVII. The occurrence of larvae of *Trichinella spiralis* in Alaskan mammals. Journal of Parasitology 42:259-271.

Raven, J., K. Caldeira, H. Elderfield, O. Hoegh-Guldberg, P. S. Liss, U. Reisbell, J. Shepard, C. Turley, and A. J. Watson. 2005. Ocean acidification due to increasing atmospheric carbon dioxide. The Royal Society, London, UK. 60 p. Accessed July 2010 at http://dge.stanford.edu/labs/caldeiralab/Caldeira downloads/RoyalSociety_OceanAcidification.pdf.

Ray, C., and G. Hufford. 2006. Last Ice: What is to be the fate of Beringian marine mammals in response climate change (with particular reference to Pacific walruses and ribbon seals)? Pages 461-463 *in* V. M. Belkovich, editor. Marine Mammals of the Holarctic 2006. Collection of Scientific Papers, Saint Petersburg, Russia. Marine Mammal Council.

Read, A. J. 2008. The looming crisis: Interactions between marine mammals and fisheries. Journal of Mammalogy 89:541-548.

Reeves, R., R. L. J. Brownell, A. M. Burdin, J. C. Cooke, J. D. Darling, G. P. Donovan, F. Gulland, S. E. Moore, D. P. Nowacek, T. J. Ragen, R. G. Steiner, G. R. VanBlaricom, A. Vedenev, and A. V. Yablakov. 2005. Report of the independent scientific review panel on the impacts of Sakhalin II phase 2 on western North Pacific gray whales and related biodiversity. International Union for the Conservation and Nature and Natural Resources (IUCN). 123 p.

Reichler, T., and J. Kim. 2008. How well do coupled models simulate today's climate? Bulletin of the American Meteorological Society 89:303-311.

Ressler, P. H., A. De Robertis, J. D. Warren, J. N. Smith, and S. Kotwicki. 2012. Developing an acoustic survey of euphausiids to understand trophic interactions in the Bering Sea ecosystem. Deep Sea Research Part II: Topical Studies in Oceanography 65–70:184-195.

Rey, F., H. R. Skjoldal, and D. Slagstad. 1987. Primary production in relation to climatic changes in the Barents Sea. Pages 29-46 *in* H. Loeng, editor. The Effect of Oceanographic Conditions on Distribution and Population Dynamics of Commercial Fish Stocks in the Barents Sea. Institute of Marine Research, Bergen, Norway.

Rice, D. W. 1998. Marine mammals of the world: systematics and distribution. Society for Marine Mammalogy, Lawrence, KS. 231 p.

Richardson, A. J., and D. S. Schoeman. 2004. Climate impact on plankton ecosystems in the northeast Atlantic. Science 305:1609-1612.

Richardson, W. J., C. R. Greene, Jr., C. I. Malme, and D. H. Thomson. 1995. Marine mammals and noise. Academic Press, Inc., San Diego, CA. 576 p.

Richter-Menge, J., and J. E. Overland. 2009. Arctic report card 2009. 77 p. Accessed June 2010 at http://www.arctic.noaa.gov/reportcard.

Riebesell, U., I. Zondervan, B. Rost, P. D. Tortell, R. E. Zeebe, and F. M. M. Morel. 2000. Reduced calcification of marine plankton in response to increased atmospheric CO_2. Nature 407:364-367.

Riedman, M. 1990. The pinnipeds: seals, sea lions, and walruses. University of California Press, Berkeley. 439 p.

Robertson, T. L. 2007. Response gap estimate for two operating areas in Prince William Sound. Nuka Research and Planning Group, LLC., Report to the Prince William Sound Regional Citizens Advisory Council. 35 p.

Roest, A. I. 1964. A ribbon seal from California. Journal of Mammalogy 45:416-420.

Rogelj, J., J. Nabel, C. Chen, W. Hare, K. Markmann, M. Meinshausen, M. Schaeffer, K. Macey, and N. Höhne. 2010. Copenhagen Accord pledges are paltry. Nature 464:1126-1128.

Rogers, T. L. 2003. Factors influencing the acoustic behaviour of male phocid seals. Aquatic Mammals 29:247-260.

Rothrock, D. A., Y. Yu, and G. A. Maykut. 1999. Thinning of the Arctic sea-ice cover. Geophysical Research Letters 26:3469-3472.

Rothrock, D. A., and J. Zhang. 2005. Arctic Ocean sea ice volume: What explains its recent depletion? Journal of Geophysical Research 110:C01002.

Ruthven, D. C., III, E. C. Hellgren, and S. L. Beasom. 1994. Effects of root plowing on white-tailed deer condition, population status, and diet. Journal of Wildlife Management 58:59-70.

Salazar, S. 2003. Impacts of the Jessica oil spill on sea lion (*Zalophus wollebaeki*) populations. Marine Pollution Bulletin 47:313-318.

Santana-Casiano, J. M., M. Gonzalez-Davila, M. J. Rueda, O. Llinas, and E. F. Gonzalez-Davila. 2007. The interannual variability of oceanic CO_2 parameters in the northeast Atlantic subtropical gyre at the ESTOC site. Global Biogeochemical Cycles 21:GB1015.

Sasaki, Y. N., Y. Katagiri, S. Minobe, and I. G. Rigor. 2007. Autumn atmospheric preconditioning for interannual variability of wintertime sea-ice in the Okhotsk Sea. Journal of Oceanography 63:255-265.

Schabetsberger, R., M. Sztatecsny, G. Drozdowski, R. D. Brodeur, G. L. Swartzman, M. T. Wilson, A. G. Winter, and J. M. Napp. 2003. Size-dependent, spatial, and temporal variability of juvenile walleye pollock (*Theragra chalcogramma*) feeding at a structural front in the southeast Bering Sea. Marine Ecology 24:141-164.

Scheffer, V. B. 1958. Seals, sea lions, and walruses: A review of the Pinnipedia. Stanford University Press, Palo Alto, CA. 179 p.

Schei, P. J., and R. D. Brubaker. 2006. Suggestions for a conceptual design of an Okhotsk Sea environmental regime -- comparison with the Barents Sea. Pages 259-276 *in* H. Kitagawa, editor. New Era in Far East Russian and Asia. Ocean Policy Research Foundation, Tokyo, Japan.

Schumacher, J. D., N. A. Bond, R. Brodeur, P. Livingston, J. Napp, and P. Stabeno. 2003. Climate change in the southeastern Bering Sea and some consequences for habitat. Pages 17-40 *in* G. Hempel and K. Sherman, editors. Large Marine Ecosystems of the World: Trends in Exploitation, Protection and Research. Elsevier, Amsterdam, UK.

Scott, J. S. 1982. Depth, temperature and salinity preferences of common fishes of the Scotian Shelf. Journal of Northwest Atlantic Fishery Science 3:29-39.

Sergeant, D. E. 1991. Harp seals, man and ice. Canadian Special Publication of Fisheries and Aquatic Sciences no. 114, 153 p. Canada Communication Group, Ottawa, Canada.

Serreze, M. C., M. M. Holland, and J. Stroeve. 2007. Perspectives on the Arctic's shrinking sea-ice cover. Science 315:1533-1536.

Severinghaus, J. P., and E. J. Brook. 1999. Abrupt climate change at the end of the last glacial period inferred from trapped air in polar ice. Science 286:930-934.

Shell Gulf of Mexico Inc. 2009. Exploration plan; 2010 exploration drilling program; Posey blocks 6713, 6714, 6763, 6764, and 6912; Karo blocks 6864 and 7007; Burger, Crackerjack, and SW Shoebill prospects; OCS lease sale 193; Chukchi Sea, Alaska. Shell Gulf of Mexico Inc., Anchorage, AK. 1414 p. Accessed at http://www.mms.gov/alaska/ref/ProjectHistory/2009_Chukchi_Shell/2009_0811_Chukchi_EP_PublicCopy.pdf.

Shi, D., Y. Xu, B. M. Hopkinson, and F. M. M. Morel. 2010. Effect of ocean acidification on iron availability to marine phytoplankton. Science 327:676-679.

Shults, L. M. 1982. Helminths of the spotted seal, *Phoca largha*, from the Bering Sea. Journal of Wildlife Diseases 18:59-62.

Shults, L. M., and K. J. Frost. 1988. Helminth-parasites of ribbon seals, *Phoca fasciata*, in the Bering Sea and their intermediate hosts. Proceedings of the Helminthological Society of Washington 55:68-73.

Shumei, N., K. Shigeru, I. Ko, U. Shotaro, T. Kenkichi, and T. Tadanori. 2001. A preliminary study for future shipping safety control regime in the ice-infested waters of the Sea of Okhotsk. Papers of the Ship Research Institute 38:209-225. (In Japanese, English Abstract).

Shuntov, V. P., E. P. Dulepova, V. I. Radchenko, and V. V. Lapko. 1996. New data about communities of plankton and nekton of the far-eastern seas in connection with climate oceanological reorganization. Fisheries Oceanography 5:38-44.

Shustov, A. P. 1965a. The distribution of ribbon seal (*Histriophoca fasciata*) in the Bering Sea. Pages 118-121 *in* F. Rieken, editor. Marine Mammals. Ichthyological Commission of the Academy of Sciences of the USSR, Moscow, Russia. (Translated from Russian by M. Slessers, U.S. Naval Oceanographic Office, Washington, D.C., Translation No. 474, 6 p.).

Shustov, A. P. 1965b. The effect of sealing on the state of the population of Bering Sea ribbon seals. Izvestiya TINRO 59:173-178. (Translated from Russian, 11 p.).

Shustov, A. P. 1965c. The food of the ribbon seal in the Bering Sea. Izvestiya TINRO 59:178-183. (Translated from Russian by F. Essapian, 10 p.).

Shustov, A. P. 1965d. Some biological features and reproductive rates of the ribbon seal (*Histriophaca fasciata*) in the Bering Sea. Izvestiya TINRO 59:183-192. (Translated from Russian by F. Essapian, 17 p.).

Shustov, A. P. 1969a. An experience of quantitative aerovisual count of seals in the north-western part of the Bering Sea. Pages 111-126 *in* Marine Mammals. Nauka, Moscow, Russia. (In Russian).

Shustov, A. P. 1969b. Relative indices and possible causes of mortality of Bering Sea ribbon seals. Pages 83-92 *in* Marine Mammals. Ichthyological Commission of the Academy of Sciences of the USSR, Moscow, Russia. (Translated from Russian by F.H. Fay, University of Alaska, Fairbanks, AK, 18 p.).

Shustov, A. P. 1970. Geographical variability in the ribbon seal (*Histriophoca fasciata)*. Izvestiya TINRO 70:138-148. (Translated from Russian by Environment Candada, Ottawa, Canada, Translation Bereau No. 048277, 20 p.).

Shustov, A. P. 1972. On the condition of the stocks and the distribution of true seals and walruses in the North Pacific (Abstract). Pages 146-147 *in* V. A. Arsen'ev, editor. Fifth All-Union Conference on Studies of Marine Mammals, Makhachkala, USSR. Akad. Nauk. SSSR. (Translated from Russian by F.H. Fay, University of Alaska, Fairbanks, AK, 2 p.).

Shustov, A. P. 1975. The analysis of harvesting return of the Bering Sea ribbon seals born in the first year of mass hunting. Pages 180-182 *in* Marine Mammals. Abstracts of the 6th All-Union Symposium, Kiev, Ukraine. Naukova dumka. (In Russian).

Simmonds, M. P., and S. J. Isaac. 2007. The impacts of climate change on marine mammals: early signs of significant problems. Oryx 41:19-26.

Simpkins, M. A., L. M. Hiruki-Raring, G. Sheffield, J. M. Grebmeier, and J. L. Bengtson. 2003. Habitat selection by ice-associated pinnipeds near St. Lawrence Island, Alaska in March 2001. Polar Biology 26:577-586.

Sinclair, E. H., A. A. Balanov, T. Kubodera, V. I. Radchenko, and Y. A. Fedorets. 1999. Distribution and ecology of mesopelagic fishes and cephalopods. Pages 485-508 *in* T. R. Loughlin and K. Ohtani, editors. Dynamics of the Bering Sea. University of Alaska Sea Grant, Fairbanks, AK.

Skjoldal, H. R., A. Hassel, F. Rey, and H. Loeng. 1987. Spring phytoplankton development and zooplankton reproduction in the central Barents Sea in the period 1979-1984. Pages 59-89 *in* H. Loeng, editor. The Effect of Oceanographic Conditions on Distribution and Population Dynamics of Commercial Fish Stocks in the Barents Sea. Institute of Marine Research, Bergen, Norway.

Skogland, T. 1984. The effects of food and maternal conditions on fetal growth and size in wild reindeer. Rangifer 4:39-46.

Sleptsov, M. M. 1940. On adaptations of pinnipeds to swimming. Zoologicheskii Zhurnal 19:379-386. (Translated from Russian by F.H. Fay, University of Alaska, Fairbanks, AK, 9 p.).

Smiley, B. D., and A. R. Milne. 1979. LNG transport in Parry Channel: possible environmental hazards. Institute of Ocean Sciences. 47 p.

Smith, R. E. H., J. F. Cavaletto, B. J. Eadie, and W. S. Gardner. 1993. Growth and lipid composition of high Arctic ice algae during the spring bloom at Resolute, Northwest Territories, Canada. Marine Ecology Progress Series 97:19-29.

Smith, T. G. 1987. The ringed seal, *Phoca hispida*, of the Canadian western Arctic. Bulletin Fisheries Research Board of Canada. 81 p.

Sokolov, A. S. 1966. Ecological function and age characteristics of North Pacific pinnipeds' red blood. Acad. Sci. Present. 169:161-187. (In Russian).

Solow, A. R. 2002. Fisheries recruitment and the North Atlantic Oscillation. Fisheries Research 54:295-297.

Solow, A. R., and A. R. Beet. 2007. Is the effect of the NAO on north-east Arctic cod, *Gadus morhua*, recruitment stock-dependent? Fisheries Oceanography 16:479-481.

Southall, B. L., A. E. Bowles, W. T. Ellison, J. J. Finneran, R. L. Gentry, C. R. Greene, Jr., D. Kastak, D. R. Ketten, J. H. Miller, P. E. Nachtigall, W. J. Richardson, J. A. Thomas, and P. L. Tyack. 2007. Marine mammal noise exposure criteria: initial scientific recommendations. Aquatic Mammals 33:411-521.

Spies, I., O. A. Ormseth, and T. T. TenBrink. 2012. Bering Sea and Aleutian Island sculpins. Pages 1735-1770 *in* S. Zador, editor. Ecosystem Considerations 2012, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, Anchorage, AK.

Spraker, T. R., L. F. Lowry, and K. J. Frost. 1994. Gross necropsy and histopathological lesions found in harbor seals. Pages 281-311 *in* T. R. Loughlin, editor. Marine Mammals and the *Exxon Valdez*. Academic Press, Inc., San Diego, CA.

Springer, A. M. 1992. A review: Walleye pollock in the North Pacific--how much difference do they really make? Fisheries Oceanography 1:80-96.

Springer, A. M., J. A. Estes, G. B. van Vliet, T. M. Williams, D. F. Doak, E. M. Danner, K. A. Forney, and B. Pfister. 2003. Sequential megafaunal collapse in the North Pacific Ocean: An ongoing legacy of industrial whaling? Proceedings of the National Academy of Sciences of the United States of America 100:12223-12228.

Springer, A. M., J. A. Estes, G. B. van Vliet, T. M. Williams, D. F. Doak, E. M. Danner, and B. Pfister. 2008. Mammal-eating killer whales, industrial whaling, and the sequential megafaunal collapse in the North Pacific Ocean: A reply to critics of Springer et al. 2003. Marine Mammal Science 24:414-442.

St. Aubin, D. J. 1988. Physiological and toxicologic effects on pinnipeds. Pages 120-142 *in* J. R. Geraci and D. J. St. Aubin, editors. Synthesis of Effects of Oil on Marine Mammals. U.S. Department of the Interior, Minerals Management Service, Atlantic OCS Region, New Orleans, LA.

St. Aubin, D. J. 1990. Physiological and toxic effects on pinnipeds. Pages 103-127 *in* J. R. Geraci and D. J. St. Aubin, editors. Sea Mammals and Oil: Confronting the Risks. Academic Press, Inc., San Diego, CA.

Stabeno, P. J., N. A. Bond, and S. A. Salo. 2007. On the recent warming of the southeastern Bering Sea shelf. Deep-Sea Research II 54:2599-2618.

Stabeno, P. J., E. V. Farley, N. B. Kachel, S. Moore, C. W. Mordy, J. M. Napp, J. E. Overland, A. I. Pinchuk, and M. F. Sigler. 2012a. A comparison of the physics of the northern and southern shelves of the eastern Bering Sea and some implications for the ecosystem. Deep-Sea Research Part II: Topical Studies in Oceanography 65-70:14-30.

Stabeno, P. J., N. B. Kachel, S. E. Moore, J. M. Napp, M. Sigler, A. Yamaguchi, and A. N. Zerbini. 2012b. Comparison of warm and cold years on the southeastern Bering Sea shelf and some implications for the ecosystem. Deep Sea Research Part II: Topical Studies in Oceanography 65–70:31-45.

Steele, M., W. Ermold, and J. L. Zhang. 2008. Arctic Ocean surface warming trends over the past 100 years. Geophysical Research Letters 35:L02614.

Steinacher, M., F. Joos, T. L. Frolicher, G. K. Plattner, and S. C. Doney. 2009. Imminent ocean acidification in the Arctic projected with the NCAR global coupled carbon cycle-climate model. Biogeosciences 6:515-533.

Stevenson, D. E., and R. R. Lauth. 2012. Latitudinal trends and temporal shifts in the catch composition of bottom trawls conducted on the eastern Bering Sea shelf. Deep-Sea Research Part II 65-70:251-259.

Stewart, R. E. A., B. E. Stewart, D. M. Lavigne, and G. W. Miller. 1989. Fetal growth of northwest Atlantic harp seals, *Phoca groenlandica*. Canadian Journal of Zoology 67:2147-2157.

Stige, L. C., G. Ottersen, K. Brander, K. S. Chan, and N. C. Stenseth. 2006. Cod and climate: effect of the North Atlantic Oscillation on recruitment in the North Atlantic. Marine Ecology Progress Series 325:227-241.

Strassmann, K., G.-K. Plattner, and F. Joos. 2009. CO_2 and non-CO_2 radiative forcings in climate projections for twenty-first century mitigation scenarios. Climate Dynamics 33:737-749.

Sugimoto, T., and K. Tadakoro. 1997. Interannual-interdecadal variations in zooplankton biomass, chlorophyll concentration and physical environment in the subarctic Pacific and Bering Sea. Fisheries Oceanography 6:74-93.

Sundby, S., and O. Nakken. 2008. Spatial shifts in spawning habitats of Arcto-Norwegian cod related to multidecadal climate oscillations and climate change. ICES Journal of Marine Science 65:953-962.

Supreme Court of the United States. 2007. Massachusetts *et al*. v. Environmental Protection Agency *et al*. Cornell University Law School, Ithica, NY. Accessed May 2009 at http://www.law.cornell.edu/supct/html/05-1120.ZS.html.

Takahashi, C. 1999. Study on stomach nematodes (Anisakidae) among Steller sea lions, spotted seals and ribbon seals captured at northeast coast of Hokkaido, Japan. Japanese Journal of Veterinary Research 47:76-77.

Taylor, C. C., H. B. Bigelow, and H. W. Graham. 1957. Climate trends and the distribution of marine animals in New England. Fishery Bulletin 57:293-345.

Teramitsu, I., Y. Yamamoto, I. Chiba, H. Iwata, S. Tanabe, Y. Fujise, A. Kazusaka, F. Akahori, and S. Fujita. 2000. Identification of novel cytochrome P450 1A genes from five marine mammal species. Aquatic Toxicology 51:145-153.

Thompson, D., C. D. Duck, and B. J. McConnell. 1998. Biology of seals of the north-east Atlantic in relation to seismic surveys. Pages 4.1-4.7 *in* M. L. Tasker and C. Weir, editors. Proceedings of the Seismic and Marine Mammals Workshop, London, UK.

Thompson, G. G., and R. R. Lauth. 2012. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands area. Pages 245-544 *in* S. Zador, editor. Ecosystem Considerations 2012, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, Anchorage, AK.

Tikhomirov, E. A. 1961. Distribution and migration of seals in waters of the Far East. Pages 199-210 *in* Conference on Pelagic Mammals, 1959, Moscow, Russia. Ichthyological Commission of the Academy of Sciences of the USSR. (Translated from Russian by L.V. Sagen, U.S. Fish and Wildlife Service, Marine Mammal Biological Laboratory, Seattle, WA, 26 p.).

Tikhomirov, E. A. 1964. Distribution and biology of pinnipeds in the Bering Sea (from materials of the First Expedition in 1962). Pages 277-285 *in* P. A. Moiseev, editor. Soviet Fisheries Investigations in the Northeast Pacific, Part III. Pischevaya Promyshlennost (Food Industry), Moscow, Russia. (Translated from Russian by Israel Program for Science Translations, Jerusalem, Israel, 9 p.).

Tikhomirov, E. A. 1966. Reproduction of seals of the family Phocidae in the North Pacific. Zoologicheskii Zhurnal 45:275-281. (Translated from Russian by Translation Bureau, Department of the Secretary of State of Canada, 19 p.).

Tikhomirov, E. A. 1968. Body growth and development of reproductive organs of the North Pacific phocids. Pages 213-241 *in* V. A. Arsen'ev and K. I. Panin, editors. Pinnipeds of the North Pacific.

Pischevaya Promyshlennost (Food Industry), Moscow, Russia. (Translated from Russian by J. Salkind, Israel Program for Science Translations, Jerusalem, Israel, 29 p.).

Tokranov, A. M. 2007. Distribution and some biological features of the Pacific sand lance *Ammodytes hexapterus* (Ammodytidae) in waters off Kamchatka in the Sea of Okhotsk. Journal of Ichthyology 47:288-295.

Toresen, R., and O. J. Østvedt. 2000. Variation in abundance of Norwegian spring-spawn herring (*Clupea harengus*, Clupeidae) throughout the 20th century and the influence of climatic fluctuations. Fish and Fisheries 1:231-256.

Traill, L. W., C. J. A. Bradshaw, and B. W. Brook. 2007. Minimum viable population size: a meta-analysis of 30 years of published estimates. Biological Conservation 139:159-166.

Traill, L. W., B. W. Brook, R. R. Frankham, and C. J. A. Bradshaw. 2010. Pragmatic population viability targets in a rapidly changing world. Biological Conservation 143:28-34.

Trites, A. W., V. B. Deecke, E. J. Gregr, J. K. B. Ford, and P. F. Olesiuk. 2007. Killer whales, whaling, and sequential megafaunal collapse in the North Pacific: a comparative analysis of the dynamics of marine mammals in Alaska and British Columbia following commercial whaling. Marine Mammal Science 23:751-765.

Tynan, C. T., and D. P. DeMaster. 1997. Observations and predictions of Arctic climatic change: potential effects on marine mammals. Arctic 50:308-322.

U.S. Department of the Interior. 2010. Fact sheet: A comprehensive, science-based offshore energy plan. U.S. Department of Interior, Washington, D.C. 3 p. Accessed at http://www.doi.gov/deepwaterhorizon/loader.cfm?csModule=security/getfile&PageID=33566.

U.S. Fish and Wildlife Service. 2008. Determination of threatened status for the polar bear (*Ursus maritimus*) throughout its range; Final Rule. Federal Register 73:95 (May 15, 2008) p. 28212-28303.

U.S. Fish and Wildlife Service, and National Marine Fisheries Service. 1996. Policy regarding the recognition of distinct vertebrate population segments under the Endangered Species Act; Notice. Federal Register 61:26 (February 7, 1996) p. 4721-4725.

U.S. Geological Survey. 2008. Circum-Arctic resource appraisal: estimates of undiscovered oil and gas north of the Arctic Circle; Fact sheet 2008-3049. U.S. Geological Survey, Menlo Park, CA. Accessed at http://pubs.usgs.gov/fs/2008/3049/fs2008-3049.pdf.

United Nations Environment Programme. 2006. Sea of Okhotsk. Global International Waters Assessment Regional Assessment 30, 53 p. University of Kalmar, Kalmar, Sweden.

United Nations Environment Programme. 2012. The emissions gap report 2012. UNEP, A UNEP Synthesis Report. 50 p.

Van Vuuren, D. P., M. Meinshausen, G. K. Plattner, F. Joos, K. M. Strassmann, S. J. Smith, T. M. L. Wigley, S. C. B. Raper, K. Riahi, F. de la Chesnaye, M. G. J. den Elzen, J. Fujino, K. Jiang, N. Nakicenovic, S. Paltsev, and J. M. Reilly. 2008. Temperature increase of 21st century mitigation scenarios. Proceedings of the National Academy of Sciences 105:15258-15262.

Ver Hoef, J. M., M. F. Cameron, P. L. Boveng, J. M. London, and E. M. Moreland. 2013. A spatial hierarchical model for abundance of three ice-associated seal species in the Eastern Bering Sea. Statistical Methodology (Published online April 8, 2013).

Viberg, H., A. Fredriksson, and P. Eriksson. 2004. Investigations of strain and/or gender differences in developmental neurotoxic effects of polybrominated diphenyl ethers in mice. Toxicological Sciences 81:344-353.

Vinogradov, G. A., and V. T. Komov. 1985. Ion regulation in perch, *Perca fluviatilis*, in connection with the problem of acidification of water bodies. Journal of Ichthyology 25:63-61.

Wade, P. R., and R. P. Angliss. 1997. Guidelines for assessing marine mammal stocks: Report of the GAMMS Workshop April 3-5, 1996, Seattle, Washington. U.S. Department Commerce, NOAA Technical Memorandum NMFS-OPR-12. 93 p.

Wade, P. R., V. N. Burkanov, M. E. Dahlheim, N. A. Friday, L. W. Fritz, T. R. Loughlin, S. A. Mizroch, M. M. Muto, D. W. Rice, L. G. Barrett-Lennard, N. A. Black, A. M. Burdin, J. Calambokidis, S. Cerchio, J. K. B. Ford, J. K. Jacobsen, C. O. Matkin, D. R. Matkin, A. V. Mehta, R. J. Small, J. M. Straley, S. M. McCluskey, G. R. VanBlaricom, and P. J. Clapham. 2007. Killer whales and marine mammal trends in the North Pacific -- a re-examination of evidence for sequential megafauna collapse and the prey-switching hypothesis. Marine Mammal Science 23:766-802.

Walsh, J. E. 2008. Climate of the Arctic marine environment. Ecological Applications 18:S3-S22.

Walsh, J. E., W. L. Chapman, V. Romanovsky, J. H. Christensen, and M. Stendel. 2008. Global climate model performance over Alaska and Greenland. Journal of Climate 21:6156-6174.

Wang, M., N. A. Bond, and J. E. Overland. 2007. Comparison of atmospheric forcing in four sub-arctic seas. Deep-Sea Research II 54:2543-2559.

Wang, M. Y., and J. E. Overland. 2009. A sea ice free summer Arctic within 30 years? Geophysical Research Letters 36:1-5.

Ward, J. R., and K. D. Lafferty. 2004. The elusive baseline of marine disease: Are diseases in ocean ecosystems increasing? PLoS Biology 2:542-547.

Watkins, W. A., and G. C. Ray. 1977. Underwater sounds from ribbon seal, *Phoca* (*Histriophoca*) *fasciata*. Fishery Bulletin 75:450-453.

Weatherly, J. W., J. E. Walsh, and H. J. Zwally. 1991. Antarctic sea ice variations and seasonal air temperature relationships. Journal of Geophysical Research 96:15119-15130.

Werner, I., and R. Gradinger. 2002. Under-ice amphipods in the Greenland Sea and Fram Strait (Arctic): environmental controls and seasonal patterns below the pack ice. Marine Biology 140:317-326.

Węsławski, J. M., S. Kwaśniewski, L. Stempniewicz, and K. Błachowiak-Samołyk. 2006. Biodiversity and energy transfer to top trophic levels in two contrasting Arctic fjords. Polish Polar Research 27:259-278.

Whitehead, P. J. P. 1985. FAO species catalogue. Vol. 7. Clupeoid fishes of the world (suborder Clupeoidei). An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. Part 1--Chirocentridae, Clupeidae and Pristigasteridae. United Nations Development Programme, Food and Agriculture Organization of the United Nations, FAO Fisheries Synopsis No. 125. 303 p.

Wickins, J. F. 1984. The effect of hypercapnic sea water on growth and mineralization in penaeid prawns. Aquaculture 41:37-48.

Wilke, F. 1954. Seals of northern Hokkaido. Journal of Mammalogy 35:218-224.

Willette, T. M., R. T. Cooney, V. Partrick, D. M. Mason, G. L. Thomas, and D. Scheel. 2001. Ecological processes influencing mortality of juvenile pink salmon (*Oncorhynchus gorbuscha*) in Prince William Sound, Alaska. Fisheries Oceanography 10:14-41.

Wood, C. M., and D. G. McDonald. 1997. Global warming: implications for freshwater and marine fish. Cambridge University Press, Cambridge, UK. 441 p.

Woodley, T. H., and D. M. Lavigne. 1991. Incidental capture of pinnipeds in commercial fishing gear. International Marine Mammal Association Inc., Technical Report 91-01. 53 p.

Wyllie-Echeverria, T., and W. S. Wooster. 1998. Year to-year variations in Bering Sea ice cover and some consequences for fish distributions. Fisheries Oceanography 7:159-170.

Yamada, Y., and T. Ikeda. 1999. Acute toxicity of lowered pH to some oceanic zooplankton. Plankton Biology and Ecology 46:62-67.

Yamamoto-Kawai, M., F. A. McLaughlin, E. C. Carmack, S. Nishino, and K. Shimada. 2009. Aragonite undersaturation in the Arctic Ocean: effects of ocean acidification and sea ice melt. Science 326:1098-1100.

Yang, M.-S., and B. N. Page. 1999. Diet of Pacific sleeper shark, *Somniosus pacificus*, in the Gulf of Alaska. Fishery Bulletin 97:406-409.

Yurakhno, M. V. 1971. Helminths of commercial marine mammals of the Bering and Chukotsk seas. M.Sc. Dissertation. Crimean Pedagogical Institute, Simferopol, Crimea. 24 p. (Translated from Russian by M. Poppino, Davis, CA, 25 p.).

Zarnke, R. L., T. C. Harder, H. W. Vos, J. M. Ver Hoef, and A. D. M. E. Osterhaus. 1997. Serologic survey for phocid herpesvirus-1 and -2 in marine mammals from Alaska and Russia. Journal of Wildlife Diseases 33:459-465.

Zarnke, R. L., J. T. Saliki, A. P. Macmillan, S. D. Brew, C. E. Dawson, J. M. Ver Hoef, K. J. Frost, and R. J. Small. 2006. Serologic survey for *Brucella* spp., phocid herpesvirus-1, phocid herpesvirus-2, and phocine distemper virus in harbor seals from Alaska, 1976-1999. Journal of Wildlife Diseases 42:290-300.

Zeebe, R. E., J. C. Zachos, K. Caldeira, and T. Tyrrell. 2008. Oceans - Carbon emissions and acidification. Science 321:51-52.

Zerbini, A. N., J. M. Waite, J. W. Durban, R. LeDuc, M. E. Dahlheim, and P. R. Wade. 2007. Estimating abundance of killer whales in the nearshore waters of the Gulf of Alaska and Aleutian Islands using line-transect sampling. Marine Biology 150:1033-1045.

Ziel, H. L., M. F. Cameron, and P. L. Boveng. 2008. Spring diet of ribbon and spotted seals in the Bering Sea (Poster presentation). Alaska Marine Science Symposium, Anchorage, AK. Accessed at ftp://ftp.afsc.noaa.gov/posters/pZiel01_bs-seal-diet.pdf.

Zimmermann, E. A. W., von. 1783. Geographische Geschiete des Menschen, und der allgemein verbreiteten vierfussigen Thiere. Leipzig, Germany. 277 p. (In German).

7 APPENDIX 1: ESTIMATES OF CURRENT RIBBON SEAL ABUNDANCE

In the spring of 2007, researchers from NMML conducted aerial surveys for ribbon and other ice-associated seals in the U.S. sector of the Bering Sea (Cameron and Boveng 2007). Details of the field methods, statistical analysis, and results of were reported by Ver Hoef et al. (2013). The population estimate for ribbon seals in the Bering Sea, east of the international date line, was 61,100 individuals, with a 95% credible interval of 35,200-189,300.

The survey area likely covered most or all of the significant ribbon seal haul-out habitat in the eastern and central Bering Sea (i.e., the U.S. EEZ) during the latter half of April 2007, as all of the sightings occurred in a small zone about 150 km from the ice edge, which is consistent with previous observations during this time of year (Burns 1970, Fay 1974, Burns 1981, Braham et al. 1984, Lowry 1985, Kelly 1988). Because there have been no recent, published surveys of the western Bering Sea or the Sea of Okhotsk, it was possible only to resort to historical surveys for assumptions about how to scale this new regional estimate to the total range for the species as an approximate current total abundance.

Fedoseev et al. (1988) used observations from survey flights in 1987 to outline aggregations of ribbon seals throughout the Bering Sea in April (23,199 nmi^2) and May (24,659 nmi^2), of which 11,738 nmi^2 and 6,415 nmi^2, respectively, were in the U.S. EEZ region corresponding to the NMML survey in 2007 (Figure A1). Assuming that the relative proportions of the total Bering Sea population in these two regions had not changed appreciably since 1987, and that the densities within seal aggregations are similar in the two regions, estimates were derived for the numbers of ribbon seals in the two areas during April and May, 2007 (Table A1). Estimates were derived for both months because the two Russian surveys provided independent representations of ribbon seal distribution during the two months that spanned the seasonal coverage of the NMML survey (12 April-4 May).

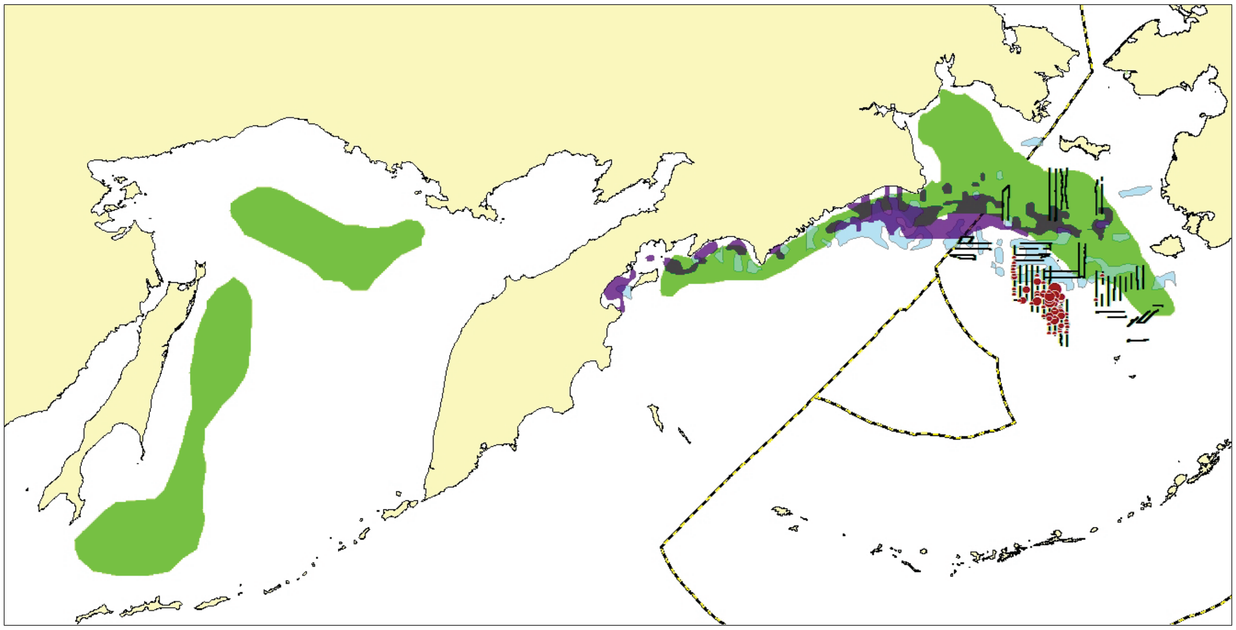


Figure A1. -- Map of the Bering Sea and Sea of Okhotsk. The black lines show the locations of aerial surveys conducted during the high ice concentration period (April 12 to May 4, 2007). The red circles indicate locations where ribbon seals were observed (larger circles indicate more ribbon seals). The green polygons represent the generalized springtime pupping area of ribbon seals as described by Fedoseev (1973), totaling 160,540 nmi^2. The blue and purple polygons represent the April and May distributions of ribbon seals on ice in the Bering Sea in as calculated by Fedoseev et al. (1988), totaling 23,199 and 24,659 nmi^2, respectively.

Unfortunately, no corresponding survey of the Sea of Okhotsk was available to enable scaling of the NMML survey estimate to a range-wide total breeding area derived from a single year's survey. Fedoseev (1973) provided a hand-drawn, generalized map of ribbon seal whelping regions in the Bering Sea and Sea of Okhotsk based on his summary of various surveys and expeditions from the 1960s. By geo-rectifying the maps in a geographic information system, the cumulative area of ribbon seal whelping regions in this figure was found to be 160,540 nmi^2, of which 74,490 nmi^2 were in the Sea of Okhotsk and 36,800 nmi^2 were in the eastern and central Bering Sea. It was again assumed that the proportions of the total ribbon seal population distributed among these three regions have not changed appreciably since the earlier surveys, and that the breeding densities are essentially the same in all three regions. This provided an estimate for the Sea of Okhotsk and a third estimate for the western Bering Sea which, when added to the 2007 survey estimate, totaled 267,000 ribbon seals (rounded to the nearest 1,000) (Table A1).

Table A1. -- Estimates of ribbon seal abundance in different regions of the total breeding range. Estimates were derived by proportionally scaling a 2007 population estimate for the eastern and central Bering Sea, based on geographic distributions of breeding areas in Fedoseev (1973) and Fedoseev et al. (1988). The proportions of ribbon seal breeding areas in each region are given in parentheses below the abundance estimate.

Breeding distributions from	Eastern and Central Bering	Western Bering Sea	Bering Sea total	Sea of Okhotsk	Range-wide total (Bering+Okhotsk)
Fedoseev et al. (1988) – April 1987	61,100 (0.506)	59,651 (0.494)	120,751	n/a	n/a
Fedoseev et al. (1988) – May 1987	61,100 (0.260)	173,900 (0.740)	235,000	n/a	n/a
Fedoseev (1973) – April and May 1960s	61,100 (0.229)	81,911 (0.307)	143,011	123,800 (0.464)	266,811

Of the values presented in Table A1, the estimate for the eastern and central Bering Sea is by far the most secure, and is the first ribbon seal estimate derived from a survey based on reasonable coverage, modern line transect methods, and empirical measures of haul-out proportions.

The variability in the three estimates for the total number of ribbon seals in the Bering Sea, ranging from 120,751 to 235,000, in part reflects variability in sea ice and seal distribution among years and even between months within years. Given the many uncertainties and questionable assumptions underlying these numbers, they certainly should not be compared to previous estimates as an indicator of trends.

The primary value of producing a range-wide estimate from the generalized, outdated distribution map in Fedoseev et al. (1988) is for identifying potential gross failures of assumptions or gross changes in distribution or density. Within our range-wide estimate of 267,000, the Sea of Okhotsk component of about 124,000 is lower than all but one of the previous estimates for that region (Table 2), and dramatically lower than the most recent estimates from Russian surveys during 1979-1990, which ranged from 410,000 to 630,000 (Fedoseev 2000). This difference is more likely to reflect errors in the estimates than a population decline. Our estimate for the Sea of Okhotsk was derived from a recent density estimate in the Bering Sea, scaled by a very generalized distribution from the 1960s of seals in the Sea of Okhotsk. Our density estimate may simply not be applicable to the distribution, and vice versa. The relatively high Russian abundance estimates lack details about how they were obtained, and the Soviet-era system of monitoring commercially harvested species often included strong positive biases. Lacking any data from the Sea of Okhotsk more recent than 1990, the BRT opted to use the smaller number.

8 APPENDIX 2: GLOSSARY OF ABBREVIATIONS

Abbreviation	Description
AFSC	Alaska Fisheries Science Center
AOGCM	Atmosphere-Ocean General Circulation Model
AR4	IPCC *Fourth Assessment Report*
AR5	IPCC *Fifth Assessment Report*
BOEM	Bureau of Ocean Energy Management
BOEMRE	Bureau of Ocean Energy Management, Regulation and Enforcement
BRT	biological review team
BSEE	Bureau of Safety and Environmental Enforcement
CAA	Clean Air Act
$CaCO_3$	calcium carbonate
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
CMIP5	Coupled Model Intercomparison Project-Phase 5
COP	UNFCC's Conferences of the Parties meetings
CO_2	carbon dioxide
CZMA	Coastal Zone Management Act
DDT	dichloro-diphenyl-trichloroethane
D-O	Dansgaard-Oeschger
DPP	BOEM's Draft Proposed Program
DPS	distinct population segment
EEZ	Exclusive Economic Zone
EPA	Environmental Protection Agency
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
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service
MPRSA	Marine Protection, Research, and Sanctuaries Act
MVP	minimum viable population
mya	million years ago
NAO	North Atlantic Oscillation
NEPA	National Environmental Policy Act
NHTSA	National Highway Traffic Safety Administration
NMFS	National Marine Fisheries Service
NMML	AFSC's National Marine Mammal Laboratory
NOAA	National Oceanic and Atmospheric Administration
NSR	Northern Sea Route

Abbreviation	Description
NWP	Northwest Passage
OCS	outer continental shelf
OCSLA	Outer Continental Shelf Lands Act
OPA	Oil Pollution Act
PBDE	polybrominated diphenyl ether
PCMDI	Program for Climate Model Diagnosis and Intercomparison
PCB	polychlorinated biphenyl
PDO	Pacific Decadal Oscillation
PDV	phocine distemper virus
PFC	perfluorinated contaminant
PhHV	phocid herpesvirus
PSD	CAA's New Source Review Prevention of Significant Deterioration program
SAT	surface air temperature
SDR	satellite-linked data recorder
SPLASH	Wildlife Computers SDR used for seal movements, diving, and haul-out timing
SPOT5	Wildlife Computers SDR used for seal movements and haul-out timing
TAC	total allowable catch
TAR	IPCC *Third Assessment Report*
TCV	Tillamook calicivirus
tpy	tons per year
UME	unusual mortality event
UNFCCC	United Nations Framework Convention on Climate Change
USCG	U.S. Coast Guard
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WCRP	World Climate Research Programme
WGCM	WCRP Working Group on Coupled Modeling

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253 ECHAVE, K., C. RODGVELLER, and S.K. SHOTWELL. 2013. Calculation of the geographic area sizes used To create population indices for the Alaska Fisheries Science Center longline survey, 93 p. NTIS number pending.

252 HOBBS, R. C. 2013. Detecting changes in population trends for Cook Inlet beluga whales (*Delphinapterus leucas)* using alternative schedules for aerial surveys, 93 p. NTIS number pending.

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249 ZIMMERMANN, M., and J. L. BENSON. 2013. Smooth sheets: How to work with them in a GIS to derive bathymetry, features and substrates, 52 p. NTIS number pending.

248 SINCLAIR, E. H., D. S. JOHNSON, T. K. ZEPPELIN, and T. S. GELATT. 2013. Decadal variation in the diet of Western Stock Steller sea lions (*Eumetopias jubatus*). U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-248, 67 p. NTIS number pending.

247 CLAUSEN, D. M., and C. J. RODGVELLER. 2013.Deep-water longline experimental survey for giant grenadier, Pacific grenadier, and sablefish in the Western Gulf of Alaska, 30 p. NTIS number pending.

246 YANG, M-S., and C. YEUNG. 2013. Habitat-associated diet of some flatfish in the southeastern Bering Sea,151 p. NTIS No. PB2013-107698.

245 ALLEN, B. M., and R. P. ANGLISS. 2013. Alaska marine mammal stock assessments, 2012, 282 p. NTIS number pending.

244 GUTHRIE, C. M. III, H. T. NGUYEN, and J. R. GUYON. 2013. Genetic stock composition analysis of Chinook salmon bycatch samples from the 2011 Bering Sea and Gulf of Alaska trawl fisheries, 28 p. NTIS number pending.

243 KONDZELA, C. M., C. T. MARVIN, S. C. VULSTEK, H. T. NGUYEN, and J. R. GUYON. Genetic stock composition analysis of chum salmon bycatch samples from the 2011 Bering Sea walleye pollock trawl fishery, 39 p. NTIS number pending.

242 FOY, R. J., and C. E. ARMISTEAD. 2013. The 2012 Eastern Bering Sea continental shelf bottom trawl survey: Results for commercial crab species, 147 p. NTIS No. PB2013-104705.

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240 HARRIS, P. M., A. D. NEFF, and S. W. JOHNSON. 2012. Changes in eelgrass habitat and faunal assemblages associated with coastal development in Juneau, Alaska, 47 p. NTIS No. PB2013-104703.

239 JOHNSON S. W., A. D. NEFF, J. F. THEDINGA, M. R. LINDEBERG, and J. M. MASELKO. 2012. Atlas of nearshore fishes of Alaska: A synthesis of marine surveys from 1998 to 2011, 261 p. NTIS number pending.