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

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

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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 was compiled by a National Oceanic and Atmospheric Administration (NOAA) Biological Review Team (BRT) in response to a petition filed by the Center for Biological Diversity to list the ribbon seal as threatened or endangered under the U.S. Endangered Species Act (16 U.S.C. 1531 et seq.) (ESA), primarily due to concern about threats to this species' habitat from climate warming and loss of sea ice.

There are two key tasks associated with conducting an ESA status review: The first is to delineate the taxonomic group under consideration; the second is to conduct an extinction risk assessment 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 2050 because past and current emissions of greenhouse gases have already largely set the course for changes in the atmosphere and climate until that time, and because of enormous uncertainty about future social and political decisions on emissions that will dominate projection of conditions further into the future.

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. A molecular genetic analysis to identify geographic population structure is a high priority for research.

Extinction Risk Assessment: To assess the extinction risk, the BRT evaluated 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,
- over-utilization 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

Demographic factors: With a population likely comprising at least 200,000 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 a recent estimate of 49,000 ribbon seals in the eastern and central Bering Sea is consistent enough with historical estimates 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. A comprehensive survey of ribbon seal abundance, a new analysis of demographic data obtained from the former Soviet commercial harvest, and genetic studies of population structure are high priorities for research and monitoring.

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 to early May 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 could 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.

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 calcifying organisms. The nature and timing of such impacts are extremely uncertain. Because of ribbon seals' apparent dietary flexibility and because the major effects of ocean acidification may not appear until the latter half of this century, this threat should be of less immediate concern than the direct effects of sea ice degradation.

Changes in ribbon seal prey, anticipated in response to ocean warming and loss of sea ice, have the potential for negative impacts, but the possibilities are complex. Some changes already documented in the Bering Sea and the North Atlantic Ocean are of a nature that could be ameliorative or beneficial to 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.

The threats associated with impacts of global warming on ribbon seal habitat, to the extent that they may pose risks to ribbon seals, were presumed to manifest throughout the current breeding and molting range (for sea-ice related threats) or throughout the entire range (for ocean warming and acidification) of the species, inasmuch as the finer-scale spatial distribution of these threats is not currently well understood. The question, therefore, of whether any of these poses a risk to the continued existence of ribbon seals in merely a significant portion of, rather than the entire, range was subsumed by this approach to the qualitative risk assessment.

Over-utilization 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. 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 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 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, 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 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, 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 ship trends within the ribbon seal's range are currently unavailable.

Several of the threats considered in this section on "Other natural or human factors affecting the species' continued existence" were associated with specific regions or times of year when ribbon seal distribution is restricted, such as increased ship traffic in the Bering Strait region or oil and gas activities during the ribbon seal breeding and molting seasons. If such threats were to occur and cause a high rate of mortality or forgone reproduction, the species could be considered threatened or endangered in a significant portion of its range. However, none of the threats considered here is presently considered to be both sufficiently likely to occur and sufficiently high in impact, alone or cumulatively, to raise concern about them posing a risk of ribbon seal extinction or becoming endangered throughout a significant portion of its range.

Status of the ribbon seal population: Qualitative assessments of the balance between identified threats and a species' capability to adjust must often be decided on the basis of expert opinion and on policy, especially policy regarding consideration given to uncertainty. Such policy is outside the scope of this status review. To assist in the process, however, the BRT addressed its summary conclusions on ribbon seal status using a scoring system in which each of the eight members assigned up to 10 likelihood points in support of the conclusion.

In consideration of all of the threats and potential threats identified above, the assessment of the risks posed by those threats, the possible cumulative impacts, and the uncertainty associated with all of these, the BRT drew the following conclusions:

1. Ribbon seals are not in current danger of extinction throughout all or a significant portion of their range. (78 out of 80 likelihood points)
2. The ribbon seal population is likely to decline gradually for the foreseeable future, primarily from slight but chronic impacts on reproduction and survival caused by reduced frequency of years with sea ice of suitable extent, quality, and duration of persistence. (51 out of 80 likelihood points)
3. Despite the expectation of a gradual decline, ribbon seals are not likely to become an endangered species within the foreseeable future throughout all or a significant portion of their range. (57 out of 80 likelihood points)

Finally, to reinforce the notion that reliable and effective assessments of species' conservation status cannot be conducted without adequate estimates of abundance, the BRT concluded that despite the expectation of a declining ribbon seal population, it will likely not be possible to detect and document a significant overall decline unless monitoring is made a very high priority for both the Bering Sea and Sea of Okhotsk.

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 (16 U.S.C. 1531 et seq.) (ESA) (Center for Biological Diversity 2007).

Section 4(b)(3)(A) of the ESA requires the Secretary to determine, to the maximum extent practicable, within 90 days of receiving a petition to list a species under the ESA, whether the petition presents substantial scientific or commercial information indicating that the petitioned action may be warranted. This finding is to be promptly published in the *Federal Register*. On 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 2008). To assist in determining whether listing the ribbon seal under the ESA *is* warranted, NMFS convened an expert panel (the 2008 Ribbon Seal Biological Review Team, or BRT) to conduct an ESA status review for this species. The BRT was composed of four marine mammal biologists, three fishery biologists, and one 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 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 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". To make this determination, the BRT established the time frame over which future events can be reasonably said to be "foreseeable", and evaluated 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,
- over-utilization for commercial, recreational, scientific, or educational purposes,

- disease or predation,
- the inadequacy of existing regulatory mechanisms, or
- other natural or manmade factors affecting its continued existence

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

This document is a compilation of the best available scientific and commercial data and a description of past, present, and likely future threats to the 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 Russians 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), thus *Histriophoca fasciata* is the currently accepted 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 12 million years ago (mya) as indicated by the common trait of a white lanugo coat (Árnason et al. 2006). A split within the tribe Phocini occurred about 9-13 mya, leading to the sub-tribe Histriophocina, and another divergence at about 4-8 mya led to the present-day genera of *Pagophilus* (harp seal) and *Histriophoca* (Árnason et al. 2006, Higdon et al. 2007). Thus, the ribbon seal probably arose in the Arctic Basin and moved into the North Pacific after the Bering Strait opened, approximately 5.4 mya (Árnason et al. 2006).

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 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 discernable 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). 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

Figure 1. -- Adult male ribbon seal.

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 currently considered 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 22 adult ribbon seals examined in the Bering Sea in 2007, 8 exceeded 100 kg in mass[1]. 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.

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[1] Unpubl. data, John Bengtson, National Marine Mammal Laboratory (NMML), 7600 Sand Point Way NE, Seattle, WA 98115.

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). Ribbon seals 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*). When captured live with a net on the ice, ribbon seals tend not to struggle as much as other pinnipeds (Lowry and Boveng *In press*), 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).

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.

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). Indeed, ribbon seals are rarely found near land except in the western Bering Sea where the shelf slope is much closer to the coast.

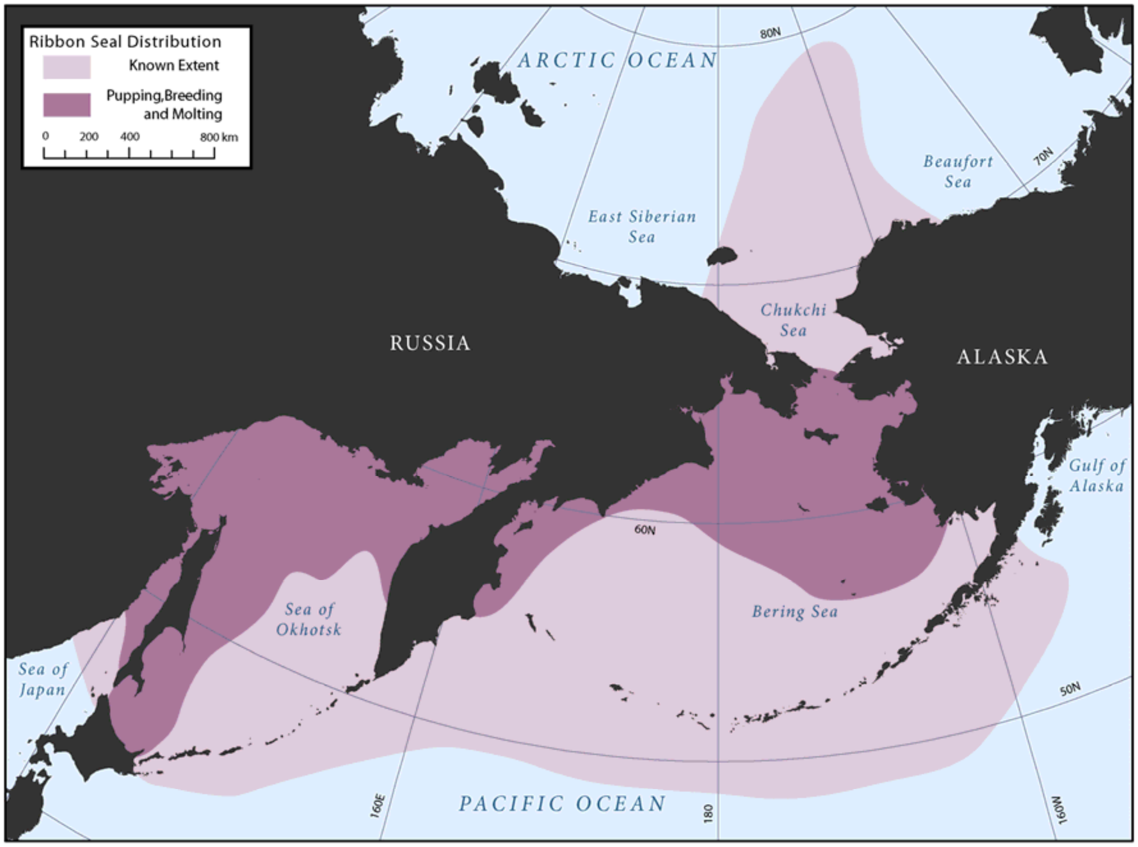

Figure 3. -- The geographic distribution of ribbon seals, based on documented observations and satellite telemetry.

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 in summer.

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 the Bering Sea have recently been corroborated by tracking with satellite-linked tags (Footnote 1). 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 4); however, 8 of the 26 ribbon seals that were tagged in the central Bering Sea in 2007 moved to the Bering Strait, Chukchi Sea, or Arctic Basin as the seasonal ice retreated northward, and spent at least a portion of the summer and autumn period in those areas (Figure 5). Three of these seals moved back south of the Bering Strait before ice formed again in the Chukchi Sea. The majority of the seals tagged in the central Bering Sea did not pass north of the Bering Strait (Figure 5). 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 shelf, diving to the seafloor when in shallow water and occasionally diving to depths of over 500 m while over the basin (Footnote 1). 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.

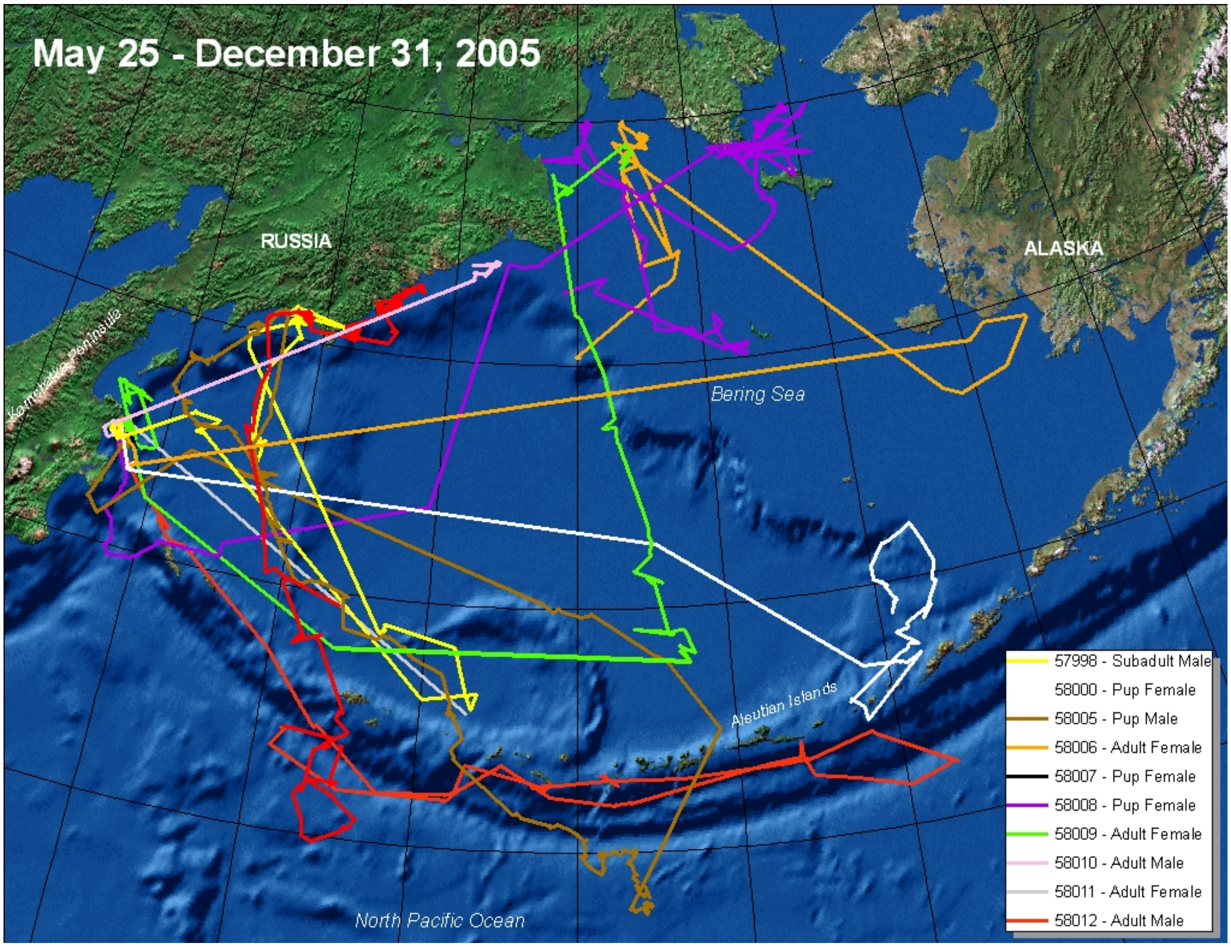

Figure 4. -- Movements of 10 satellite-tracked ribbon seals instrumented off the eastern coast of the Kamchatka Peninsula, Russia, in May 2005. The region was ice-free for much of the summer and fall, and all of the seals became pelagic, dispersing widely yet remaining in the Bering Sea and North Pacific Ocean during this time.

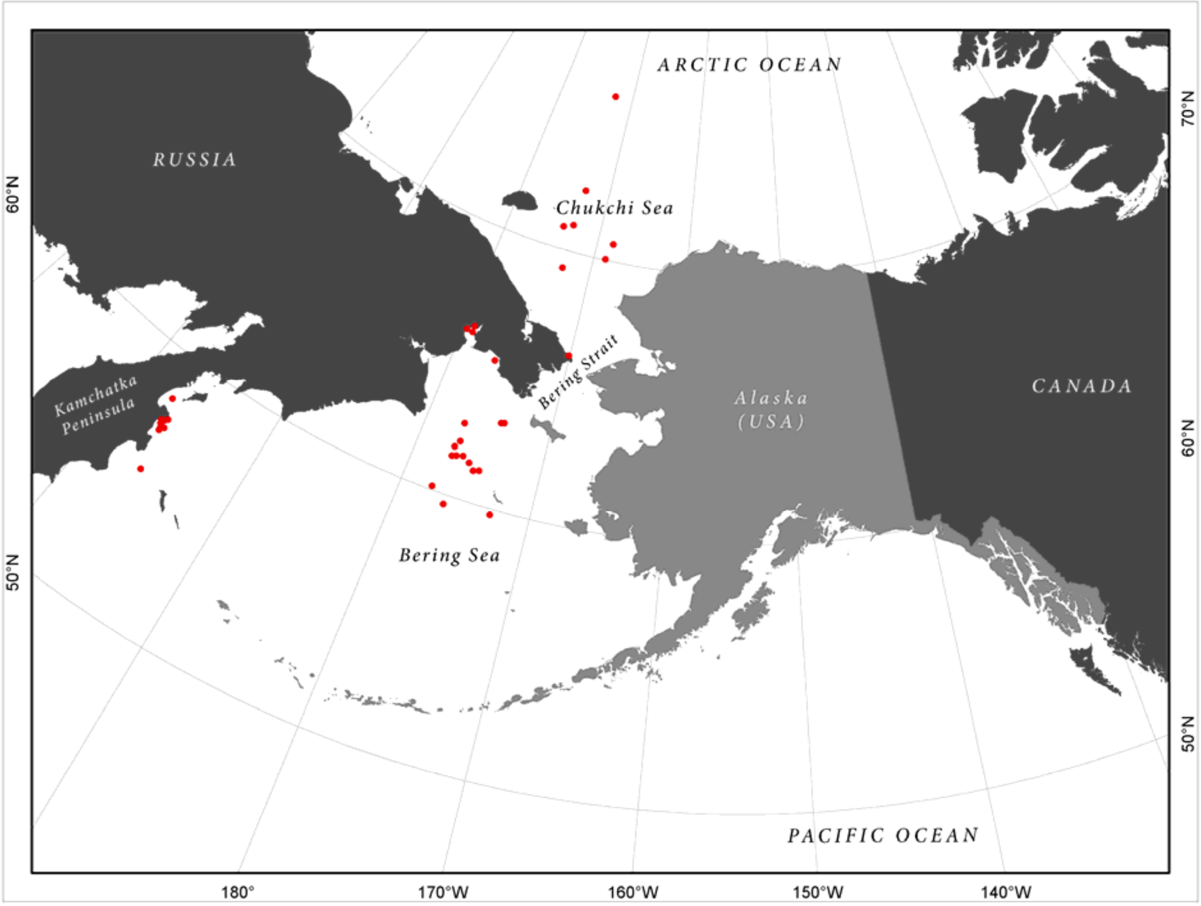

Figure 5. -- Positions at the highest recorded latitudes (red points) for each of 36 satellite-tracked ribbon seals between 1 June and 1 September from 2005 to 2008. These positions provide an indication of the proportion of the tracked sample that spent the ice-free pelagic season either north or south of the Bering Strait (no tracked seals moved north of the Bering Strait after 1 September). None of 10 seals tagged in the western Bering Sea near the Kamchatka Penninsula moved north of the Bering Strait. Of 26 seals tagged in the central Bering Sea, 8 seals moved into the Bering Strait or Chukchi Sea, but 3 of those returned south into the Bering Sea well ahead of the next southward advance of winter ice.

2.6 Life History

Female ribbon seals over the age of four or five 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 lactaction, 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 Othotsk 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 three to five 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 6 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.

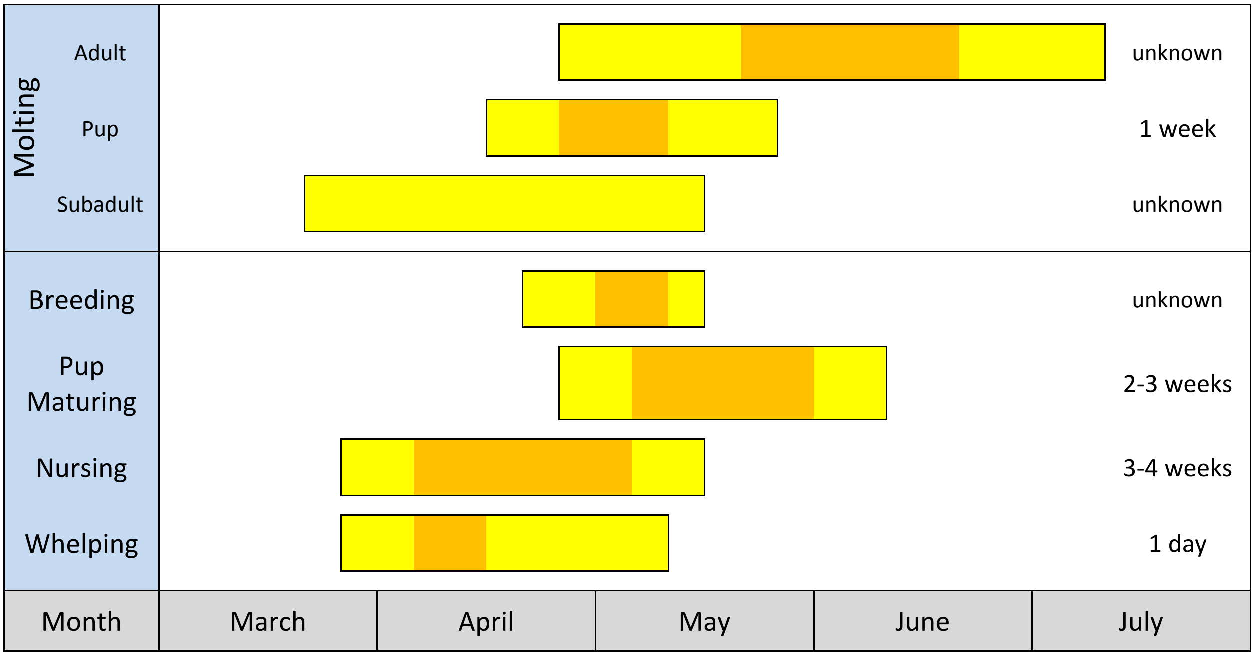

Figure 6. -- Approximate annual timing of the ribbon seal's ice-associated life history events. Yellow bars indicate the approximate range over which each event is reported to occur and orange bars indicate the reported peak timing of each event. "Pup Maturing" refers to the period when weaned pups may 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, Tikhomirov 1968, 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 46 ribbon seals tagged with satellite-linked data recorders (SDRs) are shown in Figure 7. 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[2] 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 right-hand edge of Figure 7 where the records of seals carrying SPOT5 tags continued through a second molt season; this corresponds well to the reported peak of the adult molt (Figure 6). One subadult male had a similar haul-out pattern, but the other subadults seemed to complete their intensive haul-out bouts by early June (evident in the upper left of Figure 7; relatively few records from subadults continued into the second molt season). This is consistent with the reported patterns, at least with regard to subadults molting earlier than adults. Finally, for nearly all 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

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[2] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

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.

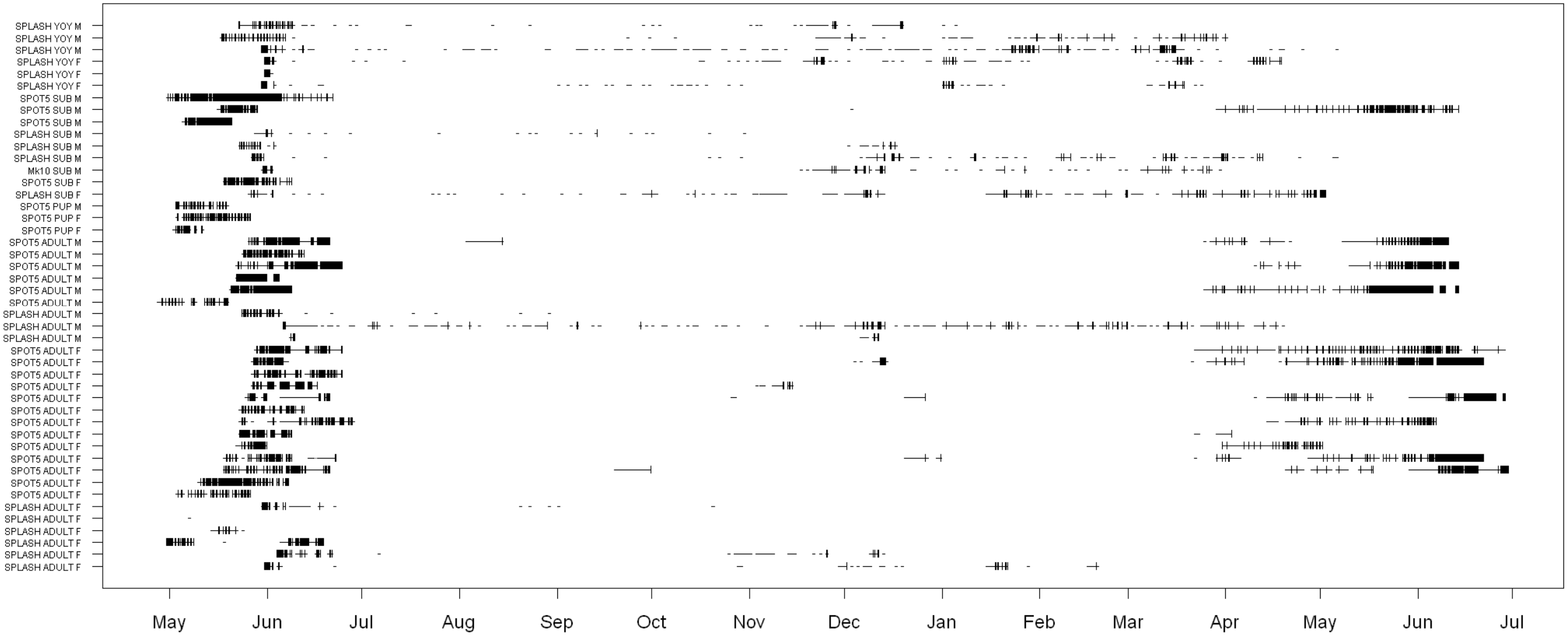

Figure 7. -- Haul-out records from 46 ribbon seals tagged with Argos satellite-linked data recorders in the spring sea ice during 2005-2008. Vertical hash marks denote haul-out (dry) time, thin horizontal lines denote time in the water, and the remainder of each timeline denotes no data. The year of tagging has been ignored to place all the records on the same time scale. Tag type (flipper-mounted SPOT5 tag vs. head- or back-mounted SPLASH and MK10 types), age class (adult, subadult, pup, or independent young of the year), and 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 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. 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.

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 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 seals.

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

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[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 ribbon seal 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) believe 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. Current research is just beginning to address these limitations and no current and reliable abundance estimates have been published.

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 1969, cited in Fedoseev 2000) to about 60,000-70,000 in 1969 (Fedoseev 2002). Following the inititation 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 have been unremarkable, composing less than one percent of seals harvested hunt 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 of the eastern Bering Sea by the National Marine Mammal Laboratory (NMML) in 2003 (Simpkins et al. 2003), 2007 (Cameron and Boveng 2007, Moreland et al. 2008), and 2008 (Footnote 1). The data from these surveys are currently being analyzed to construct estimates of abundance for the eastern Bering Sea from frequencies of sightings, ice distribution, and the timings of seal haul-out behavior. In the interim, NMML researchers have developed a provisional population estimate of 49,000 ribbon seals in the eastern and central Bering Sea (i.e., the U.S. Exclusive Economic Zone (EEZ); Appendix 1). 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 98,000 to 190,000 (Appendix 1). Similar scaling based on a range-wide distribution presented by Fedoseev (1973) produced Bering Sea, Sea of Okhotsk, and total-range estimates of 115,000, 100,000, and 215,000, respectively (Appendix 1).

Within our range-wide estimate of 215,000, the Sea of Okhotsk component of about 100,000 is lower than all 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 likely reflects a failure of assumptions rather 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. Lacking details about the Russian survey methods that produced the larger numbers, and lacking any data more recent than 1990, the BRT opted to use the smaller number but also to note that the literature suggests this may be an underestimate.

The broad range of population estimates presented above represents the current uncertainty in the total abundance of ribbon seals. This uncertainty may be reduced for the eastern Bering Sea when NMML surveys can be analyzed more completely, but adequate precision for the overall population may not be attainable without new surveys in the Russian waters of the western Bering Sea and the Sea of Okhotsk.

The current population trend of ribbon seals is unknown, due to the imprecision of available abundance estimates. 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 six 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).

3 SPECIES DELINEATION

3.1 Evaluation of Discreteness

Although Tikhomirov (1961) reported that no ribbon seals are seen in the Sea of Okhotsk after mid-July, and speculated that 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.

3.2 Determination of Species/Distinct Population Segments

Because no discrete subdivisions of the ribbon seal population have been identified, the BRT did not divide the global range of ribbon seals into distinct population segments. The entire global population was considered to comprise the species for the purpose of assessing extinction risk. However, in assessing extinction risk, the BRT considered whether any of the threats set forth below posed a risk to the species throughout all or a significant portion of its range, as a species must be declared to be endangered or threatened even if it is at risk in only a portion of its range, when that portion is 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 to determine whether the ribbon seal should be considered 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 this determination requires establishing the time frame over which future events impacting ribbon seal status can be said to be "foreseeable". 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 species may be at risk from loss of sea-ice habitat in a warming climate (Tynan and DeMaster 1997, Learmonth et al. 2006, Simmonds and Isaac 2007, Kovacs and Lydersen 2008, Laidre et al. 2008, Moore and Huntington 2008). Therefore, the BRT considered the time frame over which the effects of global climate change can be anticipated, as the primary factor in determining the horizon for reliable assessment of the risk of ribbon seals becoming endangered.

The analysis and synthesis of information presented by the Intergovernmental Panel on Climate Change in its *Fourth Assessment Report* (IPCC AR4) represents the best available scientific information on the future of climate change and the anticipated effects on sea ice. The IPCC AR4 used a range of future greenhouse gas (GHG) emissions scenarios (IPCC 2000) to project plausible outcomes under clearly-stated assumptions about socio-economic factors that will influence GHG emissions; the factors include economic and population growth rates, technological development, and the mix of energy sources used to meet global needs. The differences in emissions under these scenarios reflect an important source of uncertainty that must be recognized in association with any particular projection or prediction of future conditions.

Conditions such as surface air temperature and sea ice area are linked in the IPCC climate models to GHG emissions by the physics of radiation processes. When anthropogenic carbon dioxide (CO_2) is added to the atmosphere, it has a long residence time and is only slowly removed by ocean absorption and other processes. Based on IPCC AR4 climate models, expected global warming (defined as the change in global mean surface air temperature (SAT)) at year 2100 depends strongly on the assumed emissions scenario. By contrast, warming out to about 2040-2050 will be primarily due to emissions that have already occurred and those that will occur over the next decade. Thus, it is much less sensitive to assumed future emission scenarios (Figure SPM.5 in IPCC 2007a). 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, which can be addressed through the range in projections from different models. Based on these two types of uncertainty, we selected a time horizon from the present to the year 2050 because it is very difficult to project further ahead due to great uncertainty about and sensitivity to social and economic decisions that will determine future emission scenarios.

The IPCC AR4 summarized the supporting rationale for this selection (Meehl et al. 2007b):

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

We also note that the authors of a recent series of authoritative studies of the impacts of climate change on Arctic marine mammals, published as 12 articles composing an entire special issue of the journal *Ecological Applications*, chose the same year (2050) as the time horizon for their assessments (Walsh 2008).

Our approach to establishing the appropriate time frame for the foreseeable future was the same as the primary approach used by the USFWS in its declaration of the polar bear as threatened under the ESA (U.S. Fish and Wildlife Service 2008). The USFWS noted that the mid-century threshold for reliable assessment of threats will occur in about three polar bear generation lengths, or a total of 45 years from now, a measure that had been used previously by scientific expert groups as an appropriate time frame over which to evaluate polar bear population trends for determining the conservation status of the species. Coincidentally, the generation length of the ribbon seal (defined as the average age of the parents of an annual cohort or as the average age at which females give birth) is likely to be similar to that of the polar bear, approximately 12-15 years. However, we found no compelling reason to use a specific number of generation lengths to support or adjust the time frame for the foreseeable future with respect to ribbon seal population status. For species with overlapping generations, like the ribbon seal, facing threats that are primarily extrinsic, such as habitat destruction, commercial harvest, or incidental mortality in fisheries, the generation length may be essentially irrelevant; a sufficiently potent threat could undermine a population over the course of many generations or, conceivably, in less than one. Moreover, the time required to detect a specific change or trend in a population depends mostly on the precision of population estimates, not the generation time of the species. Therefore, and in summary, we determined that the best available scientific information allows reliable assessment of global warming and the related threats to ribbon seals through the first half of the 21st century. Beyond the year 2050, projections of climate scenarios are too heavily dependent on socio-economic assumptions and are therefore too divergent for reliable use in assessing those threats.

4.2 Analysis of Demographic Risks

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

4.2.1 Abundance

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

With a population of around 200,000 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 magnitudes of anthropogenic perturbations that are expected in the foreseeable future are addressed under Section 4.3. Thus, leaving aside low frequency (i.e., long-term trend) variation such as climate change, the answer to this question is no.

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

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

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

Genetic diversity in ice-associated seal species tends to be high (Davis et al. 2008, O'Corry-Crowe 2008) and initial results suggest the same is true for 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.

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

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

Demographic stochasticity refers to changes in vital rates that arise due to chance in the "sampling" that occurs when nature acts on individuals with variable traits. For example, a badly skewed sex ratio, and consequent poor reproduction, could result if most of the remaining females in a small population succumb by chance, even though the overall rate of mortality, averaged over both sexes, is normal. The key factor in risk of demographic stochasticity is small populations. For a large, long-lived mammal such as the ribbon seal, demographic stochasticity would be unlikely to be a concern for populations with greater than several tens 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.

4.2.2 Productivity

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

The current net productivity (population trend) of ribbon seals is unknown, due to the imprecision of available abundance estimates. Hypothetically, if the current population size is 200,000 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.

4.2.2.2 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 4.2.1.2 .

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

The 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.

4.2.2.4 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.

4.2.3 Spatial Structure

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

This question is explored in detail under Section 4.3.1.

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

Although dispersal rates are currently unknown, there is no reason to believe that they are low 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 4). 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.

4.2.3.3 Is the species at imminent 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; this risk is considered explicitly in Section 4.3.1.

4.2.3.4 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; high priority should be given to analysis and publication of these results for improving ribbon seal assessments.

4.2.4 Diversity

4.2.4.1 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.

4.2.4.2 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.

4.2.4.3 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 4.3.1.

4.2.4.4 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.

4.2.5 Relevant Modifying or Mitigating Factors

4.2.5.1 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.

4.2.5.2 Population characteristics

The highly dispersed nature of ribbon seals during the ice-free, pelagic season 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.

4.2.5.3 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.

4.2.5.4 Specific threats

Specific threats are considered below under Section 4.3.

4.2.6 Discussion of Demographic Risks and Needed Research

With a population likely comprising at least 200,000 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 a recent estimate of 49,000 ribbon seals in the eastern and central Bering Sea is consistent enough with historical estimates to suggest that no major or catastrophic change has occurred in recent decades. The species is thought to occupy its entire historically-observed range. A comprehensive survey of ribbon seal abundance, a new analysis of demographic data obtained from the former Soviet commercial harvest, and genetic studies of population structure are high priorities for research and monitoring.

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

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

4.3.1.1 Global climate change

4.3.1.1.1 Overview

Research, monitoring, and modeling of global climate change have progressed rapidly during the past several decades, yielding a vast body of information on causes of climate change, effects, and ways to mitigate the problems. In 1988, the World Meteorological Organization and the United Nations Environmental Programme established the Intergovernmental Panel on Climate Change (IPCC) to provide an objective source of information about this complex issue (IPCC 2008). The IPCC has produced four Assessment Reports that represent syntheses of the best available and most comprehensive scientific information on climate change to date. The following two excerpts from the IPCC's "Climate Change 2007: Synthesis Report, Summary for Policymakers" (IPCC 2007b), highlight some of the observed and projected changes in climate and their anticipated effects/impacts:

"Observed changes in climate and their effects:

- *Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.*
- *Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases.*
- *There is medium confidence that other effects of regional climate change on natural and human environments are emerging, although many are difficult to discern due to adaptation and non-climatic drivers*".

"Projected climate change and its impacts:

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

Both the observed and the projected effects of a warming global climate are most extreme in high latitude regions, particularly the Arctic (ACIA 2005), 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 2007a), notwithstanding the very recent findings, which seem to be published on an almost weekly basis (e.g., Stroeve et al. 2008).

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

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

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

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

4.3.1.1.2.1 Climatological conditions

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

4.3.1.1.2.2 Analogs

4.3.1.1.2.2.1 Case study of 2008

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

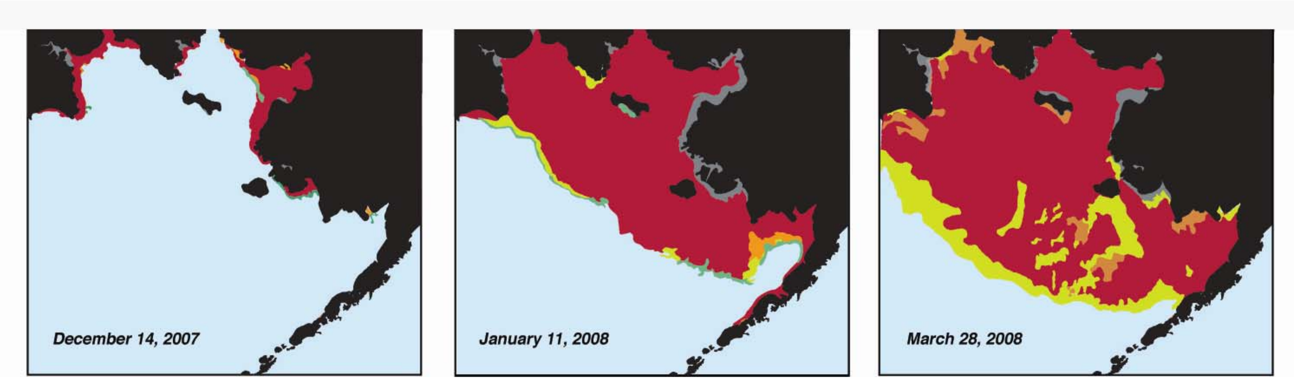

Figure 8. -- Sea ice extent in the Bering Sea on December 14, 2007; January 11, 2008; and March 28, 2008.

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

4.3.1.1.2.2.2 Sea ice in the northern Bering Sea in other years

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

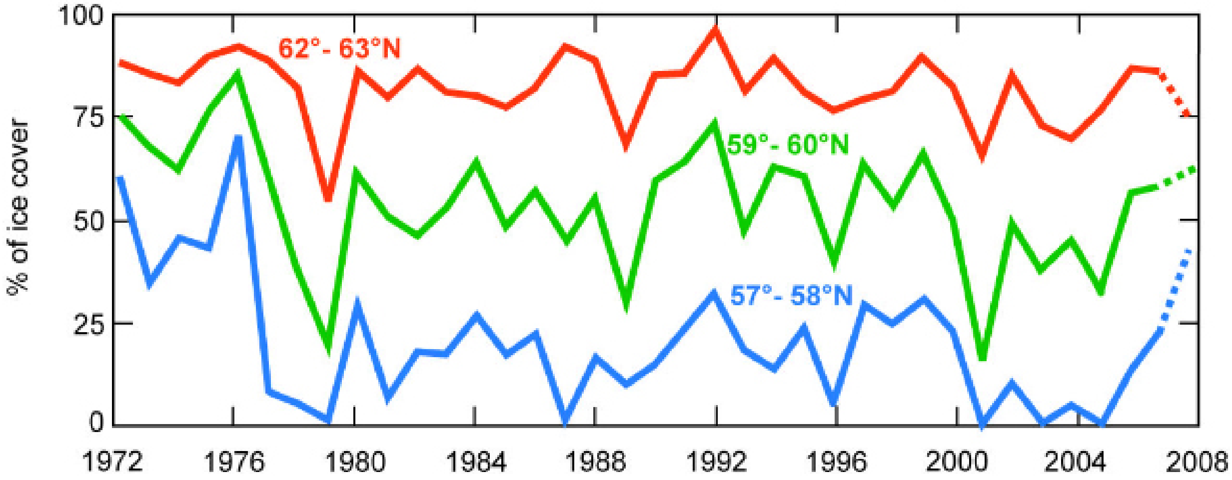

Figure 9. -- Percentage of ice coverage, averaged within each year from December through May, in the southern, central, and northern regions of the Bering Sea.

Figure 10 expands the detail from Figure 9 by showing latitude/time-of-year plots of sea ice coverage for the previous 10 years. While there is considerable year-to-year variability, even the recent very warm years had sea ice coverage in the northern Bering Sea into May or June. Thus, analogs point to considerable sea ice coverage for the future in the northern Bering Sea, despite major losses in summer Arctic Ocean sea ice and likely future reduction of average sea ice coverage in the southern Bering Sea.

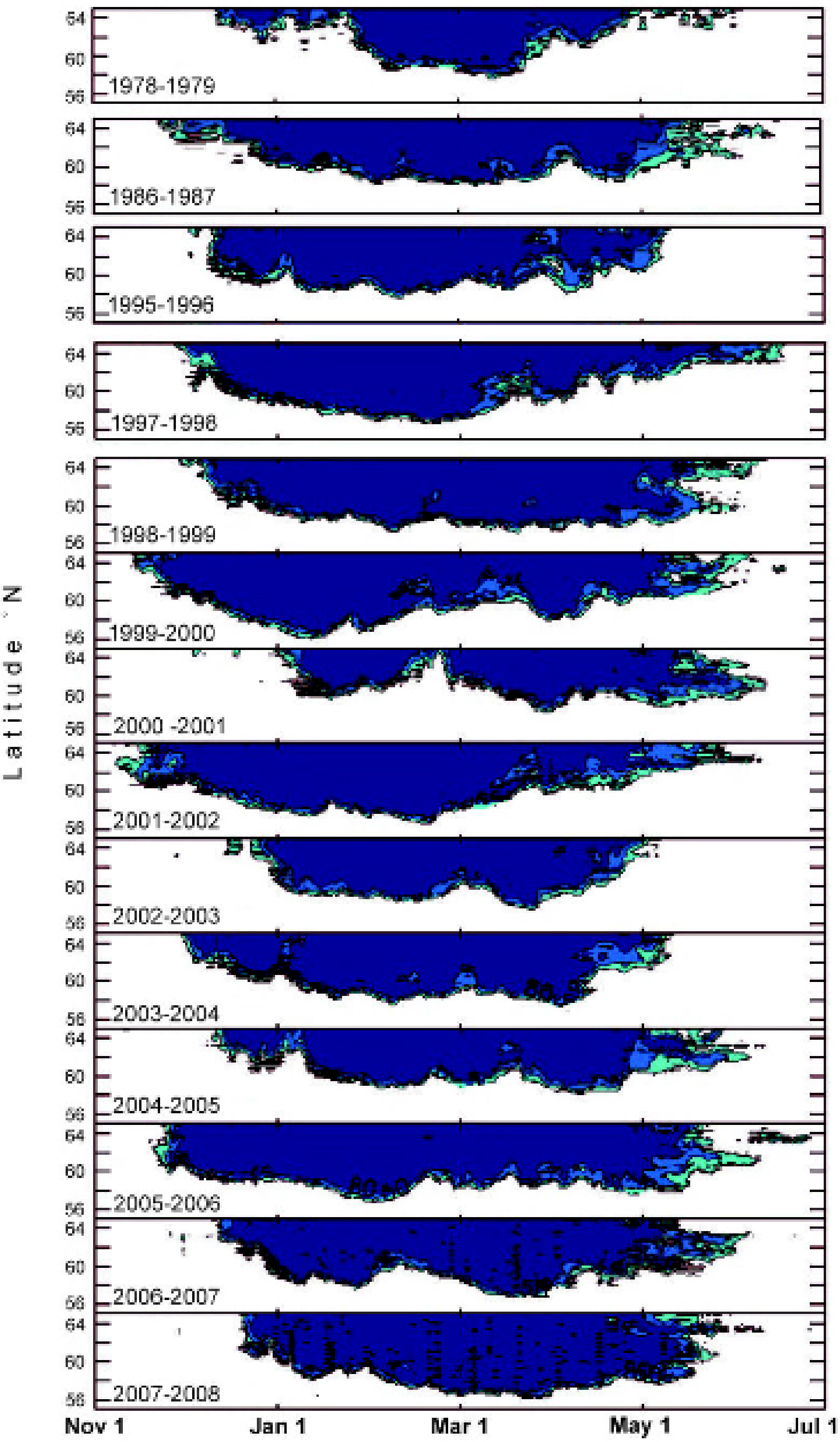

Figure 10. -- Latitude (Y-axis) and time of year (X-axis) plots of sea ice coverage in the Bering Sea during 1978-2008.

4.3.1.1.2.3 IPCC model projections

The IPCC climate models suggest a 50% sea ice loss in the central Arctic by 2050, but recent loss of multi-year sea ice due to unusually warm and meridional winds (blowing toward the central Arctic) now suggest that the central Arctic is on a faster track for September sea ice loss (Overland et al. 2008, Stroeve et al. 2008). However, as shown above, the Bering Sea ice regime has in the past been different in fundamental respects from that of the central Arctic, and these differences are important to an assessment of the potential for impacts to ribbon seals from future changes in climate and sea ice.

We have used the same procedure as in Overland and Wang (2007) for summer and winter sea ice extents to assess the confidence for using IPCC climate models (Meehl et al. 2007a) to project April and May first-year sea ice extents for the eastern Bering Sea. The primary method is an observational constraint to remove outlier models from the analysis that do poorly in simulating sea ice during the 1989 through 1999 historical period. The rate of future sea ice loss in these models has been shown to be very sensitive to the amount of sea ice that the model starts with at the end of the 20th century (Chapman and Walsh 2007). These outlier models often have less rigorous sea ice physics than those which are better at hind-casting ice in the historical period (C. Bitz, Department of Atmospheric Sciences, University of Washington, October 9, 2007, pers. comm.). Figure 11 shows the observed area of sea ice cover for April, May, and June (red lines) in the northern Bering Sea, based on values interpolated to a model grid. May in particular is characterized by high year-to-year variability with considerable sea ice present in the mid-1970s. The blue line is the composite average of four IPCC models that simulate well the annual cycle of sea ice coverage during the last 20 years. Forming composite averages reduces the influence of year to year variability. The yellow curve is the composite average of all 23 IPCC models and does not depart significantly from the “better” model composite. The grey lines in the background represent single runs (i.e., 12 individual ensemble members) from the four “better” models, which suggest the range of natural variability in northern Bering Sea ice cover.

While there is some decrease in sea ice area in April out to 2050, the historical data and range of ensemble members for future conditions suggest that it is nearly impossible to create a sea ice-free Bering Sea in April. The observations for May (red line) show a considerable number of years in recent decades that approached a minimum sea ice area. These minimums can be expected to continue, but the main message from Figure 11 is that large interannual variability will continue to dominate the northern Bering Sea for the next forty years, as shown by the range of individual ensemble members. Model results suggest that April will always have an ice cover for the next 40 years, while May will have some years with considerable sea ice cover and some years with reduced ice cover, not unlike the climatological record.

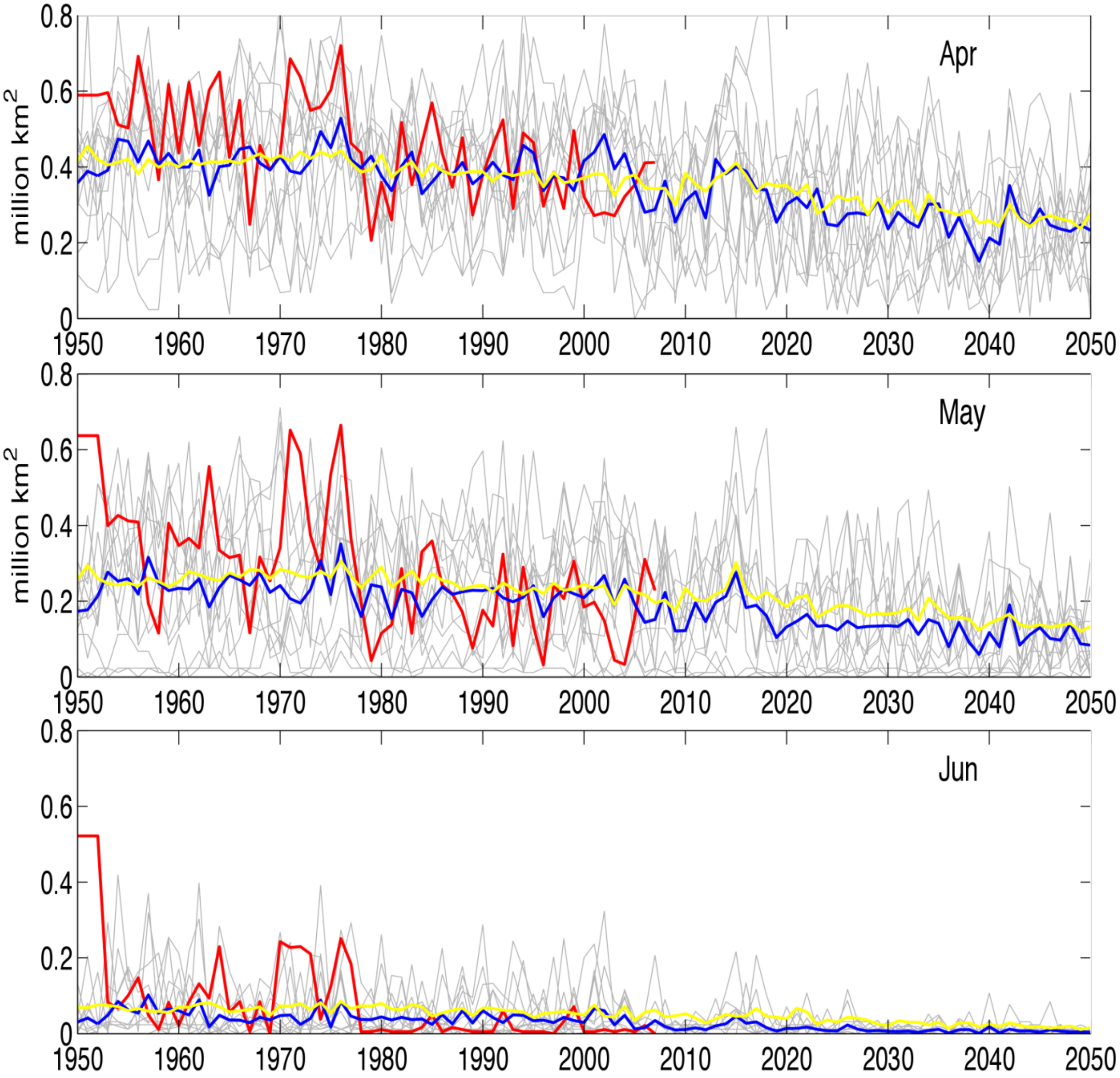

Figure 11. -- Simulation of 20th century Bering Sea ice cover extent and projections into the 21st century for the months of April-June based on IPCC/CMIP3 (Coupled Model Intercomparison Project Phase 3) global climate models. The red line is observations. The blue line is the average of four "better" models and the yellow line is the average of 23 IPCC models. The four "better" models were used to produce 12 independent runs (grey lines) with different initial conditions. The range of these individual runs provides an indication of the possible year-to-year natural variability of future sea ice extent.

Bering Sea ice in the month of June has been characterized by extreme year-to-year variability (Figure 11), perhaps because the rate of melting at that time of year is so high that even slight differences in May conditions can lead to substantially different conditions on any particular date in June. Since the mid-1970s, there have only been 1-2 years per decade with greater than 0.05 million km^2 of ice cover, and the simulations out to 2050 suggest that these events will be even rarer in the forseeable future (Figure 11).

The Sea of Okhotsk lies to the southwest of the Bering Sea and thus can be expected to have earlier radiative heating in spring. However, the region is dominated in winter and spring by cold continental air masses and offshore flow (Wang et al. 2007). During winter and spring, typical air temperatures in the northern Sea of Okhotsk are colder than in the northern Bering Sea (Wang et al. 2007). Sea ice is formed rapidly and is generally advected southward (Sasaki et al. 2007). As this region is dominated by cold air masses for much of the winter and spring, we would expect the present seasonal cycle of first year sea ice to continue to dominate the future habitat of the Sea of Okhotsk, similar to the Bering Sea.

4.3.1.1.2.4 Summary of climate change effects on annual formation and persistence of sea ice

Consideration of climatological conditions, recent analog years, and projections of the best IPCC model ensembles for this region indicate that sea ice cover will remain a major ecological factor for the northern Bering Sea and Sea of Okhotsk during late winter through spring, as will the large range of natural variability that ribbon seals have always experienced. This interannual variability, superimposed on the anticipated long-term trend, may result in more frequent years of low or minimal ice extent, particularly in May-June. Our analysis of future annual ice formation in the Bering Sea (e.g., Figure 11) indicated that there may be more frequent years of low ice coverage, and in those years the duration of sea ice persistence in spring will likely be reduced.

4.3.1.1.3 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 may be changes in the quality of ice or the timing of its availability that impact the amount of suitable habitat in the geographic areas that ribbon seals have preferred in the past.

Regional sea ice thickness is difficult to quantify with current sensing methods, though there is some evidence for thinning ice in the Northern Hemisphere. Sea ice in the Arctic Ocean declined during the 1990s (Rothrock et al. 1999), from both thinning of undeformed ice and loss of thick ridged ice (Rothrock and Zhang 2005). Some short-term models suggest further Arctic sea ice thinning to a minimum in the summers of 2006-2007 (Posey et al. 2008). 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. The annual formation of winter ice in the Bering Sea and Sea of Okhotsk will likely continue to produce ice of about the same mix of thicknesses and types that have been typical in the recorded past. Still, under the predicted long-term warming trend there may be some trend toward thinner ice floes, possibly correlated with years of low ice extent.

4.3.1.1.4 Effects of climate change on ocean conditions

4.3.1.1.4.1 Ocean warming

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

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. 2006), predators, and pathogenic vectors. These effects are considered in Sections 4.3.1.1.4.3 and 4.3.3.

4.3.1.1.4.2 Ocean acidification

Approximately 30-50% of global anthropogenic CO_2 emissions are absorbed by the world's oceans (Feely et al. 2004, Sabine et al. 2004). Increased CO_2 uptake by the oceans is expected to reduce ocean surface pH by 0.3-0.5 units over the next century, which would be the largest change in pH to occur in the last 20-200 million years (Feely et al. 2004). Ocean acidification reduces the calcium carbonate ($CaCO_3$) saturation point, which stresses calcifying organisms by making calcification more difficult. Dramatic reductions in calcium carbonate saturation have been observed in the North Pacific Ocean since the industrial revolution and saturation depths are decreasing (Feely et al. 2004). Reductions in the North Pacific are greater than in 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).

Dissolving CO_2 increases the hydrogen ion (H^+) concentration in the ocean, and thus reduces ocean pH. The use of the term "ocean acidification" to describe this process was introduced by Caldeira and Wickett (2003). As the pH of the ocean decreases (i.e., becomes less basic), the equilibrium between calcium carbonate ($CaCO_3$) and the dissolution products (Ca^{2+} and CO_3^{2-}) favors dissolution.

Waters below the calcium carbonate saturation horizon are corrosive for calcifying organisms. The calcium carbonate saturation horizon is relatively shallow in the North Pacific Ocean. For example, aragonite (one of two naturally occuring polyforms of calcium carbonate) has a saturation horizon of about 200 m in the North Pacific Ocean compared to about 2000 m in the North Atlantic Ocean (Feely et al. 2004). In the North Pacific Ocean, the shoaling (rising toward the surface) of the aragonite saturation horizon from pre-industrial times to present is between 30 and 100 m (Feely et al. 2004). By comparison, the aragonite saturation horizon has changed little in the North Atlantic Ocean (Feely et al. 2004). The saturation horizon is projected to reach the surface of the North Pacific Ocean during the 21st century (Orr et al. 2005). At that point, a wide range of North Pacific species will be exposed to corrosive waters.

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

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

In summary, ocean acidification is altering the seawater chemistry of the world's oceans. Elevated partial pressure of CO_2 is causing the calcium carbonate saturation horizon to shoal particularly in high latitudes. Ocean acidification reduces the $CaCO_3$ saturation point, which stresses calcifying organisms by making calcification more difficult. The North Pacific Ocean is a sentinel region for ocean acidification. Corrosive waters reach shallower depths there, and especially in Alaska, than in other ocean basins, so biological impacts likely will occur there earlier than in many other places, except for the Southern Ocean (Orr et al. 2005).

The greatest uncertainty in projections of ocean acidification stems from uncertainty in the global GHG emissions scenario, as it does for climatic and sea-ice projections. Following the same logic as in Section 4.1, the foreseeable future for ocean acidification is determined by the duration of influence of recent and current emissions, out to about 2050. Although the North Pacific Ocean is predicted to be one of the first areas where aragonite undersaturation will reach the surface, this is not likely to occur before 2050 (Orr et al. 2005). Nevertheless, there is considerable scope for ecosystem impacts prior to undersaturation actually reaching the surface.

4.3.1.1.4.3 Ribbon seal prey communities

4.3.1.1.4.3.1 Current status of ribbon seal prey

While the list of known prey species of ribbon seals may become more extensive as additional diet studies expand the geographic, seasonal, and ontogenetic extent of coverage, the main prey species will remain those that can be encountered frequently, are densely aggregated, possess sufficient energy content, and are appropriately sized (Węsławski et al. 2006). Several groups of 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 as forage species for management purposes that are represented in the ribbon seal diet, 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.

4.3.1.1.4.3.1.1 Abundance and distribution

The species of small pelagic crustaceans preyed upon by newly weaned and first-year ribbon seals (Table 1 – *Thysanoessa raschii*, *Stylomysis grandis*, and *Themisto* sp.) 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, but it appears to have become less abundant over the southeastern Bering Sea shelf in recent years (Hunt et al. 2008). Similarly, the range of *Themisto libellula*, a large, cold-water Hyperiid amphipod, has contracted northward based on the diets of fur seals and sea birds nesting in the Pribilof Islands and on zooplankton sampling over the southeastern Bering Sea shelf (Hunt et al. 2008). *Themisto pacifica* and *T. japonica* occur in sub-Arctic waters of the ribbon seal distribution (Bowman 1960). Overall, total zooplankton biomass has been low in all areas of the eastern Bering Sea from 1999-2005 (Napp and Shiga 2005, Hunt et al. 2008). In the Sea of Okhotsk, zooplankton abundance decreased from the mid-1980s to a low in 1997-1998, but returned to higher levels in 1999-2002 (PICES 2005).

A variety of benthic prey occurs in the 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 1 and 2-year-old ribbon seals that have limited diving capability and that spend more time foraging at night than during the day (Figure A2 in Appendix 1). In the Gulf of Alaska, a shift from cold- to warm-regime community structure resulted in a reduced abundance of pandalid shrimp (Anderson and Piatt 1999). The relative abundance of pricklebacks (stichaeids) has been generally lower in 1999-2007 than in previous years of the bottom trawl survey (Lauth 2007). Major demersal fish species in the Sea of Okhotsk have decreased in abundance in recent years. Total demersal fish biomass declined by about half between 1997 and 2000 and benthic invertebrates (including shrimps) decreased to about one-third (PICES 2005).

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, except Arctic cod[3] (Whitehead 1985, Cohen et al. 1990, Mecklenberg et al. 2002, Tokranov 2007, Froese and Pauly 2008). 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 13.6 million metric tons and is currently relatively low due to the absence of a strong recruiting year class in recent years. The abundance of smaller 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 Pacific sand lance was lower during 1999-2007 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, showing potential for increasing walleye pollock resources in the second half of the current decade (Dulepova and Radchencko 2004). The total biomass of the epipelagic fish community in the Sea of Okhotsk declined by approximately one-half 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, underwater ridges and canyons in the Bering Sea

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[3] Unpubl. data, E. Logerwell, Resource Ecology and Fisheries Management Division, AFSC, 7600 Sand Point Way NE, Seattle, WA 98115.

(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 unknown for these mesopelagic species, but between 1997 and 2000, squids slightly increased in number in the Sea of Okhotsk (PICES 2005).

4.3.1.1.4.3.2 Projected change in ribbon seal prey

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

4.3.1.1.4.3.2.1 Abundance and distribution

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

Climate change can strongly influence fish distribution and abundance (Wood and McDonald 1997) through changes in growth, survival, reproduction, and spawning distribution (Sundby and Nakken 2008). The responses can be mediated by changes at other trophic levels (Beaugrand et al. 2002, Beaugrand et al. 2003) as in some warm-water calanoid copepod species that expanded northward more than 1000 km. For example, nearly two-thirds of exploited and non-exploited fish species in the North Sea were shown to demonstrate a northward shift (average shift was 172.3 km/°C or 12 km per decade; Perry et al. 2005) in response to recent (post-1980s) rapidly warming water temperatures. The rapid warming led to the northward migration of southern species and the ecosystem changed from one dominated by cold water species to the one dominated by warm water species. It is unclear whether the northward shift in distribution of pelagic fishes is related to the observed shift in zooplankton communities, is a direct response to increasing temperatures, or reflects some other indirect mechanism. In the northwest Atlantic Ocean, centroids of mean catches also shifted north by 0.5-0.8 degrees of latitude for each 1°C increase in average water temperature (Murawski 1993). A global meta-analysis of range shifts in terrestrial species showed an average displacement of 6.1 km per decade, suggesting that latitudinal shifts in marine ecosystems may occur at a faster rate than in terrestrial ecosystems (Parmesan and Yohe 2003). In the eastern Bering Sea, Mueter and Litzow (2008) showed that reductions in sea ice have been responsible for shrinking the cold pool, a large pool of water less than 2°C. The southern edge of the cold pool, which defines the ecotone between Arctic and sub-Arctic communities, has retreated ~230 km northward since the early 1980s (Mueter and Litzow 2008). The northward expansion resulted in an increase in total biomass, species richness, and average trophic level in the area formerly occupied by the cold pool as sub-Arctic fauna colonized newly favorable habitats. Since many fishes avoid the low temperatures of the cold pool, winter surface conditions, especially the extent of sea ice, are the dominant factor controlling summer conditions for demersal taxa (Wyllie-Echeverria and Wooster 1998, Hunt and Stabeno 2002). Mueter and Litzow (2008) concluded that the retreat of sea ice has been responsible for the northern migration of the Arctic/sub-Arctic ecotone on the continental shelf. One has to wonder if extremely fast warming in some ecosystems 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 are 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. *In press*).

Impact on age-structure will be a direct result of factors influencing recruitment. If good recruitment is favored then the population of any forage fish stock will be composed of younger, smaller individuals. Poor recruitment will favor a population of older, larger individuals.

4.3.1.1.4.3.2.2 Vital rates

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

As waters warm, respiratory demands on fish bioenergetics will increase nonlinearly and assimilation efficiencies will decrease. Bioenergetic implications suggest that, even if food remains constant, growth will slow. If 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.

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 (Drinkwater 2005) have been reported as well as unspecified influences on New England groundfish stocks (Brodziak and O'Brien 2005). Sometimes the effects are localized 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). Undoubtably, a warming atmosphere will change how the PDO and NAO express themselves and their consequent temperature impacts.

4.3.1.1.4.3.2.3 Trophic dynamics

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

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

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

4.3.1.1.4.4 Summary of effects of climate change on ocean conditions

Climate-related changes in ocean temperatures and pH have already been clearly documented, and compelling predictions have been made for continued trends. These changes will certainly be accompanied by shifts in biological community composition and species’ abundance and distribution. Because of the number and complexity of physical and multi-species biological interactions that would be involved, there is no scientific consensus or prevailing theory about what scenarios are most likely.

4.3.1.2 Impacts of global climate change on ribbon seals

4.3.1.2.1 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 in most years through May; the occurrence of extensive ice in June will be highly variable, as it has in the past. Nevertheless, in association with a long-term warming trend there will likely be changes 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 for the foreseeable future. Similarly, Serreze et al. (2007, Fig. 3) showed that a high proportion of IPCC model simulations (with realistic 20th century performance) predicted substantial March sea ice coverage in the Bering Sea and Sea of Okhotsk during the decade from 2075-2084; concentrations of at least 15% occurred in nearly all simulation runs in the areas that have been observed to be the core 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 Soviet seal hunting fleets in the Sea of Okhotsk and Bering Sea for several decades. Whelping, nursing of pups, and maturation of weaned pups could conceivably 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 more frequently, as anticipated from projections of climate and sea ice, reproduction and survival of young could 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 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 slight increase in frequency of years with low ice extent in April and May (Figure 11) is likely to have some impact on reproductive rates.

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. For the foreseeable future, ice of this type is likely to occur annually in the Bering Sea and Sea of Okhotsk, but it may more frequently be confined to smaller areas or areas farther north than in the past. 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 (Footnote 1). 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.

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. 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 (Figure 9).

Adult ribbon seals, which are the last to molt, might be expected to be the most sensitive to 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 2.6) 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 11, 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, 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). The ultimate effect 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 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 slight increase in frequency of years with low ice extent in May and June (Figure 11) is likely to have some 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 11. 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). They may therefore be capable of considerable shifts in distribution to ensure contact with suitable ice through the molt period, especially in the Bering Sea where there is access through Bering Strait to the Chukchi Sea, in which ice persists 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^{o} 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 11 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^{o}N near St. Matthew Island (K. Hough, NOAA Office of Marine and Aviation Operations, June 28, 2008, pers. comm.), an area where no ice was visible on even the relatively high resolution (12.5 km) satellite images of sea ice for that day (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 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. Considering both the potential impacts and the factors potentially conferring resilience, the BRT, relying on expert opinion, collectively concluded that the net impacts will be slight but chronic and likely to cause a gradual decline in the ribbon seal population, of insufficient magnitude to place it in danger of extinction within the foreseeable future.

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

4.3.1.2.2 Ocean-condition-related impacts

Ocean acidification may impact ribbon seal survival and recruitment through disruption of trophic regimes wherever they are dependent on calcifying organisms. The nature and timing of such impacts are extremely uncertain. Because of ribbon seals' apparent dietary flexibility and because the major effects of ocean acidification may not appear until the latter half of this century, this threat should be of less immediate concern than the direct effects of potential sea ice degradation.

Changes in ribbon seal prey, anticipated in response to ocean warming and loss of sea ice, have the potential for 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. Again, however, the flexibility in ribbon seal foraging make these threats of lower concern.

4.3.2 Over-utilization for Commercial, Recreational, Scientific, or Educational Purposes

4.3.2.1 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 eight 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).

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

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).

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 represent 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 would be ribbon seals) and stated that the new industry would become profitable in 3-5 years, which suggests 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 (16 U.S.C. 1361 et seq.) (MMPA) and is not considered a threat to the species in this part of its range.

4.3.2.2 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 in 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; therefore, the subsistence harvest of ribbon seals is not considered a threat to the species.

4.3.2.3 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 and the number of allowed takes is usually low. Furthermore, the number of researchers granted permits to study ribbon seals in the United States is also very limited; therefore, the scientific and educational utilization of ribbon seals in U.S. waters is not considered a threat to the species.

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, so is also not considered a threat (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, August 22, 2008, pers. comm.).

4.3.3 Diseases, Parasites, and Predation

4.3.3.1 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 collected between 1978-1979 from ribbon seals in the Bering Sea for the presence of herpesvirus antibodies. Seven of the 24 ribbon seal samples (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 (Zarnke et al. 1997). Sera from 15 ribbon seals (63%) were found to be seronegative to both PhHV-1 and PhHV-2. 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).

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.

Quakenbush and Citta (2008) found *Brucella abortus* antibodies in 2 of 14 ribbon seals collected near Little Diomede Island, Alaska; both were young females. *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).

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.

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.

4.3.3.1.1 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 northern marine mammal health 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 (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).

4.3.3.2 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 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) cited a dissertation by Yurakhno (1971, original not seen) reporting 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 in 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, *Trichinella* in marine mammals does have a circumpolar Arctic distribution (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.

4.3.3.3 Predation

4.3.3.3.1 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 (1969) 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. Shustov (1969) and Fay et al. (1978) both reported seeing ribbon seals with wounds that looked like they were from shark attacks (Shustov 1969b). Harbor seals and other marine mammals have been found in the stomachs of Pacific sleeper sharks (Yang and Page 1999), however, whether these prey were carrion or live prey is undetermined. 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.

Of the potential predators, polar bears and killer whales 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 either of 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, has suggested the 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, a group of transient killer whales was observed, and later confirmed with photo identification, in close proximity to hauled-out ribbon seals during a research cruise in the central Bering Sea in April 2008 (Footnote 1). 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*)[4]. The extent of predation on ribbon seals is currently unknown.

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

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. 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.

4.3.3.3.2 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 and 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 does exists for some increased predation of ribbon seals by walrus as the sea icescape 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 is 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/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. 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).

4.3.3.4 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 the population impact is unknown. There may be an increased risk of outbreaks of novel pathogens or parasites as climate-related shifts in species distributions lead to new modes of transmission. There is little or no direct evidence of significant predation on 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 could pose a potentially greater risk if reduced sea ice conditions force these pagophilic species into closer proximity in the future.

4.3.4 Inadequacy of Existing Regulatory Mechanisms

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

Commercial hunting of marine mammals is prohibited in U.S. territorial waters by the MMPA and is not considered a threat to the species in this part of its range. However, the recent high commercial quotas set by Russia for ribbon seals are a potential risk. Regulations which govern commercial harvest of ice seals in Russia are over 20 years old and are artifacts of the former Soviet Union (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, September 15, 2008, pers. comm.). Therefore, it is unclear what mechanisms are currently in place in Russia to ensure that potential commercial harvests remain within sustainable levels.

Although reported harvest statistics vary from source to source, it is clear that Soviet commercial harvests were very high from 1957-1968 (Table 3) with total catches ranging between 11,300 and 27,100 ribbon seals per year (Fedoseev 1973). This heavy exploitation resulted in a number of adverse effects on ribbon seals, 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 and these regulations apparently had their intended effect as reported harvest levels were reduced during the 1970s while abundance estimates gradually increased during the same time (Table 2). Although there is no indication that sealing quotas were lifted after the 1970s, and at least one source suggests that they were reduced even further in the Sea of Okhotsk in the early 1980s (Popov 1982), other sources indicate that the commercial harvest increased again to high levels (i.e., 9,000-15,000 ribbon seals per year) in the Sea of Okhotsk during the 1980s (V. Burkanov, Kamchatka Branch of the Pacific Institute of Geography, October 3, 2008, pers. comm.) and early 1990s (Grachev 2006). Following the collapse of the Soviet Union in 1991, commercial sealing became less economically viable (Grachev 2006), ending 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.). However, if economic conditions were to change in Russia so that commercial sealing was once again profitable, high levels of harvest could again adversely affect the species. Grachev (2006) proposed that 15,000 ribbon seals could be harvested per year by three commercial sealing vessels, and 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 were shown to be unsustainable (Shustov 1965b) and "disastrous" to this species (Fedoseev 1973). Currently, 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.).

4.3.4.1 Existing Conservation Efforts

4.3.4.1.1 International Agreements

We are not aware of any conservation efforts undertaken by foreign nations specifically to protect ribbon seals.

4.3.4.1.1.1 The Convention on International Trade in Endangered Species of Wild Fauna and Flora

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is a treaty aimed at protecting species at risk from international trade. CITES regulates international trade in animals and plants by listing species in one of its three appendices. The level of monitoring and control to which an animal or plant species is subject depends on which appendix the species is listed in. Appendix I includes species threatened with extinction which are or may be affected by trade; trade of Appendix I species is only allowed in exceptional circumstances. Appendix II includes species not necessarily threatened with extinction now, but for which trade must be regulated in order to avoid utilization incompatible with their survival. Appendix III includes species that are subject to regulation in at least one country, and for which that country has asked other CITES Party countries for assistance in controlling and monitoring international trade in that species. Ribbon seals have no special status under CITES.

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

The IUCN Red List identifies and documents those species most in need of conservation attention if global extinction rates are to be reduced, and is widely recognized as the most comprehensive, apolitical global approach for evaluating the conservation status of plant and animal species. In order to produce Red Lists of threatened species worldwide, the IUCN Species Survival Commission draws on a network of scientists and partner organizations, which use a scientifically rigorous approach to determine species' risks of extinction. Ribbon seals are classified as a species of Least Concern on the IUCN Red List.

4.3.4.1.1.3 Mechanisms to Regulate Sea Ice Recession

There are no known regulatory mechanisms which effectively address reductions in sea ice habitat at this time.

4.3.4.1.2 Domestic Regulatory Mechanisms

4.3.4.1.2.1 Marine Mammal Protection Act of 1972, as Amended

In U.S. waters, ribbon seals are protected by the Marine Mammal Protection Act (16 U.S.C. 1361 et seq.) (MMPA). The MMPA was enacted in response to growing concerns among scientists and the general public that certain species and populations of marine mammals were in danger of extinction or depletion as a result of human activities. The goal of the MMPA is to protect and conserve marine mammals so that they continue to be significant functioning elements of the ecosystem of which they are a part. The MMPA set forth a national policy to prevent marine mammal species or population stocks from diminishing to the point where they are no longer a significant functioning element of the ecosystems.

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

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

The Secretaries of Commerce and of the Interior have primary responsibility for implementing the MMPA. The Department of Commerce, through NOAA, has authority with respect to whales, porpoises, seals, and sea lions. The remaining marine mammals, including polar bears, walruses, and sea otters, are managed by the Department of the Interior through the USFWS. Both agencies are responsible for the promulgation of regulations, the issuance of permits, the conduct of scientific research, and enforcement as necessary to carry out the purposes of the MMPA.

U.S. citizens who engage in a specified activity other than commercial fishing (which is specifically and separately addressed under the MMPA) within a specified geographical region may petition the

Secretaries to authorize the incidental, but not intentional, taking of small numbers of marine mammals within that region for a period of not more than five consecutive years (16 U.S.C. 1371(a)(5)(A)). The Secretary ``shall allow'' the incidental taking if the Secretary finds that ``the total of such taking during each 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 affecting the least practicable adverse impact on the species, their habitat, and their availability for subsistence uses, and (3) requirements for monitoring and reporting. The regulatory process does not authorize the activities themselves, but authorizes the incidental take of the marine mammals in conjunction with otherwise legal activities described within the regulations.

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

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

4.3.4.1.2.2 National Environmental Policy Act

The National Environmental Policy Act (NEPA) requires federal agencies to consider the environmental impacts of their proposed actions and reasonable alternatives to those actions. To meet this requirement, federal agencies conduct environmental reviews, including Environmental Impact Statement and Environmental Assessments. The NEPA does not itself regulate 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.

4.3.4.1.2.3 Outer Continental Shelf Lands Act

The Outer Continental Shelf Lands Act (43 U.S.C. 331 et seq.) (OCSLA) established federal jurisdiction over submerged lands on the outer continental shelf (OCS) seaward of the state boundaries (3-mile limit) in order to expedite exploration and development of oil and gas resources on the OCS. Implementation of OCSLA is delegated to the Minerals Management Service (MMS) of the Department of the Interior. Outer continental shelf projects that could adversely impact the Coastal Zone are subject to federal consistency requirements under terms of the Coastal Zone Management Act, as noted below.

OCSLA also mandates that orderly development of OCS energy resources be balanced with protection of human, marine, and coastal environments. The OCSLA does not itself regulate the take of ribbon seals, although through consistency determinations it helps to ensure that OCS projects do not adversely impact ribbon seals or their habitats.

4.3.4.1.2.4 Coastal Zone Management Act

The Coastal Zone Management Act (16 U.S.C. 1451 et seq.) (CZMA) was enacted to ``preserve, protect, develop, and where possible, to restore or enhance the resources of the Nation's coastal zone.'' The CZMA is a state program subject to federal approval. The CZMA requires that federal actions be conducted in a manner consistent with the state's coastal zone management plan to the maximum extent practicable. Federal agencies planning or authorizing an activity that affects any land or water use or natural resource of the coastal zone must provide a consistency determination to the appropriate state agency. The CZMA applies to ribbon seal habitats of Alaska, though the CZMA does not itself regulate the take of ribbon seals.

4.3.4.1.2.5 Marine Protection, Research and Sanctuaries Act

The Marine Protection, Research, and Sanctuaries Act (33 U.S.C. 1401 et seq.) (MPRSA) 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.

In summary, there is no evidence that the inadequacy of existing regulatory mechanisms currently poses a threat to ribbon seals. However, there are no known regulatory mechanisms which effectively address reductions in sea ice habitat at this time. Also, it is unclear what regulatory mechanisms are in place to ensure that potential Russian commercial harvests remain within sustainable levels.

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

4.3.5.1 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 have 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 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 of the spotted seal (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 as resources allow, to document any trends in the contaminants of greatest concern.

4.3.5.2 Oil and Gas Exploration, Development, and Production

4.3.5.2.1 United States

In June 2007, Secretary of the Interior Kempthorne approved the 2007-2012 Offshore Oil and Gas Leasing Program. According to this program, lease sales are planned in the Chukchi Sea in 2010 and 2012, in the Beaufort Sea in 2009 and 2011, and in the North Aleutian Basin in the southeastern Bering Sea in 2011 (Minerals Management Service 2007b).

4.3.5.2.1.1 Chukchi Sea

On February 6, 2008, the MMS completed the first Chukchi Sea lease sale (193) since 1991 (Minerals Management Service 2008b). The 193 lease sale was the most successful in Alaska's history based on the number of bids received and the number of tracts receiving bids. The 193 sale area is located offshore Alaska from north of Point Barrow to northwest of Cape Lisburne (Figure 12), and contains more than 29 million acres. The sale area extends from about 25 to 50 miles from shore out to 200 miles offshore. Tracts receiving bids are spread throughout the Chukchi Sea, with the closest to land being approximately 54 miles offshore.

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

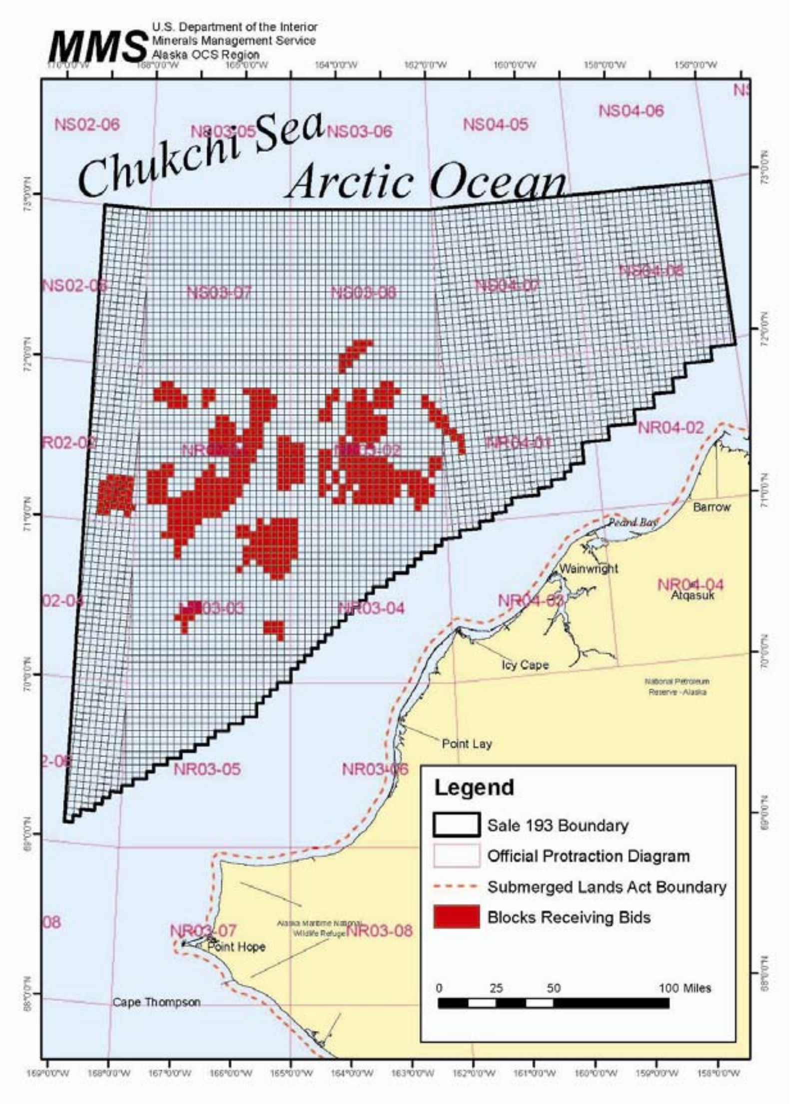

Figure 12. -- Sale 193 Lease Blocks in relation to the Alaska coastline.

4.3.5.2.1.2 North Aleutian Basin

On April 8, 2008, the MMS issued a Call for Information and a Notice of Intent to prepare an environmental impact statement (EIS) for Lease Sale 214 in the North Aleutian Basin Planning Area, proposed for 2011 (Minerals Management Service 2008a). This is the first step in the potential leasing of the area and the NEPA evaluation processes. The North Aleutian Basin is believed to be gas-prone and is located offshore of Alaska in the North Aleutian Basin Planning Area in the southeastern Bering Sea, and covers approximately 5.6 million acres (Figure 13).

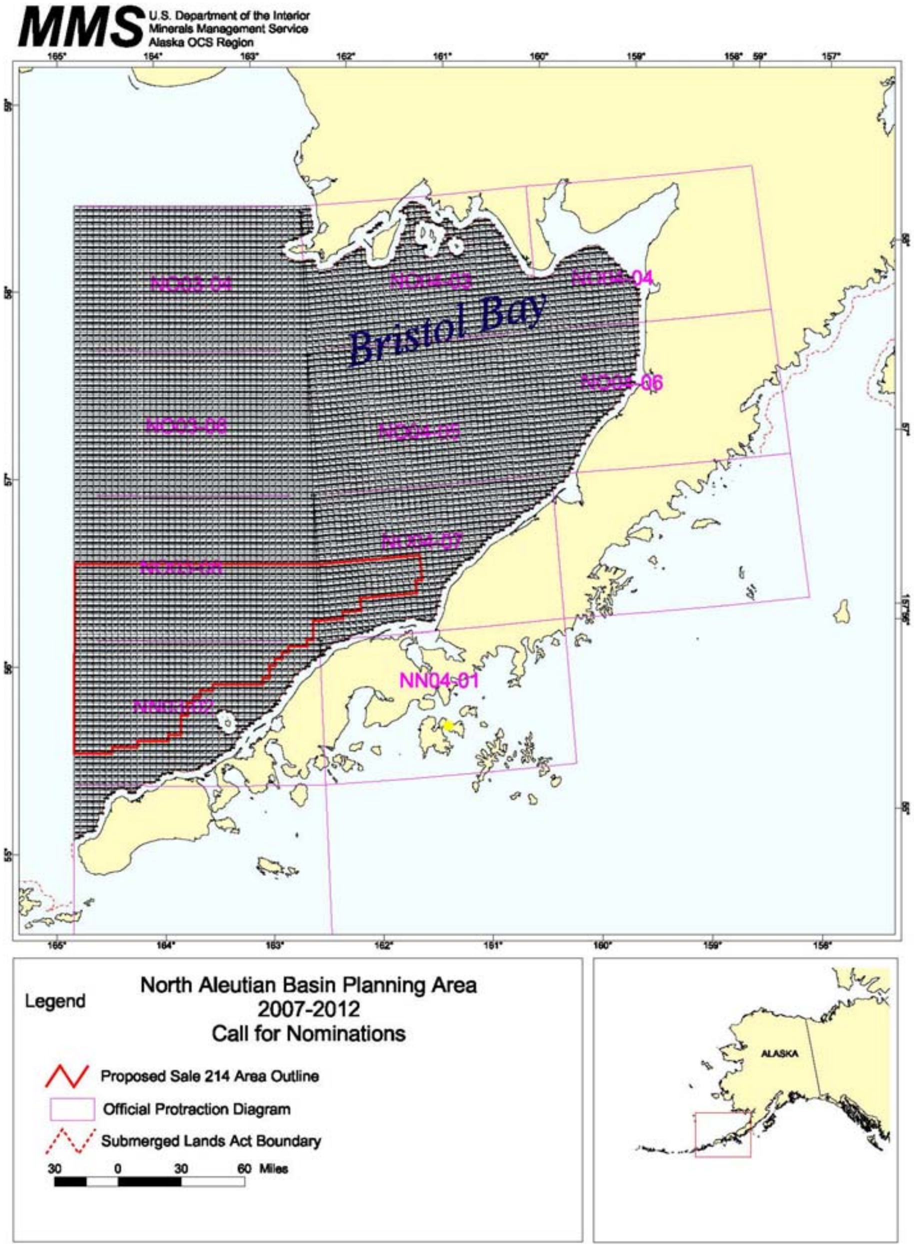

Figure 13. -- North Aleutian Basin Planning Area.

4.3.5.2.2 Russia

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

4.3.5.2.3 Effects from offshore oil and gas exploration and development

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

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

4.3.5.2.3.1 Noise and disturbance

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

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

Likewise, the effects of air and vessel traffic on ribbon seals are expected to be local and transient in nature. Some groups of ribbon seals may be disturbed from their haulouts and enter the water, although such responses most likely would be relatively minor, highly variable, and brief in nature. As discussed in Section 2.4, ribbon seals are relatively unwary of their surroundings and can often be approached quite closely by boat before being disturbed.

4.3.5.2.3.2 Seismic surveys

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

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

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). However, telemetry work by Thompson et al. (1998) indicated that some 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 hauling out, possibly to avoid underwater noise. The behavior of most of the seals reportedly returned to normal within 2 hours of the seismic array falling silent. The authors suggested that responses to more powerful commercial arrays might be more dramatic and occur at greater ranges.

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

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

4.3.5.2.3.3 Oil spills

The threat posed to ribbon seals by oil spills increases as offshore oil and gas development and shipping activities increase across their range. Ribbon seals could be affected by oil spills in several ways. Freshly spilled oil contains high levels of toxic aromatic compounds that, if inhaled, could cause serious health effects or death in 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). Corneal ulcers and abrasions, conjunctivitis, and swollen nictitating membranes have been observed in captive ringed seals placed in crude-oil-covered water (Geraci and Smith 1976), harbor seals following the *Exxon Valdez* oil spill, as well as in seals in the Antarctic after an oil spill (St. Aubin 1988). After seals were experimentally dosed with crude oil, increased gastrointestinal motility and vocalization and decreased sleep were observed (Geraci and Smith 1976, Engelhardt 1985, Engelhardt 1987). Some pinnipeds depend on scent to establish a mother-pup bond, and sea lion mothers have been observed to not recognize their oil-coated pups, though oiled gray seal pups appeared to nurse normally (St. Aubin 1990). Oil that disperses from a spill site still may (e.g., depending on temperature and whether the oil becomes frozen into ice) have high levels of toxic aromatic compounds.

Pinnipeds stressed by parasitism or other metabolic disorders may be susceptible to injury or death from even brief exposure to relatively low concentrations of hydrocarbon vapors (St. Aubin 1990). For example, parasitized lungs, relatively common in pinnipeds, can exacerbate the effects of even mild irritation of respiratory tissues (St. Aubin 1990). Furthermore, ingestion of hydrocarbons irritates and destroys epithelial cells in the stomach and intestine, affecting motility, digestion, and absorption, which can result in death or reproductive failure (St. Aubin 1990).

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

Oil spill clean-up in the broken ice and open water conditions that characterize the ribbon seal's habitat is problematic. The MMS has noted that there are difficulties in effective oil-spill response in broken-ice conditions (Minerals Management Service 2007a):

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

However, there are currently no offshore oil and gas developments in the U.S. Bering or Chukchi Seas; therefore, the potential for ribbon seals to be impacted by an oil spill in U.S. waters is currently very low. According to the MMS, if the recent 193 Chukchi Lease Sale does result in an oil and gas development, the chance of one or more large oil spills (greater than or equal to 1,000 barrels) occurring over the production life of the development is between 35-40% (Minerals Management Service 2007a). As far as is known, ribbon seals have not been affected by oil spilled as a result of industrial activities. Though the probability of an oil spill affecting a significant portion of the ribbon seal population in the foreseeable future is slight, the potential impacts from such a spill could be significant, particularly if subsequent clean-up efforts were ineffective. The potential impacts would be greatest from April to June when ribbon 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 the Bering and Chukchi Seas.

It is important to evaluate the effects of anthropogenic perturbations, such as oil spills, in the context of historical data. Without historical data on distribution and abundance, it is not possible to measure the impacts of an oil spill on 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 thus determine the magnitude of potential effects (Frost et al. 2004).

4.3.5.3 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. 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.

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). There may be similar interactions with gill-net fisheries in the U.S. coastal waters of Alaska, where these fisheries have been subject to observer programs, with the exception of the 1990 Alaska Peninsula/Aleutian Islands salmon drift gill-net fishery; no by-catch of ribbon seals was observed. Coastal gill-net fisheries 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: 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 has 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.

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 is considering an Arctic Fisheries Management Plan that would place a moratorium on development of fisheries in federally managed waters in the U.S. EEZ north of Bering Strait (North Pacific Fishery Management Council 2008). Several Russian companies recently sent longline vessels to explore fishing prospects in the Chukchi Sea, with unkown 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.).

4.3.5.4 Shipping and transportation

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

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

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

Both the NWP and the NSR pass through the range of the ribbon seal in the Bering and Chukchi Seas; therefore, increases in marine traffic along these routes present potential threats to this species, including increased risks of oil spills and other pollution hazards related to shipping accidents, increased effects of noise and disturbance, and increased GHG emissions, particularly black carbon or soot, which may further accelerate local warming in the Arctic. The possible effects of oil spills and noise disturbance on ribbon seals and the biological effects of global climate change on ribbon seals have already been discussed in this report (Sections 4.3.5.2.3.3 and 4.3.5.2.3.1, respectively) so will not be discussed further here. The potential threat to ribbon seals by the presence and movements of ships is the focus for the remainder of this section.

Increases in ship traffic are only likely to be a threat to ribbon seals during the spring when they are hauled out on sea ice to give birth, nurse pups, and molt; and then, only by ice-reinforced ships that are capable of moving through the ribbon seal's sea ice habitat. During the rest of the year, ribbon seals haul out infrequently and are thought to be spread out in such low densities while pelagic that ship traffic is not likely to be a significant threat. 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 on direct impacts from shipping on seals in open water.

As was mentioned in Section 2.4, ribbon seals are relatively unwary of their surroundings while hauled out on sea ice and can be approached quite closely by boat before being disturbed into the water. This behavior was witnessed firsthand during the spring of 2007 while conducting research in the Bering Sea ice field aboard the U.S. Coast Guard icebreaker *Healy* (Cameron and Boveng 2007). Ribbon seals that were approached closely by this 420 ft long icebreaker often were not disturbed enough to enter the water, and occasionally the ship had to divert its course to avoid potentially running over hauled-out ribbon seals, especially young ones. This unwariness to ship traffic could result in potential benefits as well as risks to ribbon seals. Seals that are not disturbed into the icy water could avoid the energetic costs of disturbance, an especially important consideration for newborn pups that have not yet put on a thick layer of insulating blubber, and for molting seals that benefit from maintaining higher skin temperatures. The obvious risk of being unwary of ship traffic is the potential for being struck by an approaching ship. It should be noted that not all ribbon seals exhibit the same level of unwariness, and many seals do enter the water upon being approached closely by ships. These ribbon seals may be put at risk from increased thermodynamic energy costs, including the possibility of newborn pups freezing to death (Krylov et al. 1964), as well as the potential disruption of molting, resting, nursing, and mating behaviors. To date, no studies have been conducted on the effects of ship traffic on ribbon seals hauled out on sea ice.

It is difficult to assess (with any certainty) the level of danger these potential threats pose to ribbon seals as a species since specific information about the type, timing, magnitude, and location of the projected increases in shipping and transportation within this species' range is currently unavailable. The final report of the comprehensive *Arctic Marine Shipping Assessment*, which will evaluate current (2004) and projected (2020 and 2050) levels and impacts of marine shipping activity in the Arctic (PAME 2004), is due to be published in 2009 (Treadwell 2008). This report should increase our ability to accurately assess the level of risk posed by Arctic marine shipping and transportation to the ribbon seal in the future.

4.3.6 Discussion of Factors and the Species' Response to Threats

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 the 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, 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 (>1.8 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°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). 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. 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 (YD), about 11.5 kya, when temperatures rose by about 10°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°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 YD 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 4.2.5):

- 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 the seals 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).

In consideration of the five factors listed under Section 4(a)(1) of the ESA, none was found that places the ribbon seal in present danger of extinction. On the other hand, 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.

4.4 Conclusions of the Extinction Risk Assessment

Demographic factors: With a population likely comprising at least 200,000 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 a recent estimate of 49,000 ribbon seals in the eastern and central Bering Sea is consistent enough with historical estimates 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. A comprehensive survey of ribbon seal abundance, a new analysis of demographic data obtained from the former Russian commercial harvest, and genetic studies of population structure are high priorities for research and monitoring.

Present or threatened destruction of habitat or range: Sea-ice cover during late 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 in the Bering Sea and Sea of Okhotsk that persists through May and June. 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. The magnitude of this anticipated impact is uncertain because the relevant physiological parameters have not been measured and the extent to which ribbon seals will compensate by moving to areas with better ice is unknown. The coarse spatial resolution of models used to predict sea-ice coverage may render them unsuitable 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 still suitable habitat for ribbon seal molting.

Ocean acidification may impact ribbon seal survival and recruitment through disruption of trophic regimes wherever they are dependent on calcifying organisms. The nature and timing of such impacts are extremely uncertain. Because of ribbon seals' apparent dietary flexibility and because the major effects of ocean acidification may not appear until the latter half of this century, this threat should be of less immediate concern than the direct effects of potential sea ice degradation.

Changes in ribbon seal prey, anticipated in response to ocean warming and loss of sea ice, have the potential for 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. Again, however, the flexibility in ribbon seal foraging make these threats of lower concern than more direct impacts from changes in sea ice.

The threats associated with impacts of global warming on ribbon seal habitat, to the extent that they may pose risks to ribbon seals, were presumed to manifest throughout the current breeding and molting range (for sea-ice related threats) or throughout the entire range (for ocean warming and acidification) of the species, inasmuch as the finer-scale spatial distribution of these threats is not currently well understood. The question, therefore, of whether any of these poses a risk to the continued existence of ribbon seals in merely a significant portion of, rather than the entire, range was subsumed by this approach to the qualitative risk assessment.

Over-utilization: There is currently very 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 rate 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. 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 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: 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, 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 ship trends within the ribbon seal's range are currently unavailable.

Several of the threats considered in this section on "Other natural or human factors affecting the species' continued existence" were associated with specific regions or times of year when ribbon seal distribution is restricted, such as increased ship traffic in the Bering Strait region or oil and gas activities during the ribbon seal breeding and molting seasons. If such threats were to occur and cause a high rate of mortality or forgone reproduction, the species could be considered threatened or endangered in a significant portion of its range. However, none of the threats considered here is presently considered to be both sufficiently likely to occur and sufficiently high in impact, alone or cumulatively, to raise concern about them posing a risk of ribbon seal extinction or becoming endangered throughout a significant portion of its range.

Status of the ribbon seal population: Qualitative assessments of the balance between identified threats and a species' capability to adjust must often be decided on the basis of expert opinion and on policy, especially policy regarding consideration given to uncertainty. Such policy is outside the scope of this status review. To assist in the process, however, the BRT addressed its summary conclusions on ribbon seal status using a scoring system[5] in which each member assigned up to 10 likelihood points in support of the conclusion.

In consideration of all of the threats and potential threats identified above, the assessment of the risks posed by those threats, the possible cumulative impacts, and the uncertainty associated with all of these, the BRT drew the following conclusions:

1. Ribbon seals are not in current danger of extinction throughout all or a significant portion of their range. (78 of 80 likelihood points)
2. The ribbon seal population is likely to decline gradually for the foreseeable future, primarily from slight but chronic impacts on reproduction and survival caused by reduced frequency of years with sea ice of suitable extent, quality, and duration of persistence. (51 of 80 likelihood points)
3. Despite the expectation of a gradual decline, ribbon seals are not likely to become an endangered species within the foreseeable future throughout all or a significant portion of their range. (57 of 80 likelihood points)

Finally, to reinforce the notion that reliable and effective assessments of species' conservation status cannot be conducted without adequate estimates of abundance, the BRT concluded that despite the expectation of a declining ribbon seal population, it will likely not be possible to detect and document a significant overall decline unless monitoring is made a very high priority for both the Bering Sea and Sea of Okhotsk.

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[5] Based upon expert judgment and the information compiled in the review, each of the eight team members allocated 10 "likelihood points" into two categories signifying agreement or disagreement with each of the three primary conclusions. Thus, a member could completely agree by giving all 10 points to the "yes" category, completely disagree by giving all 10 points to the "no" category, or reflect uncertainty by allocating part of the points to "yes" and the remainder to "no". Thus a 5:5 score would signify that a member felt there was no basis to judge whether a conclusion was valid. A total of 41 out of the 80 possible points (51%) was required for concluding that an outcome is "likely".

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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). The surveys were conducted from a helicopter based aboard the U.S. Coast Guard icebreaker *Healy* during two cruises: April 10-May 12 and May 16-June 18, 2007. The cruises ranged throughout the pack ice of the eastern and central Bering Sea, providing access to areas not surveyed since the 1970s (Braham et al. 1984) and 1980s (Fedoseev et al. 1988).

7.1 Field Methods

Line transect surveys were conducted whenever the *Healy* was near ice and the weather conditions were conducive to flying between 09:00 and 15:00 (local apparent time), which corresponds to the timing of peak seal haul-out. Each flight had 2-3 observers and was flown at a target altitude of 118 m (400 ft) and speeds of 80-95 knots. Only seals hauled out on ice were recorded. The distance from each seal to the helicopter's track line was calculated using a sighting bar mounted on each observer's window. In all, 1,567 seals, 217 of which were identified as ribbon seals (Table A1) were observed during 48 hours and 55 minutes of survey effort covering 4,414 nautical miles (nmi) of survey line on 44 flights (Figure A1).

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

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

7.2 Analysis

The software package DISTANCE (Thomas et al. 2006) was used to calculate detection probabilities and densities for each species (Moreland et al. 2008). The extent of the area (i.e., sea ice field) over which the seals were distributed changed dramatically throughout the survey as the ice shifted and melted. This change in habitat was assumed to affect the densities of seals hauled out on the ice. To compensate for the reduction in sea ice over the 69 days of the survey, the analysis was divided into three time periods: High ice coverage (April 12-May 4), medium ice coverage (May 5-May 28), and low ice coverage (May 29-June 11), and calculated average densities of 0.2796 (SE = 0.0850), 0.4080 (SE = 0.0949) and 0.1484 (SE = 0.4344) ribbon seals hauled out per nmi^2 (square nautical mile), respectively (Moreland et al. 2008). The dates of the medium and low ice concentration survey periods coincided with rapid melting of the ice in the region and the seasonal transition to a pelagic existence for some age classes

(Boveng et al. 2007), complicating the choice of an effective survey area; therefore, the medium and low ice coverage periods were not included in the rest of the analyses.

Integrating the estimated density from the high-ice period over the entire survey area, calculated as the minimum convex polygon encompassing all survey tracks (64,500 nmi^2), produced an estimate of 18,034 ribbon seals, not including an adjustment for seals in the water at the time of our surveys.

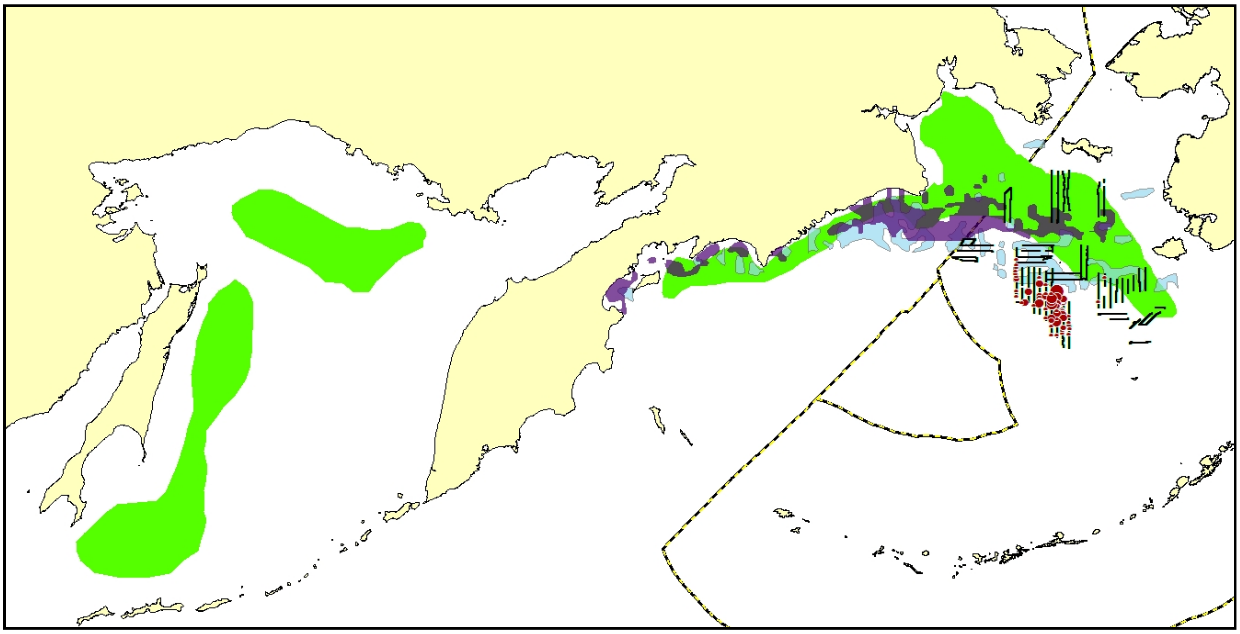

Figure A1. -- Map of the Bering Sea and Sea of Okhotsk. The black lines show the locations of aerial surveys conducted during the high ice concentration period (April 12 to May 4, 2007). The red circles indicate locations where ribbon seals were observed (larger circles circles indicate more ribbon seals). 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 (1987), totaling 23,199 and 24,659 nmi^2, respectively.

To adjust for seals that were missed because they were in the water, the estimate was divided by the average proportion of the population that was hauled out at the time of the survey period. This proportion was estimated from records of time spent in the water by seals carrying SDRs. During the spring of 2005 in the Ozernoy Gulf, Russia, and during 2007 in the eastern Bering Sea, NMML researchers attached SDRs to 42 ribbon seals that were captured on the sea ice. Sixteen of the recorders returned data corresponding to the seasonal coverage of the high-ice aerial survey period (i.e., April 12-May 4 of 2006, 2007, or 2008). The sex and age ratios of these 16 instrumented seals were approximately representative of a typical long-lived mammal population. The haul-out behavior of phocids can be affected by many factors including the day-of-year, time-of-day, age, and sex. The time of day can be particularly important as seals often choose to haul out during mid-day and feed in the water column at night. The average percent of each hour that each seal was hauled out during the dates and hours of the survey period was calculated and then averaged across individuals to estimate the proportion of all seals hauled out for each hour of the day (Figure A2).

Finally, to calculate a haul-out correction factor specific to the survey timing, the hourly proportions of seals hauled out from 09:00 to 15:00 (local time), which corresponds to the timing of the aerial surveys, were averaged. The overall proportion of ribbon seals hauled out while surveying during the high-ice-concentration period was 0.365, the inverse of which was used as the correction factor for haul-out.

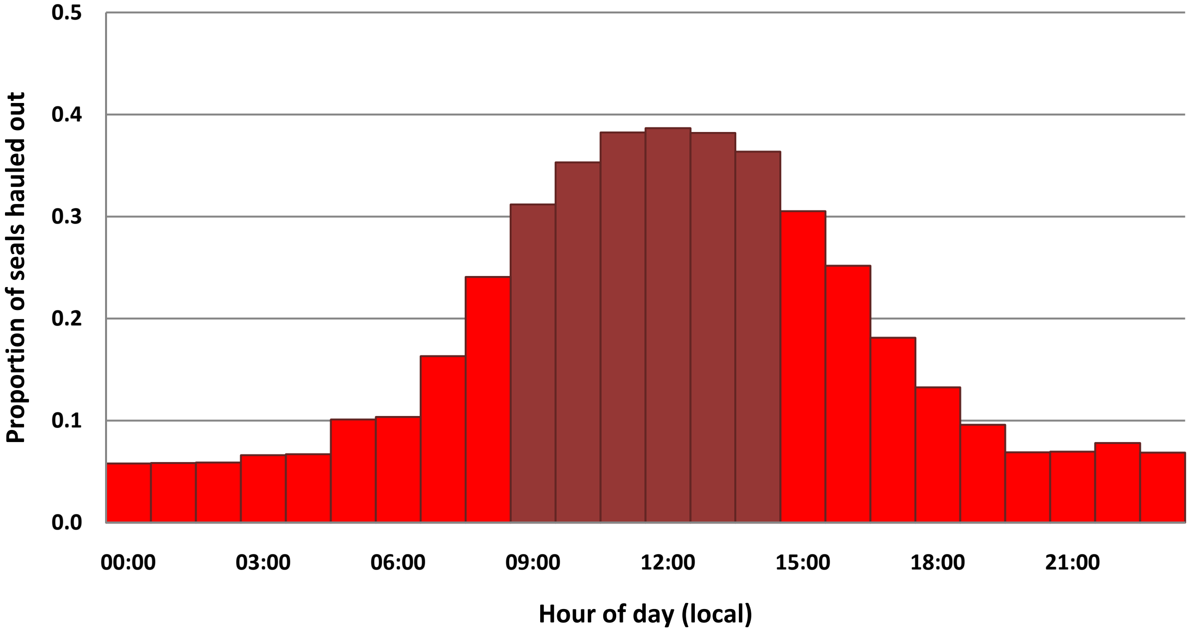

Figure A2. -- Histogram plot of the overall proportion of ribbon seals hauled out of the water each hour during April 12 to May 4 of 2006, 2007, or 2008. The darker bars indicate the time of day when surveys were conducted (i.e., 09:00 to 15:00). The average proportion of the ribbon seal population that was hauled out during these hours was 0.365.

Dividing the estimate of total seals hauled out (18,034) by the proportion hauled out (0.365) produced a total abundance estimate for the survey area and time period of 49,370 ribbon seals. A variance was not estimated for this value because this was a preliminary treatment of the data; the next iteration of the analysis will derive the haul-out correction and its variance, correctly accounting for the repeated measures (autocorrelation) structure of the data (Ver Hoef et al. Submitted). However, the coefficient of variation of the line-transect density estimate alone was about 30%.

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 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 A2). 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).

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 215,377 ribbon seals (Table A2).

Table A2. -- 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	Total Bering Sea	Sea of Okhotsk	Range-wide Total (Bering+Okhotsk)
Fedoseev et al. (1988) – April, 1987	49,370 (0.506)	48,205 (0.494)	97,574	n/a	n/a
Fedoseev et al. (1988) – May, 1987	49,370 (0.260)	140,404 (0.740)	189,774	n/a	n/a
Fedoseev (1973) – April and May, 1960s	49,370 (0.229)	66,083 (0.307)	115,453	99,914 (0.464)	215,377

Of the values presented in Table A2, 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 97,574 to 189,774, 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 215,000, the Sea of Okhotsk component of about 100,000 is lower than all 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 likely reflects a failure of assumptions rather 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. Lacking details about the Russian survey methods that produced the larger numbers, and lacking any data more recent than 1990, the BRT opted to use the smaller number but also to note that the literature suggests this may be an underestimate.

8 APPENDIX 2: GLOSSARY OF ABBREVIATIONS

Abbreviation	Description
AFSC	Alaska Fisheries Science Center
AR4	IPCC Fourth Assessment Report
BRT	Biological Review Team
CBD	Center for Biological Diversity
CDV	canine distemper virus
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMIP3	Coupled Model Intercomparision Project Phase 3
CZMA	Coastal Zone Management Act
DDT	dichloro-diphenyl-trichloroethane
D-O	Dansgaard-Oeschger
DPS	distinct population segment
EEZ	Exclusive Economic Zone
ESA	Endangered Species Act
GHG	greenhouse gas
GPS	global positioning system
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature and Natural Resources
MK10	Wildlife Computers SDR with GPS for movements, diving, and haul-out timing
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service
MPRSA	Marine Protection, Research, and Sanctuaries Act
NAO	North Atlantic Oscillation
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
nmi	nautical mile
nmi^2	square nautical mile
NMML	National Marine Mammal Laboratory, Alaska Fisheries Science Center
NOAA	National Oceanic and Atmospheric Administration
NSR	Northern Sea Route
NWP	Northwest Passage
OCS	outer continental shelf
OCSLA	Outer Continental Shelf Lands Act
PBDE	polybrominated diphenyl ether
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
PTS	permanent threshold shift
SAT	surface air temperature
SDR	satellite-linked data recorder
SPLASH	Wildlife Computers SDR used for seal movements, diving, and haul-out timing

Abbreviation	Description
SPOT5	Wildlife Computers SDR used for seal movements and haul-out timing
TAR	IPCC Third Assessment Report
TCV	Tillamook calicivirus
USFWS	U.S. Fish and Wildlife Service
WCRP	World Climate Research Programme
WGCM	WCRP Working Group on Coupled Modelling
YD	Younger Dryas interval

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AFSC-

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