Spotted Seals, *Phoca largha*, in Alaska

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Introduction

Under the reauthorization of the Marine Mammal Protection Act (MMPA) in 1988, and after a 5-year interim exemption period ending September 1995, the incidental take of marine mammals in commercial fisheries was authorized if the affected populations were not adversely impacted. The Marine Mammal Assessment Program (MMAP) of the National Marine Fisheries Service (NMFS), NOAA, provided funding to carry out population studies to determine the abundance, distribution, and stock identification of marine mammals that might have been impacted by commercial fisheries in U.S. waters (Braham and DeMaster[1]). For spotted seals, *Phoca largha*, there were insufficient data to determine incidental take levels. Accordingly, as a part of the MMAP, the NMFS National Marine Mammal Laboratory (NMML) conducted a study of spotted seals in Alaska. The objectives of this study were to: 1) provide a review of literature pertaining to management aspects of spotted seals worldwide, particularly literature that has become available since the review done by Quakenbush (1988); 2) survey the eastern Bering Sea in the spring to document distribution and abundance relative to stratified ice zones; and 3) survey the western coast of Alaska in the summer to document distribution and abundance of seals at haul-out sites.

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ABSTRACT—The worldwide literature on management of spotted seals, Phoca largha, *was reviewed and updated, and aerial surveys were flown in 1992 and 1993 to determine the species' distribution and abundance in U.S. waters. In April, spotted seals were found only in the Bering Sea ice front. In June, they were seen along deteriorating ice floes and fast ice in Norton Sound. Surveys along most of Alaska's western coast in August and September found over 2,500 spotted seals in Kuskokwim Bay and concentrations of 100–400 seals around Nunivak Island, Scammon Bay, Golovnin Bay/ Norton Sound, Cape Espenberg/ Kotzebue Sound, and Kasegaluk Lagoon. All of these sites have been used by spotted seals in the past. The sum of the highest counts, irrespective of year, was 3,570 seals (CV = 0.06). This is not an abundance estimate for all spotted seals in the Bering Sea, because it does not account for animals in the water, and we did not survey the Asian coast and some islands. Also, spotted seals and harbor seals,* Phoca vitulina, *are too similar in appearance to be identified accurately from the air, so our results probably include a mix of these species where their ranges overlap.*

Literature Review

Taxonomy

Until recently, there were three forms of harbor seals listed for the North Pacific: *Phoca vitulina richardsi*, found coastally in western North America; *P. v. stejneger*, from eastern Asia; and *P. v. largha*, the ice-inhabiting form (Shaughnessy and Fay, 1977). These authors proposed giving specific rank to *P. largha* based on habitat (*P. largha* occur on sea ice when pupping, whereas *P. vitulina* are more coastal and insular), a 2-month difference in mating seasons (effecting reproductive isolation), the whitish lanugo on newborn *P. largha* that is shed in utero in *P. vitulina*, differences in the adult pelage of *P. largha* and *P. vitulina*, and some differences in cranial characteristics (Burns et al., 1984). However, hybridization may occur, based on evidence from morphological intermediates and overlaps in range (Burns et al., 1984). As such, differentiation of these two species in the field is very difficult.

Distribution

Spotted seals occur in the seas north and west of the North Pacific Ocean: the Huanghai (Yellow Sea), Okhotsk, Bering, Chukchi, and Beaufort Seas. The limits to the spotted seals' range are northwest to Chaun Bay (lat. 70°N, long. 170°E) in the western Chukchi Sea (Shaughnessy and Fay, 1977), northeast to Herschel Island (lat. 69°35'N, long. 139°W) in the Beaufort Sea (Porsild, 1945; Galginaitis[2]), southeast to Bristol Bay in the Bering Sea (Burns and Fay[3]), and southwest to the mouth of the Yangtze River (31°N 122°E) in southern China (Allen, 1938; Wang, 1986).

There are eight known breeding concentrations of spotted seals (Fig. 1): 1) Liaodong Gulf (Huang, 1962; Wang, 1986; Dong and Shen, 1991); 2) Peter the Great Bay (Kosygin and Tikhomirov, 1970; Trukhin and Kosygin,

[1] Braham, H. W., and D. P. DeMaster. 1993. Marine Mammal Assessment Program: Status of stocks and impacts of incidental take. Natl. Mar. Mammal. Lab., NMFS, NOAA, Seattle, Wash. Manuscr. submitted to Off. Prot. Resour., NMFS, 1335 East-West Hwy., Silver Spring, MD 20910, 153 p.

[2] Galginaitis, M. 1990. Subsistence resource harvest patterns: Kaktovik. U.S. Dep. Inter., Anchorage, Alaska, OCS Study MMS 90-0039, 251 p.

[3] Burns, J. J., and F. H. Fay. 1972. Comparative biology of Bering Sea harbor seal populations. *In* Proc. 23rd Alaska Sci. Conf., College, Alaska (Alaska Div. Am. Assoc. Advance. Sci.), p. 48 (abstr.).

A spotted seal pup (still with its lanuga coat) and an adult on an ice floe in the northern Bering Sea. Photo by David Rugh, NMML.

1988); 3) the western coast of Sakhalin Island in the Tatar Strait; 4) the eastern coast of Sakhalin Island extending to northern Hokkaido; 5) northern Shelikova Gulf (Fedoseev, 1970; Kosygin and Gol'tsev, 1971; Shaughnessy and Fay, 1977); 6) northeast from Kronotsky Cape on the eastern side of the Kamchatka Peninsula (Burkanov[4]) to Olyutorski Gulf; 7) the Gulf of Anadyr in the Northwest Bering Sea; and 8) from Bristol Bay, Alaska, to west of the Pribilof Islands (Gol'tsev et al., 1975; Shaughnessy and Fay, 1977; Fedoseev et al., 1988).

Despite the geographic structuring in the distribution of spotted seal breeding concentrations, genetic differentiation has not yet been found (O'Corry-Crowe[5]). This analysis was based on the direct sequencing of mtDNA from populations sampled in Kasegaluk Lagoon, Alaska, and Kamchatka, Russia. The observed genetic consistency may in part be due to breeding on the highly mobile sea ice platform (Tikhomirov, 1966a; Burns et al.[6]), allowing for greater opportunities for genetic exchange than would be expected if breeding occurred on consistently used land sites. Also, this species has a well documented ability to travel great distances, increasing the chances for genetic exchange between populations. Movement patterns of four spotted seals satellite-tagged in Kasegaluk Lagoon revealed average travel speeds ranging from 14 to 90 km/day (Lowry et al., 1994). One male covered over 1,000 km of open water, traveling from Kasegaluk Lagoon to the Chukchi Peninsula, Russia, and back in only one month.

The spotted seal winter range is primarily restricted to a frontal zone of broken sea ice 15–65 km wide along the southern edge of the seasonal pack ice (Burns, 1970; Fay, 1974) generally where water depth is 200 m or less (Naito, 1976; Braham et al., 1984). This type of ice front occurs in Liaodong Gulf, Bohai Sea, and Korea Bay north of the Huanghai Sea (Huang, 1962; Mohr, 1965; Wang, 1986); in the Okhotsk Sea south to Peter the Great Bay near Vladivostok (Fedoseev, 1970; Kosygin and Tikhomirov, 1970; Kosygin and Gol'tsev, 1971; Trukhin and Kosygin, 1988); and from Cape Navarin, Siberia, to Bristol Bay, Alaska, in the southern Bering Sea (Shaughnessy and Fay, 1977) (Fig. 1).

Habitat

As described by Burns et al.[6], ice that seasonally covers most of the polar seas inhabited by spotted seals is dynamic, labile, rough, and variable in character with many cracks or openings. The southern edges of this moving ice, called the fringe, are subject to dispersal by wind and currents and are broken by the vertical motion of swells from the open sea. The ice fringe consists of

[4] Burkanov, V. N. 1994. Seasonal dynamics of the distribution and population structure of spotted seals (*Phoca largha*) in coastal waters of the Kamchatka Peninsula, Russia. Unpubl. manuscr.

[5] O'Corry-Crowe, G. 1994. Molecular analysis of intraspecific structure of spotted seals (*Phoca largha*) and the phylogenetic and current relationship of spotted and harbour seals (*Phoca vitulina*): preliminary findings. Rep. to NMFS, Natl. Mar. Mammal Lab., 7600 Sand Point Way NE, Seattle, Wash. 98115-0070, 12 p.

[6] Burns, J. J., L. H. Shapiro, and F. H. Fay. 1980. The relationships of marine mammal distributions, densities, and activities to sea ice conditions. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 11(1981):489-670.

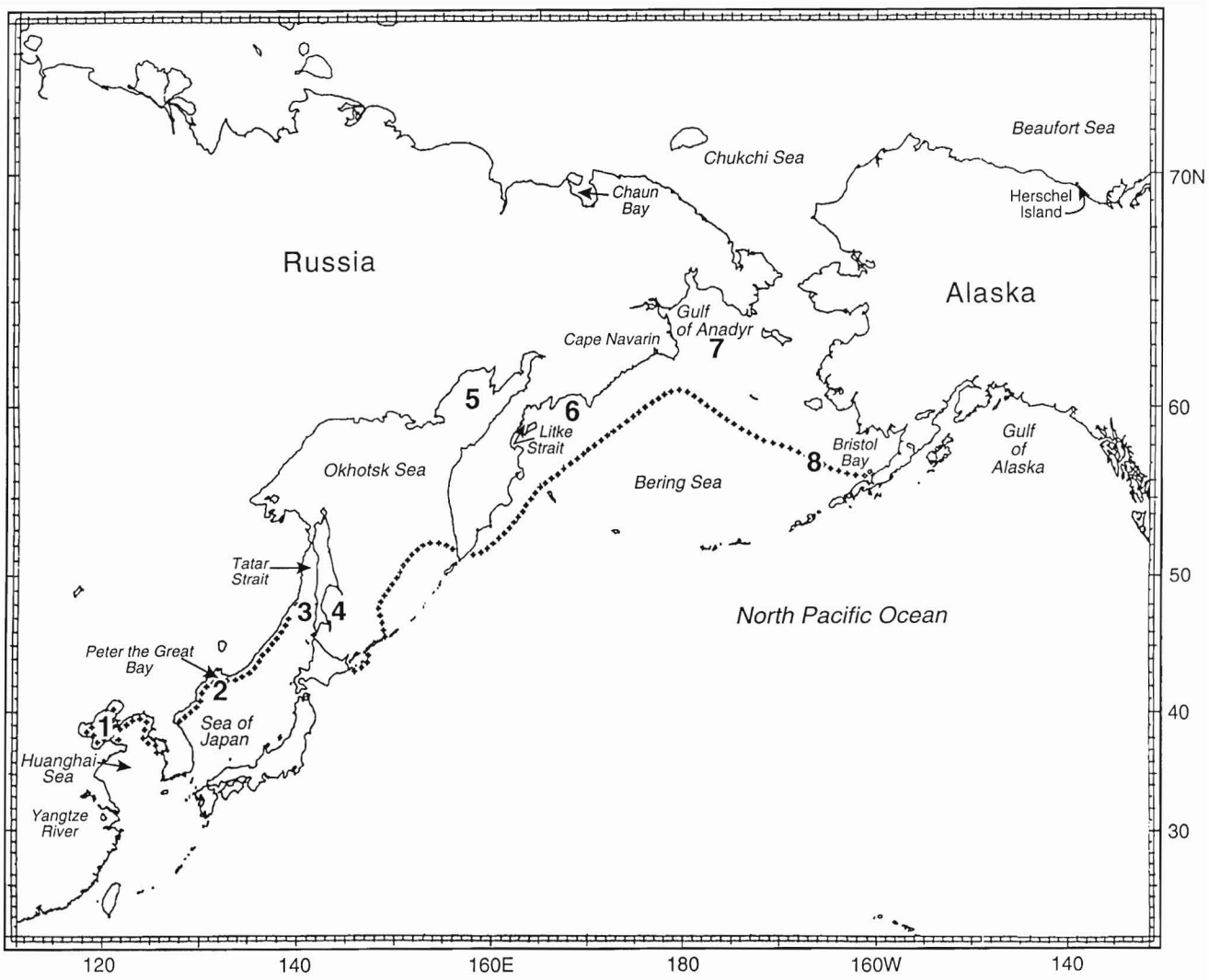


Figure 1.—Map of the entire range of spotted seals. The eight breeding concentrations are in 1) Liaodong Gulf, 2) Peter the Great Bay, 3) Tatar Strait, 4) the eastern coast of Sakhalin Island extending to northern Hokkaido, 5) Shelikova Gulf, 6) Litke Strait to the Olyutorski Gulf, 7) the Gulf of Anadyr, and 8) from Bristol Bay to the Pribilof Islands. The dotted line shows the typical maximum extent of sea ice.

slush and small cakes and may have a width of 10 km or less with some fingers of ice extending southward for many more kilometers. The zone that lies between the fringe and the consolidated pack to the north is called the front. Waves entering the ice pack fracture ice floes into relatively uniform patterns in a band from a few to over 100 km wide, defining the front. The average maximum southern limit of the ice front is depicted in Figure 1, but in some years (as in 1967) the Bering Sea may be ice free as far north as St. Lawrence Island, or (as in 1972) the ice front may reach as far south as the western limit of the Alaska Peninsula, a difference of 870 km between extremes (Burns et al.[6]).

Although sea ice is unpredictable on a local level, in broad terms it has a seasonality that is sufficiently patterned to affect the evolution of pagophilic (ice-associated) marine mammals. Decreased temperatures in the fall and winter, along with northerly and northeasterly winds, result in a southern ice expansion until melting predominates in April or May of the following spring. Seals have adapted to these patterns by using the ice for resting, molting, mating, and bearing young. On calm days during the molt, 83–84% of the seals may be hauled out on the ice (Shustov[7]). The ice platform provides several advantages over haul-sites on shore in that ice allows seals to rest near food resources, is remote from shore-based predators, is relatively sanitary, may provide shelter from the wind, and is spacious (Fay, 1974). The abundance of ice seals may in large part reflect the abundance of sea ice (Burns et al.[6]).

[7] Shustov, A. P. 1969. Concerning the question of the daily dynamics of seal patches in the Sea of Okhotsk. Reports of proceedings of the fourth all-union conference on the study of marine mammals. Moscow, Publ. "Nauka" (as cited in Fedoseev, 1971).

Above: Aerial view of spotted seals (162 by count) hauled out on a sand bar in the Kuskokwim Delta of the eastern Bering Sea on 16 September 1993. Well before the aircraft passed the seals (at 500 ft altitude), they started moving toward the water. In this photograph an unknown number have already entered the surf. **Facing page:** Aerial view of spotted seals (195 by count) hauled out on a sand bar in the Kuskokwim Delta on 16 September 1993. These seals are extremely wary of disturbances, but the high altitude of the aircraft (1700 ft) and winds up to 40 kn disguised the aircraft noise enough to allow a reasonably close approach before the group entered the water. Also, the low tide left many of the seals well above the waterline. Photos by David Rugh, NMML.

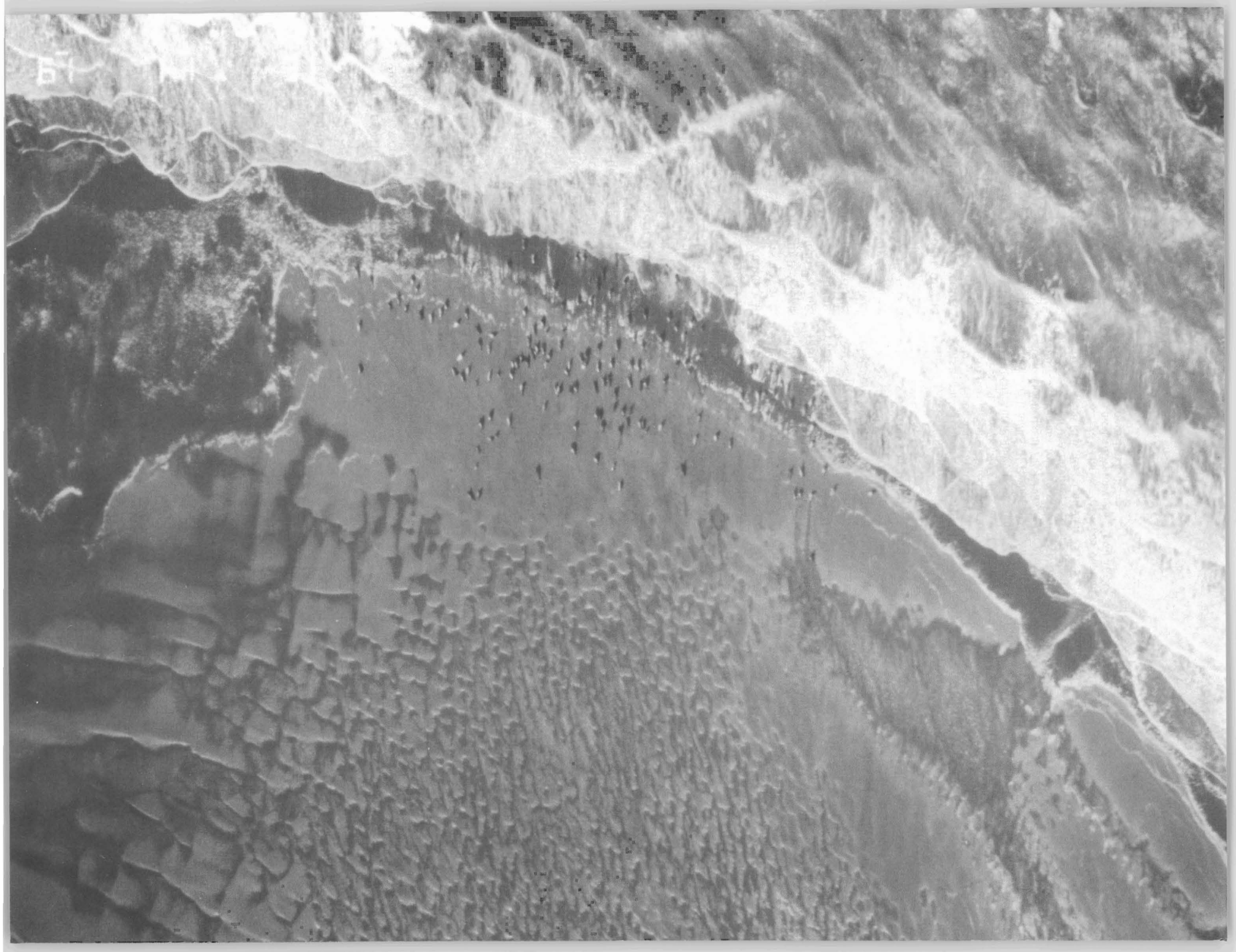
Burns et al.[6] categorized sea ice as: 1) shorefast, 2) persistent flaw zones, 3) polynyas (consistently recurring openings), 4) divergence zones, and 5) the front. Among the ice-associated (pagophilic) seals, ringed seals, *Phoca hispida*, occur in all of these ice types, bearded seals, *Erignathus barbatus*, typically occur in all but the shorefast ice, while ribbon seals, *Phoca fasciata*, and spotted seals are generally found only in the ice front from February to late April. Although some spotted seals occur on the ice fringe, as well as deep into the pack, in the early spring they typically are not found in open seas or consolidated ice. Spotted seals take advantage of shorefast ice only when the ice front has dispersed in late spring-early summer or in autumn before the ice front forms (Trukhin and Kosygin, 1988).

Spotted seals are more numerous than ribbon seals on the southern side of the front towards the ice fringe, but the ratios reverse towards the northern edge near the pack ice (Burns, 1970). Ice remnants remain stable into late spring in the Gulf of Anadyr more so than in Alaska waters, resulting in more ribbon seals occurring in the west and more spotted seals in the east. Ribbon seals apparently rely on ice throughout their molt. Spotted seals are more adaptable and may complete their molt on shore when ice is unavailable (Tikhomirov, 1961, 1964; Burns et al.[6]). In Liaodong Gulf, for example, some spotted seals give birth on shore as well as on ice (Wang, 1986).

Spotted seals use the ice front until it has melted and dispersed. This leads to their northerly migration up the coast of Alaska (Burns et al.[6]), and their use of the ice-free coast in summer (Burns, 1970).

During ice-free months, the seals use coastal haul-outs for only a small portion of the time, spending most of their time at sea (Lowry et al., 1994). The haul-out sites are generally found on nearshore rocky reefs or shoals exposed at low tide (Krylov et al., 1964). Occasionally spotted seals will use grass-covered sand bars (Naito, 1973). Tikhomirov (1966b) described three types of haul sites in the Okhotsk Sea: 1) shorelines covered by large gravel and rock fragments; 2) open, sandy or pebbly seacoast plains, islands, and bars that slope gently into the water and are usually covered by water at high tide; and 3) reefs and rocks, particularly reefs close to capes and separated from the mainland shore by water. The highest densities of animals occurred along the waterline. Frost et al.[8] found spotted seals especially common in bays, estuaries, and the mouths of rivers, where they haul out on sandy beaches, spits, and barrier islands. When they haul out, they usually select low relief, sandy/fine gravel beaches, ends of spits, or barrier islands with access to deep channels to

[8] Frost, K. J., L. F. Lowry, and G. Carroll. 1992. Use of Kasegaluk Lagoon by marine mammals. U.S. Dep. Inter., Herndon, Va., OCS Study MMS 14-35-30491, 57 p.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open water. High seal concentrations in estuarine areas were also noted by Bel'kovich and Shchekotov (1993) who observed up to 2,000 seals in at least one Russian river. These authors described seal concentrations as a mechanism for catching fish, particularly sockeye salmon. In August and September, when food resources are more readily available, seals become more disperse with 15–50 m between them, spreading as much as 20 km up from river mouths.

Behavior

During the spring, spotted seal groups may consist of a mother-pup pair and her mate for the season (Tikhomirov and Kosygin, 1966; Burns et al., 1972). Mean distances between these triads have been calculated to be 0.25 km (Burns et al., 1972) and 0.5 km (Burns and Fay[9]). This patterning of inter-animal distances is distinct enough to be used for species identification. This spacing and the lack of scarring on mature adults, suggests there are no battles in the competition for mates (Naito, 1973); breeding adults are presumed to be territorial and monogamous (Fay, 1974). In the eastern Bering Sea, most pups are born at the ice front during the first half of April and are weaned 3–4 weeks later, shortly before the adults mate in late April and early May (Burns et al.[6]). Pupping, weaning, and breeding occur earlier, from January to February, in China's waters (Wang, 1986), though birthing in captive seals occurs from February to March (Wang, 1980, as cited in Wang, 1986; Zhang, 1993). Spotted seal adults as well as pups seek shelter from storms by taking advantage of pressure ridges on ice floes. Individuals may travel as much as 10 km across the ice (Fedoseev, 1984). During the latter part of the breeding season when molting occurs, generally from April to July, larger groups (concentrations of tens to hundreds) of spotted seals can be found on ice remnants (Krylov et al., 1964) or on shore sites when ice is unavailable (Tikhomirov, 1961, 1964; Lagerev, 1988; Burns et al.[10]).

Adults and pups are segregated during the molt (Trukhin and Kosygin, 1988). Very few subadult spotted seals (ages 1–5) occur in the ice front in April where mature adults and pups are common (Burns and Harbo[11]). The immature seals begin molting in April and May, before the sexually mature adults molt in May and June (Tikhomirov, 1964; Ashwell-Erickson et al., 1986). Large numbers of pups are sometimes observed without adults (Serebrennikov, 1981), and in late summer young animals sometimes hauled out separate from adults (Bel'kovich and Shchekotov, 1993). Segregation by sex was also evident in the number of adult males that moved to summer coastal haul-out sites, while females remained among the ice remnants near the east coast of Sakhalin Island (Naito and Konno, 1979). In the fall, spotted seals move southward with the advancing ice pack, remaining close to the fringe (Burns et al.[6]). Adults leave the shore for the ice before the younger seals (Tikhomirov, 1961)

Spotted seals are shy and wary (Tikhomirov, 1966b; Fedoseev, 1984; Wang, 1986; Nelson[12]). These animals will startle at any movement or noise made by someone approaching them on foot even 700 m away (Tikhomirov, 1966b). Frost et al.[8] noted that spotted seals in large groups dove into the water when an aircraft was probably barely audible to them, as much as 2 km away and at 914 m altitude; however, Frost et al.[8] also found that when the animals were not touching each other, they were relatively insensitive to aircraft, even as low as 152 m. Spotted seals are less cautious during the pupping and mating season in spring (Krylov et al., 1964). During the summer, their manner of lying in dense concentrations allows for rapid communication throughout the group such that one alarmed animal can warn the rest (Krylov et al., 1964; Tikhomirov, 1966b). After the first wave of alarmed animals leave the beach, animals remaining on the beach spread out and appear to be more tolerant of aircraft. Many begin to haul out again 25–60 minutes after a disturbance (Krylov et al., 1964; Frost et al.[8]). An exception to this wary behavior is the population in Peter the Great Bay, Russia, which seems to have habituated to traffic noise and has not been hunted by humans (Trukhin and Kosygin, 1988).

Commercial and Subsistence Takes

Seals have been hunted for centuries in Liadong Gulf of China; a total of 30,395 seals were harvested from 1930–90 (Dong and Shen, 1991). Prior to 1970, there were no harvest limits set by the Russians in the Okhotsk and Bering Seas. According to Popov,[13] the harvest limits in 1970 were set at 7,000 in the Okhotsk Sea (5,000 from ships and 2,000 from shore) and 8,000 in the Bering Sea (6,000 from ships and 2,000 from shore), or roughly equal to 5% of the presumed total population (about 300,000 by back-calculation). During the 18–20 years prior to this harvest limit, the combined annual catch of both seas did not exceed 10,000–15,000, less than 9.4% of the presumed spotted seal population (Tikhomirov, 1966b; Popov[13]). According to Mineev (1981, 1984), from 1969 to 1983, annual harvests by Soviet ship-based operations in the Bering Sea ranged from 1,000 to 5,000 spotted seals and averaged 3,292 (SD=1,205). Shore-based operations from 1969–1983 ranged from 14 taken in 1979 to 707 taken in 1971 and averaged 347 (SD=251). Records for shore-based operations in the Chukchi Sea were only reported for a few years; the largest take of 325 occurred in 1979. The combined harvest for 1981 to 1983

[9] Burns, J. J., and F. H. Fay. 1973. Comparative biology of Bering Sea harbor seal populations. *In* Proc. 23rd Alaska Sci. Conf., College, Alaska (Alaska Div. Am. Assoc. Adv. Sci.), p. 28 (abstr.).

[10] Burns, J. J., L. H. Shapiro, and F. H. Fay. 1981. Ice as marine mammal habitat in the Bering Sea. *In* D. W. Hood and J. A. Calder (Editors), The eastern Bering Sea shelf: oceanography and resources. Vol. 2, p. 781-797. U.S. Dep. Commer., NOAA, Off. Mar. Pollut. Assess., Juneau, Alaska.

[11] Burns, J. J. and S. J. Harbo. 1977. An aerial census of spotted seal, *Phoca vitulina largha*, and walruses, *Odobenus rosmarus*, in the ice front of Bering Sea. NOAA Environ. Res. Lab., Boulder, Colo., Final Rep., Res. Unit 231, 73 p.

[12] Nelson, R. K. 1981. Harvest of the sea: coastal subsistence in modern Wainwright. North Slope Borough, Barrow, Alaska, 125 p.

[13] Popov, V. N. 1976. Status of main ice forms of seals inhabiting waters of the U.S.S.R. and adjacent to the country marine areas. FAO Rep. ACMRR/MM/SC/51, 17 p.

was less than 100 seals. The Soviet harvest was monitored by the Ministry of Fisheries, which required only that species and number taken be recorded.

Alaska subsistence hunters do not take enough spotted seals to warrant a collection program exclusive to this species (Quakenbush, 1988). Alaska's subsistence harvest averaged about 2,400 annually between 1966 and 1976 (ranging 850 to 3,600), making spotted seals one of the major subsistence resources in the Bering Strait and Yukon-Kuskokwim regions (Lowry, 1984). From September 1985 to June 1986, a combined harvest of 986 animals occurred in five Alaska villages (Iya, unpubl. data, Quakenbush, 1988). Relatively fewer spotted seals are taken in the subsistence hunt in the northern limits of their range: during a three-year study April 1987–1990, an average of only 3 seals/yr were taken between Wainwright and Barrow (Braund et al.[14]). In 1992, approximately 437 spotted seals were harvested in northern Bristol Bay (Wolfe and Mischler, 1993), but reliable information on harvests in other regions was not available. Large variances and inconsistencies in the number of spotted seals harvested are likely because survey methodologies differ among communities, animals struck and lost are not included in harvest estimates, and misidentifications of spotted seals as harbor seals are possible in regions where their ranges overlap (Wolfe[15]).

Mortality

Gross annual pup production for Bering Sea spotted seals was estimated at 20–25%, based on data collected from the Okhotsk Sea population (Lowry, 1984; Popov[13]). First year mortality could be as high as 45% but may decline to 8% in succeeding years (Popov[13]), and mortality could be as low as 4–5% after 4 years of age (Lowry, 1984). As a result, adult recruitment is expected to range from 9 to 11%. At this level of recruitment, an incidental take by commercial trawl fisheries of 22 seals over a 9-year period, which is less than 0.01% of the adult and juvenile population, would have a negligible impact on the population (Loughlin et al., 1983).

According to an appraisal of marine mammal-fisheries interactions in the Bering Sea (Loughlin and Jones, 1984), spotted seals have a relatively high likelihood of interaction with commercial fisheries' interests. From 1990 to 1992, logbook reports (albeit with possible negative bias (Credle et al., 1994)) collected by commercial fishery boat operators indicated a yearly average of one injury and one mortality from gear interaction, and one injury and 0.7 mortalities due to legal deterrence (Small and DeMaster[16]). The fisheries involved were the Alaska Peninsula salmon drift gillnet and the Bristol Bay salmon set and drift gillnet. The effects of the commercial harvest of spotted seals by the Russians and U.S. native subsistence takes, as well as competition between seals and fisheries for prey, have a potentially greater impact than incidental take by commercial trawl fisheries. The possibility of negative impacts from competition with fisheries cannot be disregarded, particularly since other Bering Sea pinniped populations which feed on walleye pollock, *Theragra chalcogramma,* are declining (Merrick et al., 1987).

Prey Preference

Spotted seals concentrate near large runs of spawning fishes, such as Pacific salmon, *Oncorhynchus* spp.; herring, *Clupea* spp.; capelin, *Mallotus villosus*; and rainbow smelt, *Osmerus mordax*, or locally abundant fishes such as Arctic cod, *Boreogadus saida,* and Pacific sand lance, *Ammodytes hexapterus* (Bukhtiyarov et al., 1984; Ognev, 1935; Tikhomirov, 1966b; Gol'tsev, 1971; Frost et al.[17]). From late May to July, and sometimes until August, herring and capelin spawn in northern Bristol Bay and along the coast south of Norton Sound (Frost et al.[18]). Spotted seals feed intensively on these fish as they approach the coast prior to and during spawning (Burns et al.[6]; Frost et al.[18]). At this time the shorefast ice is deteriorating and provides resting sites in the vicinity of the fish resources. Hundreds of seals have been seen in dense concentrations on the shorefast ice along the Yukon-Kuskokwim Delta region and in Norton Sound (Burns et al.[6]).

Lowry et al.[19] found Arctic cod were preferred by spotted seals in the northern Bering Sea during the spring, from Kotzebue to Wainwright in the summer, and near Kasegaluk Lagoon from July to September. Herring were preferred near Shishmaref from July through October and in Kotzebue Sound in October. Frost et al.[8] found shrimp (especially crangonids) in spotted seal stomachs at Shishmaref and Wainwright. They did not find Pacific sand lance in spotted seal stomachs at Kasegaluk Lagoon. In the freshwater rivers of Avak Inlet, spotted seals are known to eat Bering ciscos, *Coregonus laurettae,* and other fish (Nelson[12]).

Makhnyr and Perlov (1988) reported that spotted seals along the Sakhalin Coast ate pink salmon, *Oncorhynchus gorbuscha*, found in 83% of the stomachs sampled (n=17), kundzha, *Salvelinus leucomaenis* in 33%, redfin, *Leuciscus brandti* in 33%, *Myoxocephalus* sp. in 33%, Pleuronectids in 33%, and crab (unknown sp.) in 17%.

[14] Braund, S. R., K. Brewster, L. Moorehead, T. P. Holmes, and J. A. Kruse. 1993. North Slope subsistence study: Barrow, 1987, 1988 and 1989. U.S. Dep. Inter., Minerals Manage. Serv., Anchorage, Alaska, OCS Final Rep. 149 (MMS 91-0086), 466 p.

[15] Wolfe, R. J. Alaska Dep. Fish Game, Div. Subsistence, P.O. Box 25526, Juneau, AK 99802-5526. Letter of 22 Nov. 1991 to Brad Hanson, NMFS, Juneau, Alaska.

[16] Small, R. J., and D. P. DeMaster. 1995. Alaska region status assessment report. Rep. Off. Protect. Resour., NMFS, 1335 East-West Hwy., Silver Spring, MD 20910, 93 p.

[17] Frost, K. J., L. F. Lowry, and J. J. Burns. 1983. Distribution of marine mammals in the coastal zone of the eastern Chukchi Sea during summer and autumn. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 20(1983):563–650.

[18] Frost, K. J., L. F. Lowry, and J. J. Burns. 1982. Distribution of marine mammals in the coastal zone of the Bering Sea during summer and autumn. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 20(1983):365–562.

[19] Lowry, L. F., K. J. Frost, and J. J. Burns. 1981. Trophic relationships among ice-inhabiting phocid seals and functionally related marine mammals in the Chukchi Sea. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 11(1981): 37–95.

Fedoseev and Bukhtiyarov[20] found that spotted seals in the Okhotsk Sea fed on walleye pollock, *Theragra chalcogramma* (in 65% of the stomachs sampled (n=23)), navaga, *Eleginus navaga* (in 5%), Pacific sand lance (in 5%), and euphausiids and decapods (in 16%). According to Bukhtiyarov et al. (1984), spotted seals in Karaginski feed on Pacific sand lance (which comprised 32% of total weight of stomach contents (n=68)), herring (13%), and *Octopus* sp. (10%). In the Gulf of Anadyr, spotted seals feed on Arctic cod (which comprised 29% of the total weight of stomach contents (n=42)), pollock (13%), and sand lance (9%). Octopus occurred in 40% of all stomachs containing food.

Various prey were consumed in greater amounts depending on area: pollock in the Central Bering Sea and the Okhotsk Sea; capelin in the southeast Bering Sea; Arctic cod in the northern Bering Sea and the Gulf of Anadyr; Pacific sand lance in Karaginski Gulf; and herring and smelt in the southeastern Chukchi Sea and southwestern Seward Peninsula (Bukhtiyarov et al., 1984). It is unknown how much prey selection has been affected by changes in prey abundance as a result of commercial fisheries.

Age differences in diet were noted by Bukhtiyarov et al. (1984) and were found to be similar to those reported by Gol'tsev (1971) and Popov and Bukhtiyarov[21]. In pups, 9 of 11 species of prey found in stomachs were crustaceans, one-fourth of the stomachs had Pacific sand lance, and one-half of the stomachs contained algae. There was an apparent change in diet with age: 1-year olds concentrated on small crustaceans (and included algae, sticks, and other debris); 1- to 4-year olds ate fish, larger shrimp, and occasionally octopus; seals over 4-years old consumed fish and showed a marked increase in the number of benthic organisms eaten, such as crabs and octopus (Gol'tsev, 1971; Bukhtiyarov et al., 1984). Impacts of commercial fisheries on spotted seals through resource competition may have age-related components, particularly with species preferred by both the fisheries and the seals, such as groundfish and herring (Loughlin and Jones, 1984). It is unknown how much competition with fisheries will affect the abundance of spotted seals.

Historical Abundance Records

No accurate estimates of worldwide spotted seal abundance are available. The Russians have approximated an abundance of 450,000, but "no satisfactory method of accurately censusing *largha* seals has been attempted to date" (Burns[22], p. 14).

Historical population estimates for the breeding concentrations in Liadong Gulf were derived from harvest data (Dong and Shen, 1991). In the early 1930's the population consisted of an estimated 7,100 animals. The highest number of seals was documented in 1940 at 8,137. After 1940, the population began to decline and reached its lowest level in 1979 at 2,267 seals. From 1979 to 1982, the population appeared to stabilize at 2,300 individuals before rising again to 4,500 in 1990. In 1986, Wang (1986) reported that numbers in this region were decreasing, and the Chinese government had given the spotted seal national protection status.

The only breeding population showing signs of increasing is in Peter the Great Bay. Trukhin and Kosygin (1988) noted an increase from a few hundred spotted seals in 1968 (Kosygin and Tikhomirov, 1970) to over 1,000 in 1986.

Aerial surveys of the Okhotsk Sea in 1976 and 1979 resulted in an approximation of 200,000 spotted seals (Fedoseev, 1984). Subsequent surveys of the Okhotsk Sea using helicopters in 1986 and 1987 resulted in an estimate of 50,000 (Lagerev, 1988). These estimates, if they are a true comparison to data from Fedoseev (1984), suggest a manifold drop in abundance of spotted seals in the Okhotsk Sea.

Aerial surveys along portions of the Gulf of Karaginski and the Gulf of Anadyr during April–May 1987 resulted in estimates of 28,000 and 50,000, respectively (Fedoseev et al., 1988). Vessel-supported aerial surveys of the Gulf of Karaginski in May 1986 and May and June 1987 provided a population estimate of 10,700 (Burkanov et al., 1988). Burkanov et al. (1988) argued that Fedoseev inappropriately stratified his surveys along the coast of eastern Kamchatka in 1979 and 1987, leading to errors in abundance estimation.

In the Bering Sea, there were 200,000 to 250,000 spotted seals according to rough estimates from Alaska Department of Fish and Game studies in 1968, 1971, and 1972 (Burns[22]). These estimates were based on indirect methods and relative indices of abundance (Burns[22]). According to Burns and Harbo,[11] during April and May, in areas where adult seals are caring for pups, there may be 1 to 3 seals in the water for each one seen on the ice. Braham et al. (1984) estimated an abundance of 10,876 spotted seals (based on a stratification of the sampled area) or 13,125 spotted seals (with the area unstratified), but seals in the water were not included in these calculations. These estimates were developed from aerial surveys over the seals' prime habitat in the eastern Bering Sea in April 1976. No systematic studies of the distribution and abundance of spotted seals have been made for the Alaskan Bering Sea populations since the 1970's (Frost et al.[8]), though aerial surveys of portions of this population have been conducted during the summer in Kasegaluk Lagoon (Frost et al., 1993) and Kotzebue Sound (Frost and Lowry[23]). Fedoseev et al. (1988) surveyed only a portion of spotted seals range in the western

[20] Fedoseev, G. A., and Y. A. Bukhtiyarov. 1972. Food of seals of the Okhotsk Sea. *In* V. A. Arsen'ev, V. M. Bel'kovich, V. A. Zemskii, B. A. Zenkovich, V. E. Sokolov, and K. K. Chapskii (Editors), Abstracts of papers, Fifth All-Union Conference on Studies of Marine Mammals, p. 110-112. Akad. Nauk SSSR, Makhachkala. (Transl. from Russ. by F. H. Fay, Univ. Alaska, Fairbanks, 1977, 2 p.)

[21] Popov, V. N., and Y. A. Bukhtiyarov. 1975. On age-related changes in feeding and helminth faunas of spotted seals in the Okhotsk Sea. Abstracts 6th All-Union Conf. Mar. Mammals, 2:62-64. Naukova Dumka, Kiev.

[22] Burns, J. J. 1973. Marine mammal report. Alaska Dep. Fish Game, Pittman-Robertson Proj. Rep. W-17-3, 4, and 5, 29 p.

[23] Frost, K. J., and L. F. Lowry. 1989. Marine mammals of Kotzebue Sound and southeastern Hope Basin. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. (1989):335-384.

Bering Sea in 1987 and estimated 60,000 seals were present, based on 431 sightings seen on only 1,781 km of trackline. These results were extrapolated to an estimated 100,000 spotted seals for the entire Bering Sea.

In response to a need for an updated assessment of seal abundance, NMML conducted aerial surveys in 1992 and 1993.

Survey Methods, 1992–93

Survey Areas

Spring

The NMML aerial surveys conducted in the spring of 1992 were designed to take advantage of the spotted seals known seasonal use of the Bering Sea ice front where they haul out for breeding, pupping, and molting (Braham et al., 1984). The boundaries of the study area were roughly west of shorefast (solid) ice, north of ice-free waters, east of long. 171°W (limited by aircraft fuel capacity), and south of the Bering Strait.

Transects were selected in a nonrandom manner to maximize sighting opportunities. Survey effort focused on areas with sea ice because aerial identification of pinnipeds in the water is not reliable, and effort over solid ice was minimized for the lack of haul-out opportunity for seals. These methods were consistent with those developed in the mid-1970's (Braham et al., 1984).

The Navy-NOAA Joint Ice Center[24] provided ice analysis and forecast charts which were used to determine survey target areas and to examine the extent of different ice types relative to what we sampled. We used a Hi-8[25] video camera mounted in the aircraft's nose to record representative ice conditions.

Summer

The 1992 summer surveys were conducted primarily to establish where spotted seals haul out along the Alaska coastline. The search area was based on subsistence harvest data and historical and recent scientific reports. The surveys were coastal and included most of the shoreline area from Cape Newenham in Bristol Bay north to Point Barrow.

The search area for surveys conducted in the summer of 1993 was based on data in recent scientific reports and our observations made in August 1992. The surveys included most of the shoreline from the Kuskokwim Delta north to Kotzebue Sound. Surveys were also made around Nunivak Island and St. Lawrence Island, areas that were not completely surveyed in 1992 due to poor weather conditions. Whenever possible, surveys were synchronized with low tides at known haul-out sites.

Aircraft and Survey Protocol

The survey aircraft used in both 1992 and 1993 was a twin-engine DeHavilland Twin Otter. Its high wings and specially equipped bubble windows (44.5 cm × 67.3 cm × 25.4 cm Plexiglas) allowed for excellent visibility for observers in the forward positions immediately behind the cockpit. Typically, aircraft speed was 215 km/h (120 knots), and altitude was 150 m (500 ft). During coastline surveys, the trackline was kept at 500 m (0.25 n.mi.) offshore to avoid disturbing spotted seals concentrated on haul-out sites in the summer. Known haul-out sites were approached from downwind and at altitudes ranging from 400 to 1,370 m (1,300–4,500 ft) to minimize the startle response. Line transect grids were flown wherever concentrations of seals were found in the water. A Global Positioning System (GPS) and moving map display program on the in-flight computer allowed for accurate location data with real-time assessment of the trackline.

When flying offshore transects, primary observers were stationed on the left and right sides of the aircraft, directly behind the pilots. Secondary observers (1–3) were stationed aft, including a computer operator who also provided sighting information whenever possible. The computer operator logged survey effort, environmental conditions (visibility, weather, ice conditions, and sea state), and sighting information (whether on the left or right side of the aircraft, number of animals, species, behavior, inclinometer angle, notes on camera firings, and relevant comments) into an onboard computer. Time and location were recorded automatically every minute and with each sighting entry.

During coastal surveys, two observers searched the shoreward side of the aircraft, and one searched the seaward side. When seal groups were circled, all observations were made from the left side of the aircraft: the forward observer used binoculars to estimate group size, a second observer made estimates without optical aids, and the third observer took photographs. Aerial counts of seals were made by tallying individuals when groups were small, or by rapidly counting by tens or fifties, depending on densities.

Concentrations of seals, as found on coastal haul-outs during the summer, were photographed for detailed analysis in the laboratory. Photographic equipment included hand-held single-lens reflex 35 mm cameras (Nikon F3) with motordrive, automatic aperture, and a 70-210 mm zoom lens. The zoom lenses allowed rapid changes between overview photographs and magnified shots of specific sites. One camera was loaded with T-MAX 400 professional black and white print film; the other camera had Ektachrome 200 daylight color slide film. A Hi-8 video camera was also available for overview shots of haul-out sites. A vertically mounted Strike Camera was used to photograph overviews of haul-out sites in 1992. The Strike Camera is a military, low-level aerial camera with a 180° fore and aft and 41° lateral view using a 7.7 cm *f*2.8 lens. The magazine has capacity for 76 m of film. Each frame is 24.1 × 5.8 cm.

Laboratory Analysis

Aerial photographs of seal concentrations were projected onto a paper screen to enlarge the images and to allow each seal to be marked off as it was counted. Image quality ranged from excellent, where seal counts were highly reliable, to useless, generally due to image blur. Only when the photographs could improve the aerial estimates were the image counts used in further analy-

[24] Navy-NOAA Joint Ice Center, Customer Service Branch, National Climatic Data Center, Federal Bldg., Asheville, NC 28801-2696.

[25] Mention of trade names or commercial firms does not necessarily imply endorsement by the National Marine Fisheries Service, NOAA.

sis. Seals entering the water at a haul-out site were included in the count of hauled-out animals to better represent the expected number without the influence of the survey aircraft. Counts from photographs provided advantages over aerial estimates in that time was not limited, and multiple views of the seals could be studied without the distractions of in-flight demands. Also, several different observers could independently study the photographs, providing comparable counts. Two observers made counts from photos in 1992; four made the counts in 1993. All of these counters, except one, had been involved in aerial surveys of pinnipeds and previous counts of seals in photographs. In a manner similar to Sease et al. (1993), counts were repeated when discrepancies of over 10% occurred between counters. In most cases these discrepancies were discussed and sometimes involved additional recounts. Maximum counts were used where multiple counts were made by an individual observer. Paired t-tests were run on each observer's counts relative to mean counts of the other observers. Results indicated that the counts of 3 of the 4 observers were not significantly different (P = 0.05). Accordingly, records from the fourth person, although an experienced observer, were not used in further analysis. No significant differences were detected between aerial estimates and photo counts where both were available from respective sites (paired t-test: $P_{1992} = 0.29$; $P_{1993} = 0.11$). To equally weight results from both efforts, means of aerial estimates ($\bar{x}_{aerial}$) and photo counts ($\bar{x}_{photo}$) were averaged to establish "best estimates" ($\bar{x}_1$) at each respective site. That is,

$$\bar{x}_1 = \frac{(\bar{x}_{aerial} + \bar{x}_{photo})}{2}.$$

Where no photographs were taken or photo images were extremely blurry, only aerial estimates were used. A coefficient of variance (CV) was established for each site based on the multiple samplings on the day with maximum counts (generally where n = 3 or 4); but when only one sampling was available (n = 1), the maximum CV from sites sampled multiple times was used.

Results

Spring Surveys

Ice Fringe

The first survey, on 16 April 1992, was over an area south of the ice front in northern Bristol Bay west to approximately long. 165°W (Fig. 2; 4 flight hours). Sea ice covered 10–30% of the general area, with ice covering 50–80% across some bands. The ice was thin, and only a few areas had bergs large enough to support marine mammals. A variety of pinnipeds were seen: 83 walruses, *Odobenus rosmarus*; 2 Steller sea lions, *Eumetopias jubatus*; 2 harbor seals, and 6 unidentified pinnipeds), but no spotted seals were identified.

Ice Front

Sea ice in the vicinity of Nunivak Island was surveyed on 17 and 18 April (Fig. 2; 8 flight hours). Shorefast ice extended 28 km offshore (to long. 165°40'W) where dense but fractured ice of the ice front was encountered. This dense ice continued to the western limit of the survey area (long. 170°W). Ice charts for 13 April showed 90–100% ice coverage for this area with ice densities ranging from 30–120 cm. This ice type dominated the Bering Sea from the Bering Strait to the southern ice edge which lay along the continental ice shelf. Fog prevented surveying west of long. 170°W; otherwise, sighting conditions were ideal with low wind and high overcast. Sightings in the ice front included 57 spotted seals (Fig. 2) and many other pinnipeds (51 bearded seals, 8 ringed seals, 333 walruses, and 34 unidentified pinnipeds). Sighting times and locations are available in Table 1 of Rugh et al.[26]. The spotted seal sighting density in the ice front, between lat. 58°50'N and 60°40'N, was 0.52 seals per km^2 (0.28/n.m.^{2}). Sighting rates of ice seals over sea ice were 3–4 times higher than sightings over water, and in the latter case species identifications could rarely be made confidently.

[26] Rugh, D. J., K. E. W. Shelden, D. E. Withrow, H. W. Braham, and R. P. Angliss. 1993. Spotted seal (*Phoca largha*) distribution and abundance in Alaska, 1992. *In* Annu. Rep. to MMPA Assessment Program, Off. Prot. Resour., NMFS, NOAA, 1335 East-West Hwy, Silver Spring MD 20910, p. 98-127.

Table 1.—Descriptions of sites where spotted seal concentrations were seen along the western coast of Alaska.

Site code	Descriptive location	Substrate	Latitude	Longitude	Nearest village
A	Pilot Bar[1], easternmost shoal Kuskokwim Bay	Sandy shoal	59°33'N	162°17'W	Quinhagak 17 mi NE
B	Middle Bar[1], Kuskokwim Bay	"	59°37'N	162°26'W	Quinhagak 18 mi ENE
C	North Bar[1], Kuskokwim Bay	"	59°38'N	162°35'W	Quinhagak 22 mi E
D	Shoals south of Kipnuk, in Kuskokwim Bay	"	59°29'N	162°50'W	Kwigillingok 23 mi NNW
E	"	"	59°34'N	163°20'W	Kwigillingok 19 mi NNE
F	"	"	59°34'N	163°35'W	Kwigillingok 23 mi NE
G	"	"	59°40'N	163°49'W	Kwigillingok 24 mi ENE
H	Nunivak I.	Nearshore	60°00'N	166°00'W	
I	Neragon I.,Scammon Bay	"	61°59'N	165°56'W	Romanzof 16 mi S
J	Norton Sd.	At sea	63° to 65°N	161° to 167°W	
K	Carolyn I.,Golovnin Bay	Near shore	64°27'N	162°50'W	Golovin 7 mi NW
L	Southeast Cape, St. Lawrence I.	"	62°58'N	169°45'W	Savoonga 56 mi NE
M	West end Seward Pen.	"	64°45' to 65°35'N	166°30' to 168°00'W	
N	Cape Espenberg	"	66°37'N	163°33'W	Kotzebue 30 mi NE
O	Rex Pt., Goodhope Bay	"	66°05'N	163°19'W	Deering 16 mi W
P	Avak Inlet, Kasegaluk L.	Sandy shoal	70°16'N	161°37'W	Wainwright 40 mi NE
Q	Akoliakatat, Kasegaluk L.	"	70°18'N	161°21'W	Wainwright 32 mi NE
R	Kasegaluk L.	In water	70°10'N	162°00'W	Wainwright 40 mi NE

[1] Names used in Frost et al. (text footnote 18).

Ice Pack

From 18 to 20 April, surveys were flown north of the ice front in the northern Bering Sea, including around St. Lawrence Island, and over the shear zone in the Chukchi Sea near the Alaskan coast as far north as Point Barrow (Fig. 2; 10 flight hours). Dense, large ice floes with fractures dominated the eastern Bering Sea. Although visibility was good, no spotted seals were seen north of the ice front. Pinniped sightings included 46 bearded seals, 32 ringed seals, 559 walruses, and 3 unidentified pinnipeds.

Late Spring Ice

Nonsystematic surveys were conducted from Barrow to Bethel 5–7 June (Fig. 3; 16 flight hours). Ice conditions varied from 90% ice coverage around Barrow to predominately open seas with only bands of ice in the northern Bering Sea and open water south of Nunivak Island. Four seals, probably spotted seals, were seen in the waters around St. Lawrence Island. Between Nome and Bethel, 9 seals were seen, and all but one were within 74 km of each other in northern Norton Sound (Fig. 3). Other pinniped sightings included 9 bearded seals, 669 ringed seals, 1 Steller sea lion, 180 walruses, and 29 unidentified pinnipeds.

Summer Surveys

Survey Dates and Area Covered

The western coast of Alaska was surveyed 16–24 August 1992 (Fig. 4; 54 flight hours) and 5–17 September 1993 (Fig. 5; 33 flight hours), with many areas surveyed multiple times. Survey tracklines included offshore shoals, islets, and islands from Cape Newenham (at the western edge of Bristol Bay) to Point Barrow (northernmost part of Alaska). Nunivak and St. Lawrence Islands were included in this survey but not the Pribilof, St. Matthew, and Diomede Islands. Visibility of the surveyed coastline was generally good to excellent. Table 5 in Rugh et al.[26] and Table 6 in Rugh et al.[27] provide details on environmental conditions encountered at these sites, including wind speed and direction, weather, temperature, and tide.

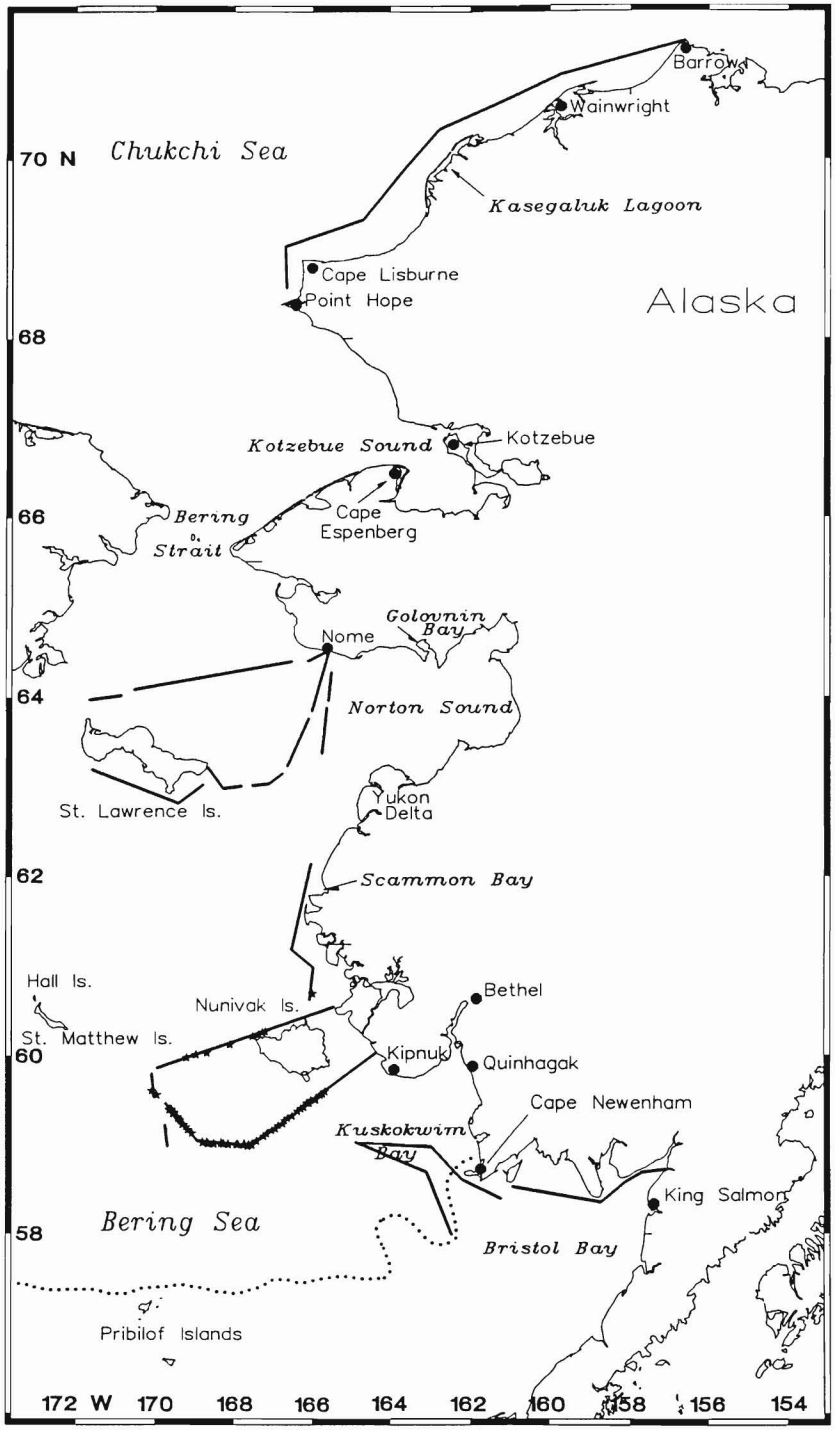

Figure 2.—Map of western Alaska showing aerial survey tracklines (solid lines) and spotted seal sightings (stars) during surveys conducted by NMML in April 1992. The dotted line indicates an approximated ice edge typical for these dates.

[27] Rugh, D. J., K. E. W. Shelden, and D. E. Withrow. 1994. Spotted seal, *Phoca largha*, studies in Alaska, 1993. *In* Annu. Rep. to MMPA Population Assessment Program, Off. Prot. Resour., NMFS, NOAA, 1335 East-West Hwy., Silver Spring MD 20910, p. 95-125.

Locations of Seals

Spotted seal groups were found at the locations listed in Table 1 and in Figures 4 and 5. The principal locations with seal concentrations were (ordered from south to north) Kuskokwim Bay, Nunivak Island, Scammon Bay, Golovnin Bay, St. Lawrence Island, Cape Espenberg, Good Hope Bay, and Kasegaluk Lagoon. In 1992, seals were hauled out on the Kuskokwim shoals, on Neragon Island (Scammon Bay), and on sand bars in Kasegaluk Lagoon. Seals were concentrated in the water but not hauled out at Golovnin Bay and Cape Espenberg. In 1993, all seals observed north of Kuskokwim Bay were in the water, often close to shore. Line transects were conducted over groups observed off Neragon Island in Scammon Bay, Carolyn Island in Golovnin Bay, St. Lawrence Island, and Cape Espenberg. We also checked on local reports of seal sightings well inland on the Noatak and Yukon Rivers, but no seals were seen.

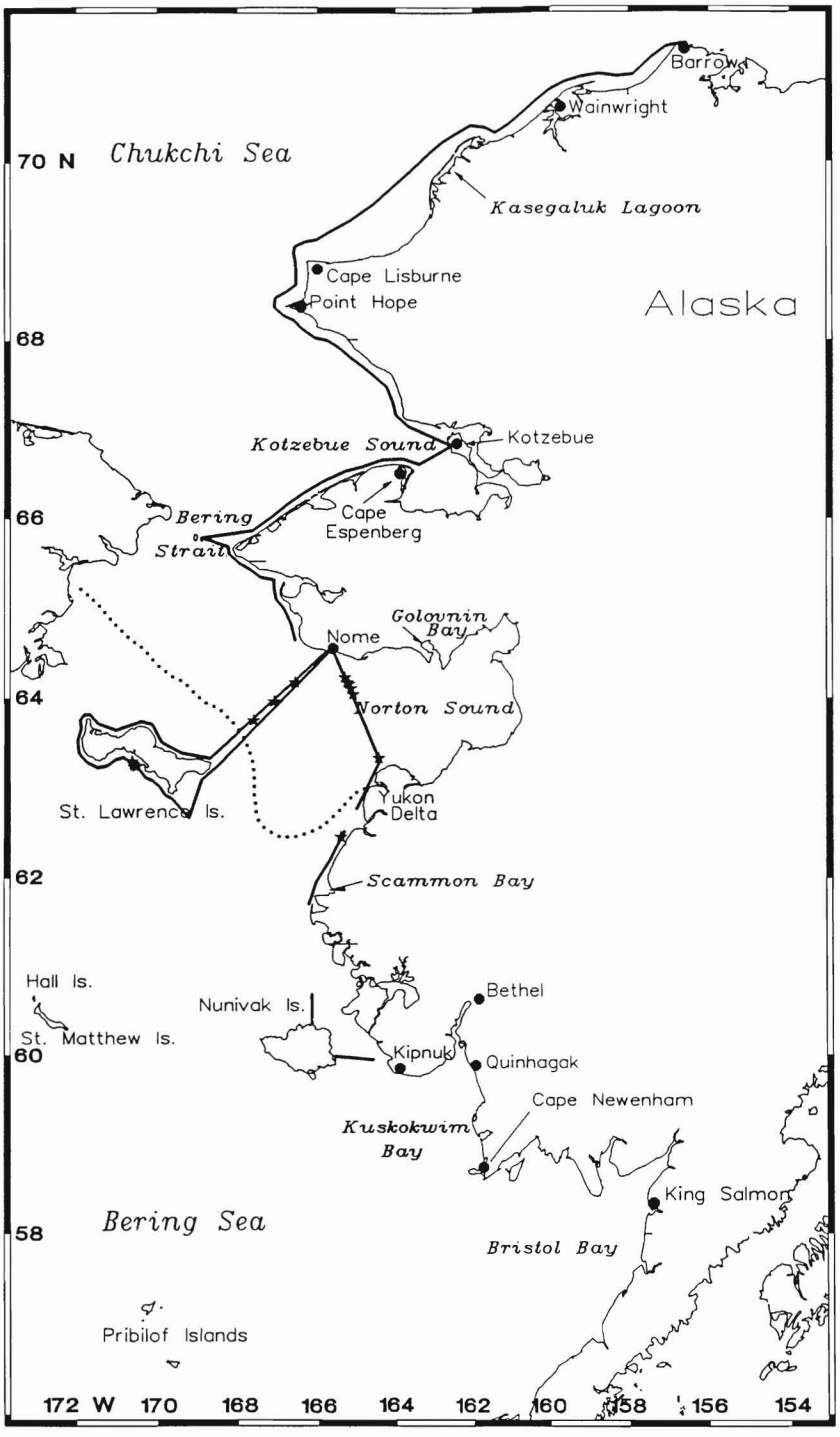

Figure 3.—Map of western Alaska showing aerial survey tracklines (solid lines) and spotted seal sightings (stars) during surveys conducted by NMML in June 1992. The dotted line indicates an approximated ice edge typical for these dates.

Group Size

Seal concentrations on land ranged from 2 to over 500, but were generally >50. Seals on land were typically close to each other, often within a body length. Seals in the water were sometimes concentrated within a few square kilometers, but they were much more dispersed than when on land.

Summary Estimates

Estimates are summarized by general locations in Table 2. The August 1992 sum of counts from all sites, without including duplicates, was 2,109 seals; the sum from September 1993 was 2,968, though some sites were not surveyed in both years. Using mean counts from days with highest estimates for all sites visited in either 1992 or 1993, there were 3,570 seals seen and 3,356 seals hauled out (CV = 0.06).

Kuskokwim Bay was the dominant sighting area, incorporating 72% of the counts when all sites from both years were considered; however, an unknown proportion of these animals may be harbor seals. The Kuskokwim shoals were surveyed thoroughly on only one day in August 1992 and on 3 days in September 1993.

Discussion

The aerial surveys conducted in 1992 and 1993 corroborated information reported in the literature on the distribution, behavior, and relative abundance of spotted seals. Furthermore, the summer surveys have provided the most

thorough coverage yet of coastal haul-out sites in western Alaska. In 1992, aerial survey methods were tested and distributional studies of spotted seals were conducted over the Bering Sea pack ice in the spring and along the Alaska coast during the summer. The three aerial surveys conducted in 1992 between Bristol Bay and Point Barrow provided a geographic delineation of spotted seal distribution. In 1993, the survey effort concentrated on known haul-out sites in September. Surveys of the ice front were not conducted in the spring of 1993 due to funding limitations, aircraft logistics, and data collection efficiency. Only one-third of the spring range can be adequately surveyed with the aircraft available, and previous efforts have shown the sample size per unit time of search makes it more productive to survey haul-out sites during the ice-free period than to survey over sea ice in the spring. For example, Braham et al. (1984) recorded 552 spotted seals during 83 hours of aerial surveys over the spring ice (0.7 seals per km), whereas Rugh et al.[26] recorded 4,100 seals (albeit clumped and including some duplicate sightings) during 54 hours of aerial surveys over 3,200 km of shore during August (1.3 seals per km). It was determined that summer surveys could at least provide a minimum population size through a raw count of visible seals, more accurately meeting the proposed legislative mandates for managing fisheries interactions than spring surveys.

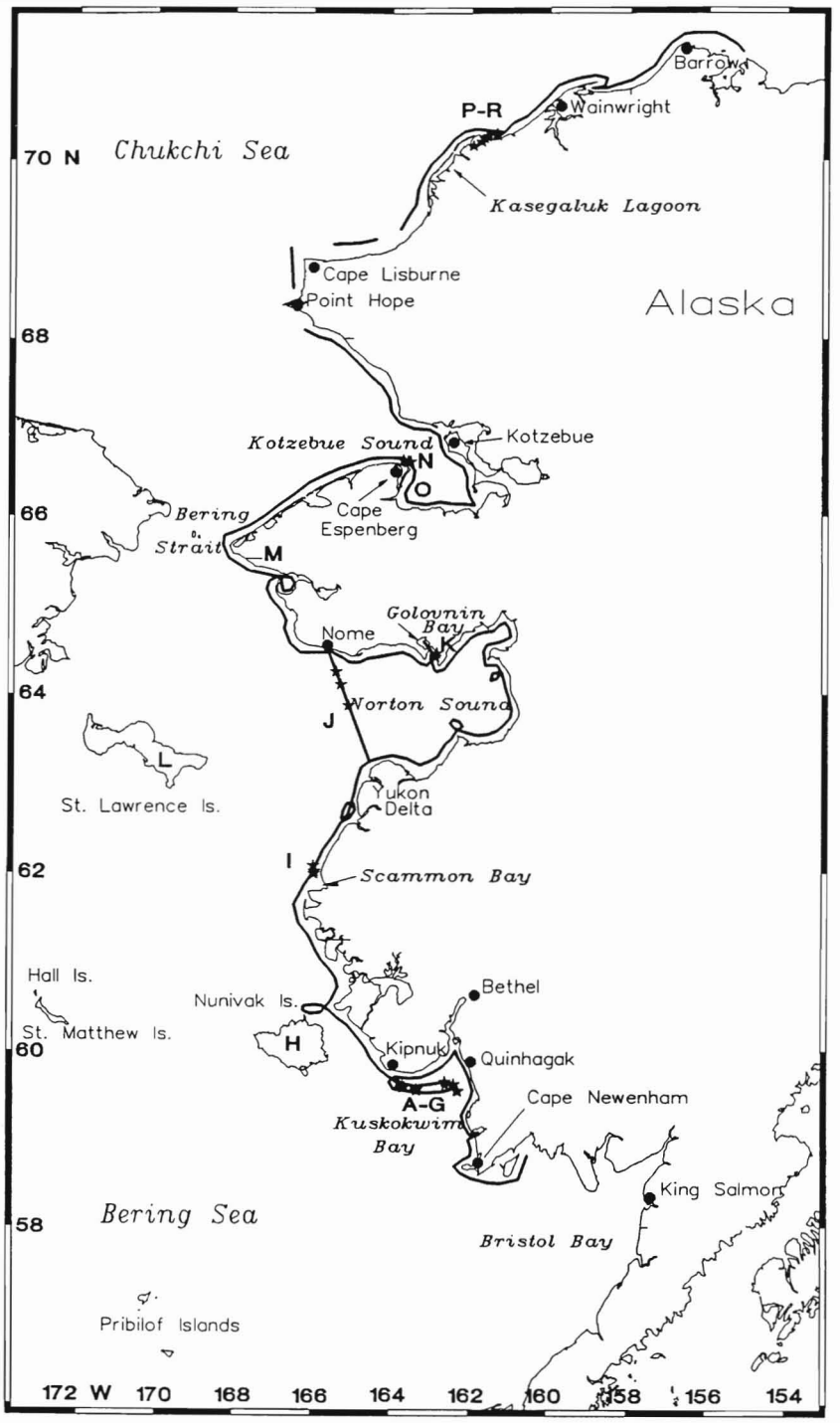

Figure 4.—Map of western Alaska showing aerial survey tracklines (solid lines) and spotted seal sightings (stars) during surveys conducted by NMML in August 1992. Lettered sighting concentrations are listed in Table 2.

Distribution

Spring

Our 1992 research confirmed the reported distribution of spotted seals in April and June within the area that we surveyed east of long. 170°W. No spotted seals were seen in open water areas or in the ice fringe south of the Bering Sea ice front in April, perhaps in part due to the difficulty of finding and identifying pinnipeds in the water. We found spotted seals throughout the 170–250 km wide ice front. North of the front, no spotted seals were seen. Although our sample effort was small, the distribution of seal sightings (Fig. 2) was similar to distributions reported by others, such as Burns et al.[6] and Braham et al. (1984), except that the ice front was much wider than the 15–65 km described by Burns (1970) and Fay (1974).

We found densities of 0.52 spotted seals per km^2 over the ice front, comparable to the 0.6 per km^2 found by Fedoseev (1984). However, in ship-based surveys conducted amongst ice remnants in the Bering Sea east of long. 170°W 24 May–6 June 1977, Burns et al.[6] found seal densities of 2–6/km^2, of which 80% to 94% were spotted seals (i.e., 1.6–5.6 spotted seals/km^2). The remainder consisted of ribbon seals (5%) and bearded and ringed seals (about 1% each). Burns et al.[6] also conducted aerial surveys 28 May–9 June 1978 and found seal densities of 1 to 5 per km^2 with densities rising from west to east across the Bering Sea. Bearded seals predominated in the west (74%) and spotted seals in the east (69%); ribbon seals made up about 12% overall and ringed seals about 4%. Burns et al.[6] found that spotted seals, relative to the other ice seals, had the broadest general distribution in the ice front. Kosygin (1966) found, of the seals available to hunters in the Gulf of Anadyr, 90% were ribbon seals and, in the eastern Bering Sea, 50% were spotted seals.

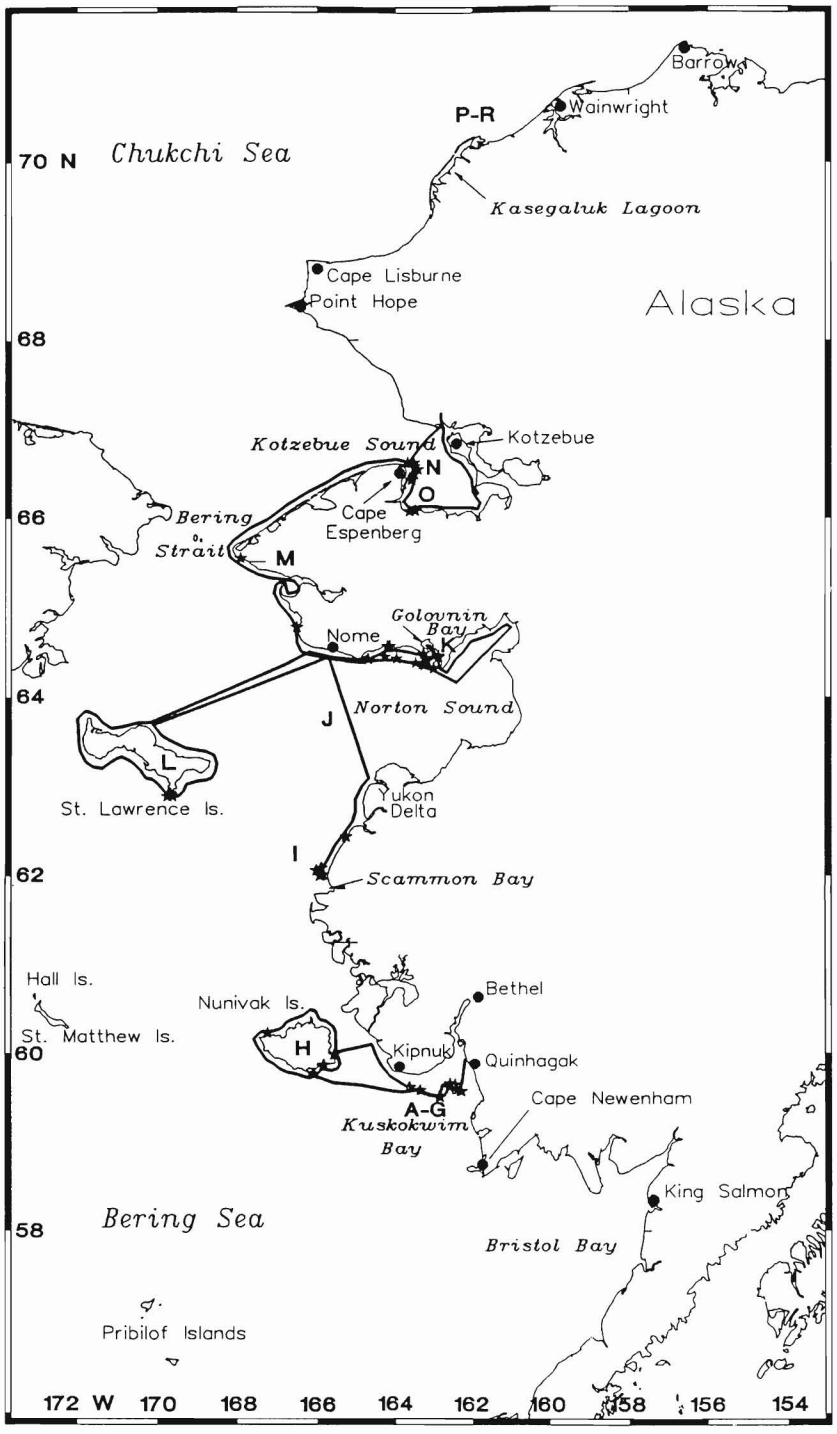

Figure 5.—Map of western Alaska showing aerial survey tracklines (solid lines) and spotted seal sightings (stars) during surveys conducted by NMML in September 1993. Lettered sighting concentrations are listed in Table 2.

Our sightings of spotted seals on large ice floes and shorefast ice in June were consistent with the literature (Burns et al.[6]). The seals concentrate on these deteriorating ice remnants until they become inadequate as rest sites, after which the animals use coastal haul-out sites.

Summer

Our surveys in August 1992 and September 1993 found spotted seals hauled out on sandy, low beaches on offshore shoals, islets, and islands. We did not find seals on grassy sites, as reported by Naito (1973), nor on rocky coasts, as reported in Russia by Tikhomirov (1966b). Although it was difficult to collect accurate counts of seals, our coverage of the west coast of Alaska was thorough enough that it is unlikely any large groups on land were missed. The sites where we found spotted seals (Table 1, Fig. 4, 5) have been reported as haul-out sites in the past (Frost et al.[18]; Frost and Lowry [23]); that is, no new haul-out sites were identified. Some consistency in site preferences was indicated by the repeated use of certain Kuskokwim shoals between days and between years, even when the previous survey was only hours before. Others have also seen large seal concentrations in Kuskokwim Bay. D.

Jonrowe and R. Baxter (in Frost et al.[18]) reported approximately 5,650 and 6,000 seals on bars near Quinhagak during aerial surveys for herring in Kuskokwim Bay 17 and 20 May 1978. Other sightings in this area go back to July 1972 (R. Baxter in Frost et al.[18]) and July 1973 (W. Arvey in Frost et al.[18]) as well as June 1977 (D. Jonrowe in Frost et al.[18]). Although these surveys were at different times of the year, the repeated sightings of large groups of seals show some inter-year consistency of haul-out use in this area. Unless other research teams are looking specifically for spotted seals, they might not report them because the seals are so elusive. Therefore, a lack of sightings reported from observers not specifically surveying for spotted seals does not necessarily indicate a lack of seals.

Table 2.—Best estimates of number of seals at each site surveyed during August 1992 and September 1993. The day with the highest overall estimate was used rather than highest estimates for each site.

Site name	Site code	1992	1993	Final estimate	CV
Kuskokwim Bay	A	300[1]	413[1]	2,558[1]	0.06
"	B	195[1]	220[1]		
"	C	473[1]	353[1]		
"	D	0	190[1]		
"	E	225[1]	558[1]		
"	F	175[1]	822[1]		
"	G	0	2[1]		
Nunivak I.	H	—[2]	185[1]	185[1]	0.39
Neragon I.	I	363[1]	56	363[1]	0.22
Norton Sd.	J	3	15	15	
Carolyn I.	K	52	7	52	
St. Lawrence I.	L	—[2]	18	18	
Seward Peninsula	M	0	3	3	
Cape Espenberg	N	>73	89	89	
Goodhope Bay	O	—[2]	37	37	
Kasegaluk Lagoon	P	0	—[2]	250[1]	0.28
"	Q	250[1]	—[2]		
"	R	0	—[2]		
Total				3,570	0.06

[1] Seals were hauled out.
[2] Site was not surveyed.

Factors Affecting Counts

Spotted seals in the water are difficult to detect from the air except in ideal conditions, and species identification is equivocal. When resting on ice, they are highly visible and fairly identifiable to the trained eye. On shore, seals are not as visible as on ice, but they can still be seen well ahead of the aircraft. Wherever we found spotted seals on land, they were in concentrations of 50 or more; in the water, seals were often alone or in relatively low densities. This characteristic of being in tightly clumped groups on shore (which increases chances of being alerted to approaching predators), along with the types of sites selected for hauling out (with a clear view of anything that might approach), and their immediate flight reaction to the presence of aircraft, all indicate the spotted seal's high sensitivity to intermittent disturbance. Proximity of villages may have a bearing on where seals choose to haul out. The seals' preference for offshore shoals and low elevation islets without vegetation could help maximize their ability to evade hunters or predators. Concentrations of animals seem to react more severely than the scattered small groups found on the sea ice in spring. The wariness of spotted seals on summer haul-out sites was some of the most extreme that we have experienced among marine mammals. Even when approaches were made at altitudes of 1,370 m, seals were observed entering into the water several kilometers ahead of the aircraft. In fact, the water disturbance from fleeing animals became a sighting cue. Wind noise, especially with accompanying surf sounds, can significantly mask aircraft noise. Also, aircraft approaches into the wind may minimize auditory impacts prior to passing the site. High winds may have more of an affect acoustically than aircraft altitudes.

Beyond the quiet approach, the most apparent factor in maximizing counts of hauled out seals in the summer may be to find them on the low end of a waning tide. A rising tide tends to concentrate resting seals near the water line as they retreat up the beach ahead of the rising water. It is easier to count seals during a waning tide when resting seals are more distributed across the beach. Although the study area had maximal tidal ranges less than 2.7 m, there may have been sufficient tidal influence to affect the seals haul-out behavior, either through availability of haul-out sites on the tidal flats or through influences the tides may have had on food resources, as described by Bel'kovich and Shchekotov (1993). Solar intensity, precipitation, availability of prey, and time since last disturbance may also be factors in determining how many seals are hauled out.

With most aerial surveys of pinnipeds at concentrated haul-out sites, counts from photographs provide far more accurate estimates of abundance than do visual estimates made from the aircraft. Photographs of spotted seals are difficult to analyze because they often show only a blur of escaping animals. Because the seals were usually off the beach by the time the aircraft passed, the camera had to be aimed well forward of the aircraft. This meant shooting through the aircraft's Plexiglas bubble windows in 1992, which resulted in images far inferior to those shot through an open side window in 1993. In spite of the difficulties of this photographic method, results from three out of four counters were not significantly different from each other and were not different from aerial estimates of the same sites. This allowed the aerial estimates and photo counts to be treated in common, providing multiple samplings for most sites.

Species Identification

Aerial identification of spotted seals is confounded by their similarity to harbor seals. Based on the literature (Quakenbush, 1988), we identified spotted seals by geographic location (seals north of Bristol Bay), haul-out site preferences (on ice when available), and behavior (spotted seals tend to flee earlier than harbor seals when on land (our observation and Burns[28])). Sightings of

[28] Burns, John. Living Resources Inc., P.O. Box 83570, Fairbanks, AK 99708. Personal commun.

pups in August along the south coast of Nunivak Island, in particular in a lagoon near Cape Mendenhall (Brian McCaffery[29]) suggest these may have been harbor seals; however, ADFG records of seals harvested at Mekoryuk (Frost et al.[8]) indicate there were spotted seals on the north side of Nunivak Island. At Nanvak Bay (between Cape Newenham and Cape Pierce in northwest Bristol Bay) both spotted seals and harbor seals have been identified (Johnson[30]; Frost et al.[18], Jemison[31]). Because Kuskokwim Bay lies between Nunivak Island and Nanvak Bay, it is possible that animals on the Kuskokwim shoals are also a mix of both spotted seals and harbor seals. This mix might change through the seasons.

Abundance Estimates

Currently, estimates of spotted seal abundance in the Bering Sea should be considered unreliable. For example, Fedoseev et al. (1988) extrapolated an abundance of 100,000 based on only 431 sightings. Burns[22] approximated an abundance of 200,000 to 250,000, though he admits there was no satisfactory method for censusing spotted seals. He used projections from relative abundances of other animals but later described this as an unreliable technique (Braham et al., 1984). Methods employed in the past are imprecise and of little value in meeting the 1988 amendments to the MMPA for determining impacts of incidental takes. The most precise estimates to date are by Braham et al. (1984), indicating the abundance of seals hauled out in the spring in the eastern Bering Sea ranges between 10,000–13,000. These data, however, are nearly 16 years old and did not include a correction for seals not hauled out during the survey.

The association of spotted seals with sea ice, their wide ranging migrations, large geographic range, and sensitive behavior make them extremely hard to study at the population level. There is a lack of adequate correction factors for the number of spotted seals not visible on tracklines because they may be underwater in the spring and for the number of seals at sea during coastal surveys during the summer. It is not clear what conditions would result in maximal hauling out, nor what proportion of the population would be hauled out at any point in time. The Alaska Department of Fish and Game (with partial support from NMML) put satellite tags on five spotted seals in Kasegaluk Lagoon. Preliminary results indicate that, from August to October, these seals were hauled out an overall average of 6.8% of the time, with individual averages ranging from 1.2% to 13.9% (Lowry et al., 1994). There were no significant diurnal trends during this period. Although our inter-year sightings totaled 3,356 (2,988–3,724) seals hauled out in the survey area, an unknown portion of these animals may have been harbor seals. If spotted seals only haul-out north of Kuskokwim Bay and Nunivak Island, then our surveys encountered only about 613 (475–751) hauled-out spotted seals. Using the extremes of these records, (475–3,724) corrected for the proportion of time seals might have been hauled out (6.8%), suggest minimum and maximum population estimates of 6,985 to 54,765 spotted seals along the west coast of Alaska in the summer.

There are several potential explanations for the large discrepancy between our summer sighting totals and Burns'[22] estimate of 200,000–250,000 in the Bering Sea: 1) Burns might have greatly overestimated the population size because of the methods used, 2) we did not survey the Russian coastline where there could be many concentrations of spotted seals, 3) the proportion of spotted seals hauled out during our summer surveys may have been less than proportions seen during spring surveys over sea ice, 4) seals could have been hauled out on sea ice in the northern Chukchi Sea in summer (although there is no indication that large numbers haul out there), 5) the optimum environmental conditions under which to survey for spotted seals are unknown, or 6) the population may have declined since the late 1960's and early 1970's. Additional research is needed to develop a reliable abundance estimate for spotted seals.

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[29] McCaffery, Brian. U.S. Fish Wildl. Serv., P.O. Box 346, Bethel, AK 99559. Personal commun. 16 Sept. 1993.

[30] Johnson, B. W. 1975. The harbor seal population of Nanvak Bay. Univ. Alaska, Fairbanks. Unpubl. manuscr., 13 p.

[31] Jemison, L. A. 1993. Abundance and distribution of marine mammals in northern Bristol Bay and southern Kuskokwim Bay—a status report of the 1992 marine mammal monitoring effort at Togiak National Wildlife Refuge. U.S. Fish Wildl. Serv., Togiak Natl. Wildl. Refuge, P.O. Box 270, Dillingham, AK 99576, 22 p.

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