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RINGED SEAL (*Phoca hispida hispida*): Alaska Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Ringed seals have a circumpolar distribution and are found in all seasonally ice-covered seas of the Northern Hemisphere as well as in certain freshwater lakes (King 1983). Most taxonomists currently recognize five subspecies of ringed seals: *Phoca hispida hispida* in the Arctic Ocean and Bering Sea; *Phoca hispida ochotensis* in the Sea of Okhotsk and northern Sea of Japan; *Phoca hispida botnica* in the northern Baltic Sea; *Phoca hispida lagodensis* in Lake Ladoga, Russia; and *Phoca hispida saimensis* in Lake Saimaa, Finland. Morphologically, the Baltic and Okhotsk subspecies are fairly well differentiated from the Arctic subspecies (Ognev 1935, Müller-Wille 1969, Rice 1998) and the Ladoga and Saimaa subspecies differ significantly from each other and from the Baltic subspecies (Müller-Wille 1969, Hyvärinen and Nieminen 1990, Amano et al. 2002). Genetic analyses support isolation of the lake-inhabiting populations (Palo 2003, Palo et al. 2003, Valtonen et al. 2012) but suggest gene flow from the Arctic to the Baltic as well as widespread mixing within the Arctic (Palo et al. 2001, Davis et al. 2008, Kelly et al. 2009, Martinez-Bakker et al. 2013). Differences in body size, morphology, growth rates, or diet between ringed seals in shorefast versus pack ice have been taken as evidence of separate breeding populations in some locations (McLaren 1958, Fedoseev 1975, Finley et al. 1983); however, this has not been thoroughly examined and the taxonomic status of the Arctic subspecies remains unresolved (Berta and Churchill 2012). For the purposes of this stock assessment, the Alaska stock of ringed seals is considered the portion of *Phoca hispida hispida* that occurs within the U.S. Exclusive Economic Zone (EEZ) of the Beaufort, Chukchi, and Bering seas (Fig. 1).

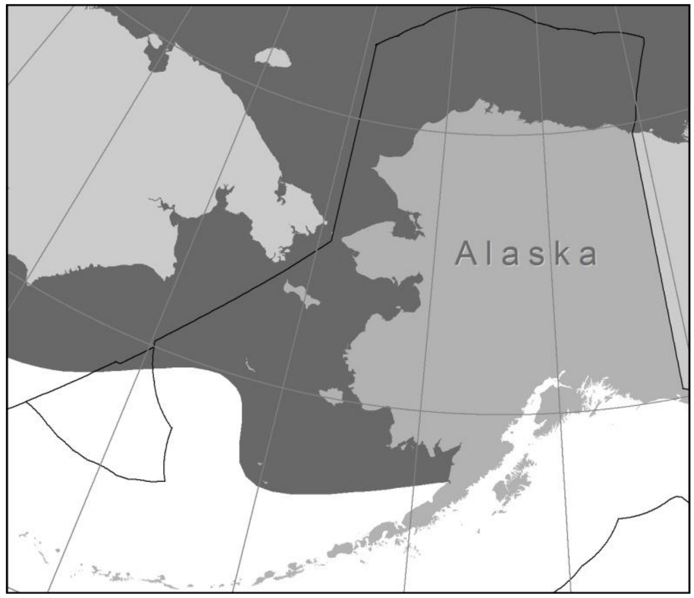

Figure 1. Approximate distribution of ringed seals (dark shaded area). The combined summer and winter distribution are depicted.

Throughout their range, ringed seals have an affinity for ice-covered waters and are well adapted to occupying both shorefast and pack ice (Kelly 1988a). They remain in contact with ice most of the year and use it as a platform for pupping and nursing in late winter to early spring, for molting in late spring to early summer, and for resting at other times of the year. This species rarely comes ashore in the Arctic; however, in more southerly portions of its range where sea or lake ice is absent during summer and fall, ringed seals are known to use isolated haul-out sites on land for molting and resting (Härkönen et al. 1998, Trukhin 2000, Kunnasranta 2001, Lukin et al. 2006). In Alaska waters, during winter and early spring when sea ice is at its maximal extent, ringed seals are abundant in the northern Bering Sea, Norton and Kotzebue Sounds, and throughout the Chukchi and Beaufort seas. They occur as far south as Bristol Bay in years of extensive ice coverage but generally are not abundant south of Norton Sound except in nearshore areas (Frost 1985). Although details of their seasonal movements have not been adequately documented, it is thought that most ringed seals that winter in the Bering and Chukchi seas migrate north in spring as the seasonal ice melts and retreats (Burns 1970) and spend summer in the pack ice of the northern Chukchi and Beaufort seas, as well as in nearshore ice remnants in the Beaufort Sea (Frost 1985). During summer, ringed seals range hundreds to thousands of kilometers to forage along ice edges or in highly productive open-water areas (Freitas et al. 2008, Kelly et al. 2010b). With the onset of freeze-up in the fall, ringed seal movements become increasingly restricted and seals that have summered in the Beaufort Sea are thought to move west and south with the advancing ice pack, with many seals dispersing throughout the Chukchi and Bering seas while some remain in the Beaufort Sea (Frost and Lowry 1984, Crawford et al. 2012, Harwood et al. 2012). Many adult ringed seals return to the same small home ranges they occupied during the previous winter (Kelly et al. 2010b).

POPULATION SIZE

Ringed seal population surveys in Alaska have used various methods and assumptions, had incomplete coverage of their habitats and range, and were conducted more than a decade ago; therefore, current, comprehensive, and reliable abundance estimates or trends for the Alaska stock are not available. Burns and Harbo (1972) conducted aerial surveys along the North Slope of Alaska (between Point Lay and Kaktovik) during June 1970 and reported a minimal estimate of 11,612 ringed seals in areas of shorefast ice. Frost and Lowry (1984) produced a rough estimate of 40,000 ringed seals in the Alaska Beaufort Sea during winter and spring by applying an assumed correction factor for availability bias (i.e., for seals not hauled out at the time of the surveys) to the average density observed from 7 years of aerial surveys in the Alaska and Yukon Beaufort Sea and extrapolating over the entire area of the continental shelf. Their estimate during summer of 80,000 ringed seals was based on the assumption that this population doubles as seals from the Bering and Chukchi seas move in with the receding ice edge. Based on an analysis of surveys conducted during the 1970s, Frost (1985) estimated 1 to 1.5 million ringed seals in Alaska waters, of which 250,000 were estimated in shorefast ice. These estimates were considered conservative when compared with polar bear predation rates (Frost 1985); however, details of the analysis were not published. Frost et al. (1988) reported detailed methods and results of surveys conducted in the Alaska Chukchi and Beaufort seas during May-June 1985-1987. Survey effort was directed towards shorefast ice within 20 nmi of shore, though some areas of adjacent pack ice were also surveyed, and estimates were based on observed densities extrapolated over estimates of available habitat without correcting for availability bias. In the Chukchi Sea, total numbers of hauled out ringed seals in shorefast ice ranged from 18,400 ± 1,700 in 1985 to 35,000 ± 3,000 in 1986. The 1987 estimate of 20,200 ± 2,300 was similar to 1985. In the Beaufort Sea, the estimated number of ringed seals hauled out within the 20-m depth contour ranged from 9,800 ± 1,800 in 1985 to 13,000 ± 1,600 in 1986. The 1987 estimate (19,400 ± 3,700) was considerably higher but may have included seals that had moved in from other areas as the ice began to break up (Frost et al. 1988). Frost et al. (2004) conducted surveys within 40 km of shore in the Alaska Beaufort Sea during May-June 1996-1999, and observed ringed seal densities ranging from 0.81 seals/km^2 in 1996 to 1.17 seals/km^2 in 1999. Moulton et al. (2002) conducted similar, concurrent surveys in the Alaska Beaufort Sea during 1997-1999 but reported substantially lower ringed seal densities than Frost et al. (2004). The reason for this disparity was unclear (Frost et al. 2004). Bengtson et al. (2005) conducted surveys in the Alaska Chukchi Sea during May-June 1999 and 2000. While the surveys were focused on the coastal zone within 37 km of shore, additional survey lines were flown up to 185 km offshore. Population estimates were derived from observed densities corrected for availability bias using a haul-out model from six tagged seals. Ringed seal abundance estimates for the entire survey area were 252,488 (SE = 47,204) in 1999 and 208,857 (SE = 25,502) in 2000. The estimates from 1999 and 2000 in the Chukchi Sea only covered a portion of this stock's range and were conducted over a decade ago. Using the most recent estimates from surveys by Bengtson et al. (2005) and Frost et al. (2004) in the late 1990s and 2000, for the purposes of an Endangered Species Act (ESA) status review of the species, Kelly et al. (2010a) estimated the total population in the Alaska Chukchi and Beaufort seas to be at least 300,000 ringed seals, which Kelly et al. (2010a) state is likely an underestimate since the Beaufort surveys were limited to within 40 km of shore.

During April-May in 2012 and 2013, U.S. and Russian researchers conducted comprehensive and synoptic aerial abundance and distribution surveys of ice-associated seals in the Bering and Okhotsk seas (Moreland et al. 2013). Preliminary analysis of the U.S. surveys, which included only a small subset of the 2012 data, produced an estimate of about 170,000 ringed seals in the U.S. EEZ of the Bering Sea in late April (Conn et al. 2014). This estimate does not account for availability bias, thus the actual number of ringed seals is likely much higher, perhaps by a factor of two or more. The full data sets are currently being processed and analyzed to provide abundance estimates for bearded, spotted, ribbon, and ringed seals in the Bering and Okhotsk seas. Similar surveys in the Chukchi and Beaufort seas are planned for the near future, pending funding.

Minimum Population Estimate

The estimate of 300,000 ringed seals presented in Kelly et al. (2010a) is based on estimates from surveys by Bengtson et al. (2005) and Frost et al. (2004) in the late 1990s and 2000. This estimate is likely an underestimate, as it is based on surveys of a portion of the range, and is more than 8 years old. A reliable estimate of N_{MIN} for the total population in the Alaska Chukchi and Beaufort sea regions is not available.

Current Population Trend

Frost et al. (2002) reported that trend analysis based on an ANOVA comparison of observed seal densities in the central Beaufort Sea suggested marginally significant but substantial declines of 50% on shorefast ice and 31% on all ice types combined from 1985-1987 to 1996-1999. A Poisson regression model indicated highly significant density declines of 72% on shorefast ice and 43% on pack ice over the 15-year period. However, the apparent decline between the mid-1980s and the late 1990s may have been due to a difference in the timing of surveys rather than an actual decline in abundance (Frost et al. 2002, Kelly et al. 2006). As these surveys represent only a fraction of the stock's range and occurred more than a decade ago, current and reliable data on trends in population abundance for the Alaska stock of ringed seals are considered unavailable.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

A reliable estimate of the maximum net productivity rate is currently unavailable for the Alaska stock of ringed seals. Hence, until additional data become available, it is recommended that the pinniped maximum theoretical net productivity rate (R_{MAX}) of 12% be employed for this stock (Wade and Angliss 1997).

POTENTIAL BIOLOGICAL REMOVAL

Under the 1994 reauthorized Marine Mammal Protection Act (MMPA), the potential biological removal (PBR) is defined as the product of the minimum population estimate, one-half the maximum theoretical net productivity rate, and a recovery factor: PBR = $N_{MIN} \times 0.5R_{MAX} \times F_R$. The recovery factor ($F_R$) for this stock is 0.5, the value for pinniped stocks with unknown population status (Wade and Angliss 1997). Since the data used to produce the abundance estimate presented in Kelly et al. (2010a) are more than 8 years old, and no reliable N_{MIN} is available, PBR is undetermined.

ANNUAL HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fisheries Information

Detailed information (including observer programs, observer coverage, and observed incidental takes of marine mammals) for federally-managed and state-managed U.S. commercial fisheries in Alaska waters is presented in Appendices 3-6 of the Alaska Stock Assessment Reports.

Between 2009 and 2013, incidental serious injury and mortality of ringed seals was reported in 4 of the 22 federally regulated commercial fisheries in Alaska monitored for incidental mortality and serious injury by fisheries observers: the Bering Sea/Aleutian Islands flatfish trawl, Bering Sea/Aleutian Islands pollock trawl, Bering Sea/Aleutian Islands Pacific cod trawl, and Bering Sea/Aleutian Islands Pacific cod longline fisheries (Table 1). Based on data from 2009 to 2013, the average annual rate of mortality and serious injury incidental to U.S. commercial fishing operations is 4.1 ringed seals.

Table 1. Summary of incidental mortality and serious injury of the Alaska stock of ringed seals due to U.S. commercial fisheries from 2009 to 2013 and calculation of the mean annual mortality and serious injury rate (Breiwick 2013; NMML, unpubl. data). Methods for calculating percent observer coverage are described in Appendix 6 of the Alaska Stock Assessment Reports.

Fishery name	Years	Data type	Percent observer coverage	Observed mortality	Estimated mortality	Mean estimated annual mortality
Bering Sea/Aleutian Is. flatfish trawl	2009 2010 2011 2012 2013	obs data	99 99 99 99 99	1 0 6 (+1)[a] 3 3	1.0 0 6.0 (+1)[b] 3.0 3.0	2.8 (CV = N/A)
Bering Sea/Aleutian Is. pollock trawl	2009 2010 2011 2012 2013	obs data	86 86 98 98 97	1 0 3 0 0	1.0 0 3.0 0 0	0.8 (CV = 0.03)

Fishery name	Years	Data type	Percent observer coverage	Observed mortality	Estimated mortality	Mean estimated annual mortality
Bering Sea/Aleutian Is. Pacific cod trawl	2009 2010 2011 2012 2013	obs data	63 66 60 68 80	0 0 1 0 0	0 0 1.0 0 0	0.2 (CV = 0)
Bering Sea/Aleutian Is. Pacific cod longline	2009 2010 2011 2012 2013	obs data	60 64 57 51 67	0 0 1 0 0	0 0 1.6 0 0	0.3 (CV = 0.61)
Minimum total estimated annual mortality						4.1 (CV = 0.17)

[a]Total mortality and serious injury observed in 2011: 6 in sampled hauls + 1 in an unsampled haul.
[b]Since the total known mortality and serious injury (6 observed in sampled hauls + 1 in an unsampled haul) exceeds the estimated mortality and serious injury (6.0) for the fishery in 2011, the observed mortality and serious injury (in sampled + unsampled hauls) will be used as a minimum estimate for that year.

Alaska Native Subsistence/Harvest Information

Ringed seals are an important resource for Alaska Native subsistence hunters. Approximately 64 Alaska Native communities in western and northern Alaska, from Bristol Bay to Kaktovik, regularly harvest ice seals (Ice Seal Committee 2014). The Ice Seal Committee, as co-managers with NMFS, recognizes the importance of harvest information and has been collecting it since 2008 as funding and available personnel have allowed. Annual household survey results are compiled in a statewide harvest report that includes historical ice seal harvest information back to 1960. This report is used to determine where and how often harvest information has been collected and where efforts need to be focused in the future (Ice Seal Committee 2014). Current information, within the last 5 years, is available for 11 communities (Kivalina, Noatak, Buckland, Deering, Emmonak, Scammon Bay, Hooper Bay, Tununak, Quinhagak, Togiak, and Twin Hills) (Table 2), but more than 50 other communities harvest ringed seals and have not been surveyed in the last 5 years or have never been surveyed. Harvest surveys are designed to confidently estimate harvest within the surveyed community, but because of differences in seal availability, cultural hunting practices, and environmental conditions, extrapolating harvest numbers beyond that community is misleading. For example, during the past 5 years (2009-2013), only 11 of the 64 coastal communities have been surveyed for ringed seals and of those only 6 have been surveyed for two or more consecutive years (Ice Seal Committee 2015). Based on the harvest data from these 11 communities (Table 2), a minimum estimate of the average annual harvest of ringed seals in 2009-2013 is 1,040 seals. The Ice Seal Committee is working toward a better understanding of ice seal harvest by conducting more consecutive surveys with the goal of being able to report a statewide ice seal harvest estimate in the future.

Table 2. Ringed seal harvest estimates from 2009 to 2013 and the Alaska Native population for each community (Ice Seal Committee 2015).

Community	Alaska Native population (2013)	Estimated ringed seal harvest				
		2009	2010	2011	2012	2013
Kivalina	352			16		
Noatak	514			3		
Buckland	519			26		
Deering	176			0		
Emmonak	782			56		
Scammon Bay	498			137	169	
Hooper Bay	1,144	889	458	674	651	667
Tununak	342	232	162	257	219	

Community	Alaska Native population (2013)	Estimated ringed seal harvest				
		2009	2010	2011	2012	2013
Quinhagak	694		163	117	140	160
Togiak	842	1	1	0		
Twin Hills	66	0	0			
Total		1,122	784	1,286	1,179	827

Other Mortality

Beginning in mid-July 2011, elevated numbers of sick or dead seals, primarily ringed seals, with skin lesions were discovered in the Arctic and Bering Strait regions of Alaska. By December 2011, there were more than 100 cases of affected pinnipeds, including ringed seals, spotted seals, bearded seals, and walrus, in northern and western Alaska. Due to the unusual number of marine mammals discovered with similar symptoms across a wide geographic area, NOAA and USFWS declared a Northern Pinniped Unusual Mortality Event (UME) on December 20, 2011. Disease surveillance efforts in 2012-2013 did not detect any new cases similar to those observed in 2011, but the UME investigation remains open for ice seals based on continuing reports in 2013 and 2014 of ice seals in the Bering Strait region with patchy hair loss. To date, no specific cause for the disease has been identified.

Between 2009 and 2013, one ringed seal mortality, due to a gunshot wound to the head, was reported to the NMFS Alaska Region stranding database (Helker et al. 2015). This seal, presumably a struck and lost animal from the subsistence hunt, had skin lesions consistent with those seen in animals considered part of the multi-species Northern Pinniped 2011 Unusual Mortality Event.

STATUS OF STOCK

On December 28, 2012, NMFS listed Arctic ringed seals (*Phoca hispida hispida*) and, thus, the Alaska stock of ringed seals, as “threatened” under the ESA (77 FR 76706). The primary concern for this population is the ongoing and anticipated loss of sea ice and snow cover stemming from climate change, which is expected to pose a significant threat to the persistence of these seals in the foreseeable future (based on projections through the end of the 21st century; Kelly et al. 2010a). Because of its “threatened” status under the ESA, this stock was designated as “depleted” under the MMPA. As a result, the stock was classified as a strategic stock. On March 11, 2016, the U.S. District Court for the District of Alaska issued a memorandum decision in a lawsuit challenging the listing of ringed seals under the ESA (Alaska Oil and Gas Association et al. v. Pritzker, Case No. 4:14-cv-00029-RPB). The decision vacated NMFS’ listing of the Arctic ringed seals as a “threatened” species. Consequently, it is also no longer designated as “depleted” or classified as a strategic stock. Since PBR is undetermined, it is not possible to determine whether direct human-caused mortality and serious injury exceeds PBR and it is not known whether the current annual level of incidental U.S. commercial fishery-related mortality and serious injury (4.1) exceeds 10% of the PBR. However, mortality and serious injury occurring incidental to commercial fishing is likely small. The total estimated average annual level of human-caused mortality and serious injury based on commercial fisheries observer data (4.1) and a minimum estimate of the Alaska Native harvest (1,040) is 1,044 ringed seals. Population trends and status of this stock relative to its Optimum Sustainable Population are currently unknown.

HABITAT CONCERNS

The main concern about the conservation status of ringed seals stems from the likelihood that their sea-ice and snow habitats have 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 (Kelly et al. 2010a). Climate models consistently project overall diminishing ice and snow cover through the 21st century with regional variation in the timing and severity of those loses. Increasing atmospheric concentrations of greenhouse gases are driving climate warming and increasing acidification of the ringed seal’s habitat. Changes in ocean temperature, acidification, and ice cover threaten prey communities on which ringed seals depend. Laidre et al. (2008) concluded that on a worldwide basis ringed seals were likely to be highly sensitive to climate change based on an analysis of various life-history features that could be affected by climate.

The greatest impacts to ringed seals from diminished ice cover will be mediated through diminished snow accumulation. While winter precipitation is forecasted to increase in a warming Arctic (Walsh et al. 2005), the duration of ice cover will be substantially reduced, and the net effect will be lower snow accumulation on the ice (Hezel et al. 2012). Ringed seals excavate subnivean lairs (snow caves) in drifts over their breathing holes in the ice, in which they rest, give birth, and nurse their pups for 5-9 weeks during late winter and spring (Chapskii 1940, McLaren 1958, Smith and Stirling 1975). Snow depths of at least 50-65 cm are required for functional birth lairs (Smith and Stirling 1975, Lydersen and Gjertz 1986, Kelly 1988b, Lydersen 1998, Lukin et al. 2006), and such depths typically are found only where 20-30 cm or more of snow has accumulated on flat ice and then drifted along pressure ridges or ice hummocks (Lydersen et al. 1990, Hammill and Smith 1991, Lydersen and Ryg 1991, Smith and Lydersen 1991). According to climate model projections, snow cover is forecasted to be inadequate for the formation and occupation of birth lairs within this century over the Alaska stock's entire range (Kelly et al. 2010a). Without the protection of the lairs, ringed seals—especially newborns—are vulnerable to freezing and predation (Kumlien 1879, McLaren 1958, Lukin and Potelov 1978, Smith and Hammill 1980, Lydersen and Smith 1989, Stirling and Smith 2004). Changes in the ringed seal's habitat will be rapid relative to their generation time and, thereby, will limit adaptive responses. As ringed seal populations decline, the significance of currently lower-level threats—such as ocean acidification, increases in human activities, and changes in populations of predators, prey, competitors, and parasites—may increase.

Additional habitat concerns include the potential effects from increased shipping (particularly in the Bering Strait) and oil and gas exploration activities (particularly in the outer continental shelf leasing areas), such as disturbance from vessel traffic, seismic exploration noise, or the potential for oil spills.

CITATIONS

Amano, M., A. Hayano, and N. Miyazaki. 2002. Geographic variation in the skull of the ringed seal, *Pusa hispida*. J. Mammal. 83:370-380.

Bengtson, J. L., L. M. Hiruki-Raring, M. A. Simpkins, and P. L. Boveng. 2005. Ringed and bearded seal densities in the eastern Chukchi Sea, 1999-2000. Polar Biol. 28: 833-845.

Berta, A., and M. Churchill. 2012. Pinniped taxonomy: review of currently recognized species and subspecies, and evidence used for their description. Mammal Rev. 42:207-234.

Breiwick, J. M. 2013. North Pacific marine mammal bycatch estimation methodology and results, 2007-2011. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-260, 40 p.

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

Burns, J. J., and S. J. Harbo. 1972. An aerial census of ringed seals, northern coast of Alaska. Arctic 25:279-290.

Chapskii, K. K. 1940. The ringed seal of western seas of the Soviet Arctic (The morphological characteristic, biology and hunting production). Pp. 147 *In* N. A. Smirnov (ed.), Proceedings of the Arctic Scientific Research Institute, Chief Administration of the Northern Sea Route. Izd. Glavsevmorputi, Leningrad, Moscow. (Translated from Russian by the Fisheries Research Board of Canada, Ottawa, Canada, Translation Series No. 1665, 147 pp.)

Conn, P. B., J. M. Ver Hoef, B. T. McClintock, E. E. Moreland, J. M. London, M. F. Cameron, S. P. Dahle, and P. L. Boveng. 2014. Estimating multispecies abundance using automated detection systems: ice-associated seals in the Bering Sea. Methods Ecol. Evol. 5:1280-1293. DOI: 10.1111/2041-210X.12127.

Crawford, J. A., K. J. Frost, L. T. Quakenbush, and A. Whiting. 2012. Different habitat use strategies by subadult and adult ringed seals (*Phoca hispida*) in the Bering and Chukchi seas. Polar Biol. 35:241-255.

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

Fedoseev, G. A. 1975. Ecotypes of the ringed seal (*Pusa hispida* Schreber, 1777) and their reproductive capabilities. Biology of the Seal. Proceedings of a Symposium held in Guelph, 14-17 August 1972. Rapports et Proces-verbaux des Réunions. Conseil International pour l'Éxploration de la Mer. 169:156-160.

Finley, K. J., G. W. Miller, R. A. Davis, and W. R. Koski. 1983. A distinctive large breeding population of ringed seals (*Phoca hispida*) inhabiting the Baffin Bay pack ice. Arctic 36:162-173.

Freitas, C., K. M. Kovacs, R. A. Ims, M. A. Fedak, and C. Lydersen. 2008. Ringed seal post-moulting movement tactics and habitat selection. Oecologia 155:193-204.

Frost, K. J. 1985. The ringed seal (*Phoca hispida*). Pp. 79-87 *In* J. J. Burns, K. J. Frost, and L. F. Lowry (eds.), Marine Mammals Species Accounts. Alaska Department of Fish and Game, Juneau, AK.

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

Frost, K. J., L. F. Lowry, J. R. Gilbert, and J. J. Burns. 1988. Ringed seal monitoring: relationships of distribution and abundance to habitat attributes and industrial activities. Final Report Contract No. 84-ABC-00210 submitted to U.S. Dep. Interior, Minerals Management Service, Anchorage, AK. 101 pp.

Frost, K. J., L. F. Lowry, G. Pendleton, and H. R. Nute. 2002. Monitoring distribution and abundance of ringed seals in northern Alaska. OCS Study MMS 2002-04. Final Report from the Alaska Department of Fish and Game, Juneau, AK, for U.S. Minerals Management Service, Anchorage, AK. 66 pp. + appendices.

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

Hammill, M. O., and T. G. Smith. 1991. The role of predation in the ecology of the ringed seal in Barrow Strait, Northwest Territories, Canada. Mar. Mammal Sci. 7:123-135.

Härkönen, T., O. Stenman, M. Jüssi, I. Jüssi, R. Sagitov, and M. Verevkin. 1998. Population size and distribution of the Baltic ringed seal (*Phoca hispida botnica*). Pp. 167-180 *In* M. P. Heide-Jørgensen and C. Lydersen (eds.), Ringed Seals in the North Atlantic. NAMMCO Scientific Publications, Vol. 1, Tromsø, Norway.

Harwood, L. A., T. G. Smith, and J. C. Auld. 2012. Fall migration of ringed seals (*Phoca hispida*) through the Beaufort and Chukchi seas, 2001–02. Arctic 65:35-44.

Helker, V. T., B. M. Allen, and L. A. Jemison. 2015. Human-caused injury and mortality of NMFS-managed Alaska marine mammal stocks, 2009-2013. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-300, 94 p.

Hezel, P. J., X. Zhang, C. M. Bitz, B. P. Kelly, and F. Massonnet. 2012. Projected decline in spring snow depth on Arctic sea ice caused by progressively later autumn open ocean freeze-up this century. Geophys. Res. Lett. 39:L17505.

Hyvärinen, H., and M. Nieminen. 1990. Differentiation of the ringed seal in the Baltic Sea, Lake Ladoga and Lake Saimaa. Finnish Game Res. 47:21-27.

Ice Seal Committee. 2014. The subsistence harvest of ice seals in Alaska – a compilation of existing information, 1960-2012. 76 pp.

Ice Seal Committee. 2015. The subsistence harvest of ice seals in Alaska – a compilation of existing information, 1960-2013. 75 pp.

Kelly, B. P. 1988a. Ringed seal, *Phoca hispida*. Pp. 57-75 *In* J. W. Lentfer (ed.), Selected Marine Mammals of Alaska: Species Accounts with Research and Management Recommendations. Marine Mammal Commission, Washington, DC.

Kelly, B. P. 1988b. Locating and characterizing ringed seal lairs and breathing holes in coordination with surveys using forward looking infra-red sensors. Fisheries and Oceans Freshwater Institute Final Report. 17 pp.

Kelly, B. P., O. H. Badajos, M. Kunnasranta, and J. Moran. 2006. Timing and re-interpretation of ringed seal surveys. Coastal Marine Institute University of Alaska Fairbanks, Final Report. 60 pp.

Kelly, B. P., M. Ponce, D. A. Tallmon, B. J. Swanson, and S. K. Sell. 2009. Genetic diversity of ringed seals sampled at breeding sites; implications for population structure and sensitivity to sea ice loss. University of Alaska Southeast, North Pacific Research Board 631 Final Report. 28 pp.

Kelly, B. P., J. L. Bengtson, P. L. Boveng, M. F. Cameron, S. P. Dahle, J. K. Jansen, E. A. Logerwell, J. E. Overland, C. L. Sabine, G. T. Waring, and J. M. Wilder. 2010a. Status review of the ringed seal (*Phoca hispida*). U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-212, 250 p.

Kelly, B. P., O. H. Badajos, M. Kunnasranta, J. R. Moran, M. Martinez-Bakker, D. Wartzok, and P. Boveng. 2010b. Seasonal home ranges and fidelity to breeding sites among ringed seals. Polar Biol. 33:1095-1109.

King, J. E. 1983. Seals of the World. 2nd edition British Museum (Natural History), London. 240 pp.

Kumlien, L. 1879. Mammals. Pp. 55-61 *In* Contributions to the Natural History of Arctic America Made in Connection with the Howgate Polar Expedition 1877-78. Government Printing Office, Washington, DC.

Kunnasranta, M. 2001. Behavioural biology of two ringed seal (*Phoca hispida*) subspecies in the large European lakes Saimaa and Ladoga. Ph.D. Diss., University of Joensuu, Joensuu, Finland. 86 pp.

Laidre, K. L., I. Stirling, L. F. Lowry, Ø. Wiig, M. P. Heide-Jørgensen, and S. H. Ferguson. 2008. Quantifying the sensitivity of Arctic marine mammals to climate-induced habitat change. Ecol. Appl. 18(2):S97-S125.

Lukin, L. R., and V. A. Potelov. 1978. Living conditions and distribution of ringed seal in the White Sea in the winter. Soviet J. Mar. Biol. 4:684-690.

Lukin, L. P., G. N. Ognetov, and N. S. Boiko. 2006. Ecology of the ringed seal in the White Sea. UrO RAN, Ekaterinburg, Russia. 165 pp. (Translated from Russian by the Baltic Fund for Nature (BFN), State University of St. Petersburg, Russia.)

Lydersen, C. 1998. Status and biology of ringed seals (*Phoca hispida*) in Svalbard. Pp. 46-62 *In* M. P. Heide-Jørgensen and C. Lydersen (eds.), Ringed Seals in the North Atlantic. NAMMCO Scientific Publications, Vol. 1. Tromsø, Norway.

Lydersen, C., and I. Gjertz. 1986. Studies of the ringed seal (*Phoca hispida* Schreber 1775) in its breeding habitat in Kongsfjorden, Svalbard. Polar Res. 4:57-63.

Lydersen, C., and M. Ryg. 1991. Evaluating breeding habitat and populations of ringed seals *Phoca hispida* in Svalbard fjords. Polar Rec. 27:223-228.

Lydersen, C., and T. G. Smith. 1989. Avian predation on ringed seal *Phoca hispida* pups. Polar Biol. 9:489-490.

Lydersen, C., P. M. Jensen, and E. Lydersen. 1990. A survey of the Van Mijen Fiord, Svalbard, as habitat for ringed seals, *Phoca hispida*. Holarctic Ecol. 13:130-133.

Martinez-Bakker, M. E., S. K. Sell, B. J. Swanson, B. P. Kelly, and D. A. Tallmon. 2013. Combined genetic and telemetry data reveal high rates of gene flow, migration, and long-distance dispersal potential in Arctic ringed seals (*Pusa hispida*). PLOS ONE 8:e77125.

McLaren, I. A. 1958. The biology of the ringed seal (*Phoca hispida* Schreber) in the eastern Canadian Arctic. Bull. Fish. Res. Board Can. 118:97.

Moreland, E., M. Cameron, and P. Boveng. 2013. Bering Okhotsk Seal Surveys (BOSS), joint U.S.-Russian aerial surveys for ice-associated seals, 2012-13. Alaska Fisheries Science Center Quarterly Report (July-August-September 2013):1-6.

Moulton, F. D., W. J. Richardson, T. L. McDonald, R. E. Elliott, and M. T. Williams. 2002. Factors influencing local abundance and haulout behavior of ringed seals (*Phoca hispida*) on landfast ice of the Alaskan Beaufort Sea. Can. J. Zool. 80:1900-1917.

Müller-Wille, L. L. 1969. Biometrical comparison of four populations of *Phoca hispida* Schreb. in the Baltic and White Seas and Lakes Ladoga and Saimaa. Commentationes Biologicae Societas Scientiarum Fennica 31:1-12.

Ognev, S. I. 1935. Mammals of the U.S.S.R. and Adjacent Countries. Vol. 3. Carnivora. Glavpushnina NKVT, Moscow, Russia. 641 pp. (Translated from Russian by the Israel Program for Scientific Translations, Jerusalem, Israel. 741 pp.)

Palo, J. 2003. Genetic diversity and phylogeography of landlocked seals. Dissertation. Universiy of Helsinki, Helsinki, Finland. 29 pp.

Palo, J. U., H. S. Mäkinen, E. Helle, O. Stenman, and R. Väinölä. 2001. Microsatellite variation in ringed seals (*Phoca hispida*): genetic structure and history of the Baltic Sea population. Heredity 86:609-617.

Palo, J. U., H. Hyvärinen, E. Helle, H. S. Mäkinen, and R. Väinölä. 2003. Postglacial loss of microsatellite variation in the landlocked Lake Saimaa ringed seal. Conserv. Genet. 4:117-128.

Rice, D. W. 1998. Marine Mammals of the World: Systematics and Distribution. Society for Marine Mammalogy, Lawrence, KS. 231 pp.

Smith, T. G., and M. O. Hammill. 1980. A survey of the breeding habitat of ringed seals and a study of their behavior during the spring haul-out period in southeastern Baffin Island. Addendum to the Final Report to the Eastern Arctic Marine Environmental Studies (EAMES) project. Department of Fisheries and Oceans, Arctic Biological Station, Canadian Manuscript Report of Fisheries and Aquatic Sciences, No. 1561. 47 pp.

Smith, T. G., and C. Lydersen. 1991. Availability of suitable land-fast ice and predation as factors limiting ringed seal populations, *Phoca hispida*, in Svalbard. Polar Res. 10:585-594.

Smith, T. G., and I. Stirling. 1975. The breeding habitat of the ringed seal (*Phoca hispida*). The birth lair and associated structures. Can. J. Zool. 53:1297-1305.

Stirling, I., and T. G. Smith. 2004. Implications of warm temperatures, and an unusual rain event for the survival of ringed seals on the coast of southeastern Baffin Island. Arctic 57:59-67.

Trukhin, A. M. 2000. Ringed seal on the eastern coast of Sakhalin Island. Pp. 4 *In* V. M. Belkovich, A. N. Boltunov, and I. V. J. Smelova (eds.), Marine Mammals of the Holarctic. 2000. Materials from the International Conference, Archangel, Russia. Pravda Severa. (Translated from Russian by Olga Romanenko, 4 pp.)

Valtonen, M., J. Palo, M. Ruokonen, M. Kunnasranta, and T. Nyman. 2012. Spatial and temporal variation in genetic diversity of an endangered freshwater seal. Conserv. Genet. 13:1231-1245.

Wade, P. R., and R. Angliss. 1997. Guidelines for assessing marine mammal stocks: report of the GAMMS Workshop April 3-5, 1996, Seattle, Washington. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-OPR-12, 93 p.

Walsh, J. E., O. Anisimov, J. O. M. Hagen, T. Jakobsson, J. Oerlemans, T. D. Prowse, V. Romanovsky, N. Savelieva, M. Serreze, A. Shiklomanov, I. Shiklomanov, and S. Solomon. 2005. Section 6.2. Precipitation and evapotranspiration. Pp. 184-189 *In* Arctic Climate Impact Assessment. Cambridge University Press, Cambridge, UK.