PACIFIC WALRUS (*Odobenus rosmarus divergens*): Alaska Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

The family Odobenidae is represented by a single modern species, *Odobenus rosmarus,* of which two subspecies are generally recognized: the Atlantic walrus (*O. r. rosmarus*) and the Pacific walrus (*O. r. divergens*). The two subspecies occur in geographically isolated populations. The Pacific walrus is the only stock occurring in U.S. waters and considered in this account.

Pacific walrus range throughout the continental shelf waters of the Bering and Chukchi seas, occasionally moving into the East Siberian Sea and the Beaufort Sea (Figure 1). During the summer months most of the population migrates into the Chukchi Sea; however, several thousand animals, primarily adult males, aggregate near coastal haulouts in the Gulf of Anadyr, Bering Strait region, and in Bristol Bay. During the late winter breeding season walrus are found in two major concentration areas of the Bering Sea where open leads, polynyas, or thin ice occur (Fay *et al.* 1984). While the specific location of these groups varies annually and seasonally depending upon the extent of the sea ice, generally one group ranges from the Gulf of Anadyr into a region southwest of St. Lawrence Island, and a second group is found in the southeastern Bering Sea from south of Nunivak Island into northwestern Bristol Bay.

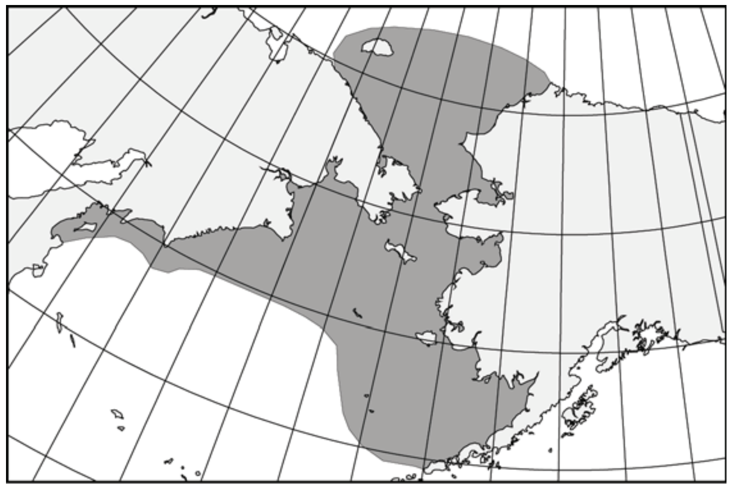

Figure 1. Approximate distribution of Pacific walrus in U.S. and Russian territorial waters (shaded area). The combined summer and winter distributions are depicted.

Pacific walrus are currently managed as a single panmictic population; however, stock structure has not been thoroughly investigated. Scribner *et al.* (1997) found no difference in mitochondrial and nuclear DNA among walrus sampled shortly after the breeding season from four areas of the Bering Sea (Gulf of Anadyr, Koryak Coast, southeast Bering Sea, and St. Lawrence Island). More recently, Jay *et al.* (2008) found indications of stock structure based on differences in the ratio of trace elements in the teeth of walruses sampled in January and February from two breeding areas (southeast Bering Sea and St. Lawrence Island). Further research on stock structure of Pacific walruses is needed.

POPULATION SIZE

The size of the Pacific walrus population has never been known with certainty. Based on large sustained harvests in the 18th and 19th centuries, Fay (1982) speculated that the pre-exploitation population was represented by a minimum of 200,000 animals. Since that time, population size is believed to have fluctuated markedly in response to varying levels of human exploitation (Fay *et al*. 1989). Large-scale commercial harvests reduced the population to an estimated 50,000-100,000 animals in the mid-1950s (Fay *et al.* 1997). The population is believed to have increased rapidly in size during the 1960s and 1970s in response to reductions in hunting pressure (Fay *et al.* 1989).

Between 1975 and 1990, visual aerial surveys were carried out by the United States and Russia at 5-year intervals, producing population estimates ranging from 201,039 to 234,020 animals (Table 1). The estimates generated from these surveys are considered minimum values that are not suitable for detecting trends in population size (Hills and Gilbert 1994, Gilbert *et al.* 1992). Efforts to survey the Pacific walrus population were suspended after 1990 due to unresolved problems with survey methods that produced population estimates with unknown bias and unknown or large variances that severely limited their utility (Gilbert *et al.* 1992, Gilbert 1999).

An international workshop on walrus survey methods, hosted by the U.S. Fish and Wildlife Service (USFWS) and U.S. Geological Survey (USGS) in 2000, concluded that it would not be possible to obtain a population estimate with adequate precision for tracking trends using the existing visual methodology and any feasible amount of survey effort (Garlich-Miller and Jay 2000). Workshop participants recommended investing in research on walrus distribution and haul-out patterns, and exploring new survey tools, including remote sensing systems and development of satellite transmitters, prior to conducting another aerial survey. Remote sensing systems were viewed as having great potential

Table 1. Estimates of Pacific walrus population size, 1975-2006. Estimates are highly variable and not directly comparable among years (Fay *et al*. 1997, Gilbert 1999) because of differences in survey methodologies, timing of surveys, segments of the population surveyed, and incomplete coverage of areas where walrus may have been present. Therefore, these estimates do not provide a definitive basis for inference with respect to population trends.

Year	Population Estimate	References
1975	221,350	Gol'tsev 1976, Estes and Gilbert 1978, Estes and Gol'tsev 1984
1980	246,360	Johnson *et al.* 1982, Fedoseev 1984
1985	234,020	Gilbert 1986, 1989a, 1989b; Fedoseev and Razlivalov 1986
1990	201,039	Gilbert *et al.* 1992
2006	129,000	Speckman *et al*. in prep.

to address many of the shortcomings of visual aerial surveys by sampling larger areas per unit of time (Burn *et al*. 2006), objectively detecting and quantifying walruses (Udevitz *et al.* 2001), and reducing observer error (Burn *et al*. 2006).

Four years of field study by the USFWS and Russian partners led to the development of a survey method that uses thermal imaging systems to reliably detect walrus groups hauled out on sea ice (Burn *et al.* 2006, Udevitz *et al*. 2008). At the same time, the USGS developed satellite transmitters that record information on haul-out status of individual walrus, which can be used to estimate the proportion of the population in the water. This allows correction of an estimate of walrus numbers on ice to account for walrus in the water that cannot be detected in thermal imagery. These technological advances led to a joint U.S.-Russia survey in March and April of 2006, when the Pacific walrus population hauls out on sea ice habitats across the continental shelf of the Bering Sea.

The goal of the 2006 survey was to estimate the size of the Pacific walrus population (Speckman *et al.* in prep.). U.S. and Russian teams coordinated aerial survey efforts on their respective sides of the international border. The Bering Sea was partitioned into survey blocks, and a systematic random sample of transects within a subset of the blocks was surveyed with airborne thermal scanners using standard strip-transect methodology. An independent set of scanned walrus groups was aerially photographed. Counts of walrus in photographed groups were used to model the relation between thermal signatures and the number of walrus in groups, which was used to estimate the number of walrus in groups that were detected by the scanner but not photographed. The probability of thermally detecting various-sized walrus groups was modeled to estimate the number of walrus in groups undetected by the scanner. Thermal imagery detects walrus that are hauled out on sea ice, but is unable to detect walrus swimming in water. Therefore, data from walrus tagged with satellite transmitters were used to adjust on-ice estimates to account for walrus in the water during the survey.

The estimated area of available walrus sea ice habitat in 2006 averaged 668,000 km^2, and the area of surveyed blocks was 318,204 km^2. The number of Pacific walrus within the surveyed area was estimated at 129,000 with 95% confidence limits of 55,000 to 507,000 individuals (Speckman *et al.* in prep.). As this estimate does not account for areas that were not surveyed, some of which are known to have had walrus present, it is negatively biased to an unknown degree.

Minimum Population Estimate

An estimate of minimum population size (N_{MIN}) can be calculated using Equation 1 from the PBR Guidelines (Wade and Angliss 1997): $N_{MIN} = N/\exp(0.842 * [\ln(1+[CV(N)^2]^{1/2})$. However, the 2006 estimate of Pacific walrus population size is known to be negatively biased (Speckman *et al.* in prep.), which provides assurance that walrus population size was greater than the estimate (NMFS 2005). The 2006 estimate of 129,000 walruses within the surveyed area is, therefore, also the best estimate of N_{MIN}.

Current Population Trend

The 2006 estimate is lower than other estimates of Pacific walrus population size to date (Table 1). However, estimates of population size from 1975 to 2006 (Table 1) are highly variable and not directly comparable among years (Fay *et al*. 1997, Gilbert 1999) because of differences in survey methodologies, timing of surveys, and segments of the population surveyed, as well as incomplete coverage of areas where walrus may have been present. Therefore, these estimates do not provide a definitive basis for inference with respect to population trends.

A decline in Pacific walrus population size from its peak in the late 1970s and 1980s would not be unexpected. Walrus researchers in the 1970s and 1980s were concerned that the population had reached or exceeded carrying capacity, and predicted that density-dependent mechanisms would begin to cause a decrease in population size (Fay and Stoker 1982b, Fay *et al*. 1986, Sease 1986, Fay *et al*. 1989). Estimates of demographic parameters from the late 1970s and 1980s support the idea that population growth was slowing (Fay and Stoker 1982a, Fay *et al*. 1986, Fay *et al*. 1989). Garlich-Miller *et al*. (2006) found that the median age of reproduction for female walrus decreased in the 1990s, which is consistent with reduction in density-dependent pressures. However, data are not available to allow conclusion of whether changes in walrus life-history parameters might have been mediated by changes in walrus abundance, or by changes in the carrying capacity of the environment.

The estimate for 2006 of about 129,000 walruses is biased low because some areas known to be important to walrus were not surveyed due to poor weather conditions. The area south of Nunivak Island was not surveyed, an area where walrus are known to aggregate (Krogman *et al*. 1979), and where several thousand walrus were sighted after the 2006 survey was completed (USFWS unpublished data). Additional unsurveyed areas were located to the southwest of St. Lawrence Island and to the south of Cape Navarin, where aggregations of walrus have been documented during April in other years (Fay 1957, Fedoseev 1979, Fay 1982, Braham *et al*. 1984, Fay *et al*. 1984, Fedoseev *et al*. 1988, Burn *et al*. 2006, Burn *et al*. 2009). However, earlier estimates of walrus population size are also likely to be negatively biased since they did not adjust for walrus in the water, a proportion of the population that may be as high as 0.65 – 0.87 (Born and Knutsen 1997, Gjertz *et al*. 2001, Jay *et al*. 2001, Born *et al*. 2005, Acquarone *et al*. 2006, Lydersen *et al*. 2008). In summary, as noted above, the estimates in Table 1 are not directly comparable and cannot be used to identify current population trends; more surveys will be required to verify any trends in population size and to quantify such changes.

MAXIMUM NET PRODUCTIVITY RATES

Estimates of net productivity rates for walrus populations have ranged from 3-13% per year with most estimates falling between 5-10% (Chapskii 1936, Mansfield 1959, Krylov 1965, 1968, Fedoseev and Gol'tsev 1969, Sease 1986, DeMaster 1984, Sease and Chapman 1988, Fay *et al.* 1997).

Chivers (1999) developed an individual age-based model of the Pacific walrus population using published estimates of survival and reproduction. The model yielded a maximum population growth rate (R_{MAX}) of 8%. This estimate remains theoretical because age-specific survival rates for free ranging walrus are poorly known.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) of a marine mammal stock is defined in the Marine Mammal Protection Act (MMPA) as the product of the minimum population estimate (N_{MIN}), one-half the maximum theoretical net productivity rate (R_{MAX}), and a recovery factor (F_R): $PBR = N_{MIN} \times 0.5\ R_{MAX} \times F_R$. The recovery factor ($F_R$) for the Pacific walrus is 0.50 (NMFS 2005) as the population has unknown status (Speckman *et al.* in prep.). R_{MAX} is estimated as 0.08 (Chivers 1999). Therefore, for the Pacific walrus population, PBR = 2,580 walrus (129,000 x 0.5 (0.08) x 0.50).

ANNUAL HUMAN CAUSED MORTALITY AND SERIOUS INJURY

Fisheries Information

A complete list of fisheries and marine mammal interactions is published annually by NOAA-Fisheries, the most recent of which was published on December 1, 2008 (73 FR 73032). Pacific walrus occasionally interact with trawl and longline gear of groundfish fisheries. No data are available on incidental catch of walrus in fisheries operating in Russian waters, although trawl and longline fisheries are known to operate there. In Alaska each year, fishery observers monitor a percentage of commercial fisheries and report injury and mortality to marine mammals incidental to these operations. Overall, 13 observed fisheries operate in Alaska within the range of the Pacific walrus in the Bering Sea, and could potentially interact with them. Incidental mortality during the 5-year period 2002-2006 was recorded only for one fishery, the Bering Sea/Aleutian Island flatfish trawl fishery (non-pelagic; Table 2), which according to NOAA-Fisheries' List of Fisheries is a Category II Commercial Fishery with an estimated 34 vessels and/or persons participating in the fishery. No incidental injury was recorded during this time period; therefore, annual serious injury is estimated to be zero. Observer coverage for this fishery averaged 64.7% during 2002-2006. The mean number of observed mortalities was 1.8 walrus per year, with a range of 0 to 3 (Table 2). The total estimated

Table 2. Summary of incidental mortality of Pacific walrus due to commercial fisheries from 2002-2006 and estimated mean annual mortality. All mortalities occurred in the Bering Sea/Aleutian Islands flatfish trawl fishery. Fisheries observer data provided by NMFS. NE = no estimate made because no take was recorded.

Fishery	Year	Data type	Observer coverage (%)	Observed mortality (in given years)	Estimated mortality (in given years)	95% CI
Bering Sea/ Aleutian Islands flatfish trawl	2002	obs data	58.4	2	3.3	1.4 – 7.5
	2003		64.1	0	NE	NE
	2004		64.3	2	3.1	1.4 – 6.8
	2005		68.3	3	4.1	2.3 – 7.31
	2006		67.8	2	2.8	1.4 – 5.9
Mean	2002-2006	obs data	64.7	1.8	2.66 CV = 0.39	1.83 – 3.86

annual fishery-related incidental mortality in Alaska was 2.66 walrus per year (CV = 0.39). We consider fishery mortality insignificant.

Subsistence Harvest

Over the past 47 years the Pacific walrus population has sustained estimated annual harvest removals ranging from 3,184 to 16,127 animals per year (mean: 6,713; Figure 2). Recent harvest levels are lower than the long-term average over this period. It is not known whether recent reductions in harvest levels reflect changes in walrus abundance or hunting effort. Factors affecting harvest levels include: 1) the cessation of Russian commercial walrus harvests after 1991; 2) changes in political, economic, and social conditions of subsistence hunters in Alaska and Chukotka; and 3) the effects of variable weather and ice conditions on hunting success.

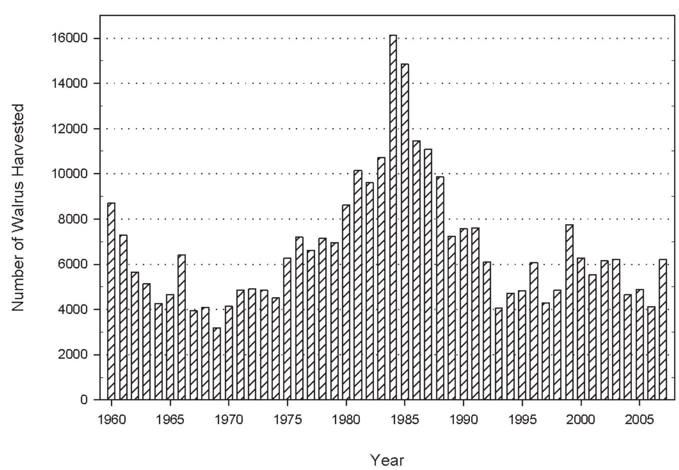

Figure 2. Estimated subsistence harvest of Pacific walrus in the U.S.and Russia, 1960-2007.

The USFWS uses the average annual harvest over the past five years as a representative estimate of current harvest levels in the U.S. and Russia. Total U.S. annual harvest is estimated using data collected by direct observation in selected communities and through the statewide regulatory Marking, Tagging, and Reporting Program (MTRP). The two sources of data are combined to calculate annual reporting compliance and to correct for any unreported harvest. Total U.S. subsistence harvest is estimated as the sum of reported and estimated unreported harvests. Harvest estimates in Russia were collected through both an observer program and a reporting program instituted by the Russian government.

The estimated number harvested is multiplied by 1.72 to adjust for walruses wounded but not retrieved (struck and lost; Fay *et al.* 1994), yielding the estimated total number taken. Fay *et al*. (1994) estimated the proportion of targeted walrus that were struck and lost at 42% using data collected between 1952 and 1972. Current accuracy of this estimate is unknown. Based on the same study, all walruses that have been shot with a firearm are assumed to be mortally wounded (Fay *et al.* 1994).

Table 3. Estimated harvest of Pacific walrus, 2003-2007. Russian harvest information was provided by ChukotTINRO and the Russian Agricultural Department. U.S. harvest information was collected by the U.S. Fish and Wildlife Service, and adjusted for unreported walrus using the Mark Recapture method, which yields upper and lower harvest estimates. Number struck and lost is estimated using a 42% struck and lost rate from Fay *et al.* (1994).

Year	Estimated Total Number Taken	Number Harvested, U.S.	Number Harvested, Russia	Number Struck and Lost
2003	5,909 – 6,551	2,002 – 2,375	1,425	2,482 – 2,751
2004	4,429 – 4,858	1,451 – 1,700	1,118	1,860 – 2,040
2005	4,762 -5,037	1,292 – 1,451	1,470	2,000 – 2,115
2006	3,907 – 4,262	1,219 – 1,425	1,047	1,641 – 1,790
2007	5,789 – 6,571	2,185 – 2,638	1,173	2,432 – 2,760
Mean	4,960 – 5,457	1,630 – 1,918	1,247	2,083 – 2,292

Harvest mortality levels from 2003-2007 are estimated at 4,960 – 5,457 walrus per year (Table 3). The sex-ratio of the reported U.S. walrus harvest over this time period was 1.55:1 males to females. The sex-ratio of the reported Russian walrus harvest was 3.76:1 males to females based on harvest information collected by ChukotTINRO in 2003 and 2005 only.

Other Removals

Between 2003 and 2007, satellite transmitters were affixed by crossbow to 143 walrus (annual mean: 28.6), and collections of skin and blubber biopsy samples were attempted from 214 walrus (annual mean: 42.8). No mortalities or serious injuries were associated with these research activities. Four orphaned walrus calves were rescued from the wild and placed on public display between 2003 and 2007. Based on this information, an estimated 0.8 walrus per year were removed from the wild due to other human activities.

Total Estimated Human-Caused Mortality and Serious Injury

The total estimated annual human-caused mortality or removal is calculated to be 4,963 - 5,460 walrus per year (2.66 attributed to fisheries interactions, 4,960 to 5,457 due to harvest, and 0.8 due to other human activities). There is insufficient information to accurately estimate human-caused serious injury, but there is no evidence that levels of human-caused serious injury are significant.

STATUS OF STOCK

Pacific walrus are not designated as depleted under the MMPA, and are not listed as threatened or endangered under the Endangered Species Act of 1973 (ESA), as amended. In February 2008, the USFWS received a petition to list the Pacific walrus under the ESA. The 90-day finding on this petition was published in the Federal Register on September 10, 2009 (74 FR 46548), and found that there was substantial information in the petition to indicate that listing the Pacific walrus under the ESA may be warranted. A status review of the Pacific walrus under the ESA was initiated on October 1, 2009, and a 12-month finding will be published in the Federal Register on or before September 10, 2010. Based on the best available data, the estimated incidental mortality and serious injury related to commercial fisheries (2.66 walrus per year) is less than 10% of the calculated PBR and therefore can be considered insignificant and approaching a zero mortality and serious injury rate. However, the total human-caused removals exceed estimated PBR. Therefore, the Pacific walrus stock is classified as strategic.

Conservation Issues and Habitat Concerns

Oil and Gas Exploration

In 2008, the Minerals Management Service held an oil and gas lease sale for offshore blocks in the eastern Chukchi Sea. A significant proportion of the Pacific walrus population migrates into the Chukchi Sea region each summer, and the shallow, productive, ice covered waters of the eastern Chukchi Sea are considered particularly important habitat for female walrus and their dependent young. The USFWS works to monitor and mitigate potential impacts of oil and gas activities on walrus and polar bears through incidental take regulations (ITR) as authorized under the

MMPA. Activities operating under these regulations must adopt measures to: ensure that impacts to walruses remain negligible; minimize impacts to their habitat; and ensure no unmitigable adverse impact on their availability for Alaska Native subsistence use. ITR also specify monitoring requirements that provide a basis for evaluating potential impacts of current and future activities on marine mammals.

Climate Change

Impacts to walrus of changes in arctic and subarctic ice dynamics are not well understood. Walrus are dependent on sea ice as a substrate for birthing, nursing, and resting between foraging trips. Annual winter ice in the Bering Sea is predicted to decrease in extent by 40% by the year 2050 (Overland and Wang 2007). Summer sea-ice extent in the Chukchi Sea has decreased rapidly in recent years (Meier et al. 2007, Stroeve et al. 2008), retreating off the shallow continental shelf and over deep Arctic Ocean waters where walruses presumably can not feed. Declines in sea-ice extent, duration, and thickness are expected to continue (Overpeck et al. 2005, Maslanik et al. 2007, Stroeve et al. 2007).

Some impacts of the loss of summer sea ice on walrus have been documented. Over the past decade, the number of walrus coming to shore along the coastline of the Chukchi Sea in Russia has increased (Kavry et al. 2008). Female and young walrus are arriving earlier and staying longer at coastal haulouts as summer ice disappears. Numbers in the tens of thousands have been reported anecdotally from some haulouts in Chukotka (Kavry *et al*. 2008, A.A. Kochnev personal communication). In fall of 2007 and 2009, large walrus aggregations were also observed along the Alaska coast. The ability of the food supply within foraging range of coastal haulouts to support large numbers of walruses over the long term is unknown. Thin walrus that appear to be physiologically stressed have also been reported from Chukotka (Ovsyanikov *et al*. 2008, A.A. Kochnev personal communication). Walrus at dense coastal haulouts are vulnerable to disturbance, which can result in increased mortality from stampedes (Ovsyanikov 1994, Kavry *et al*. 2008). The USFWS will review all available information on the impacts of climate change on the Pacific walrus population when it considers the petition to list them under the ESA.

Subsistence Harvest

Impacts of climate change on subsistence harvests of walrus are also difficult to predict. Changes in walrus distribution, abundance, individual health, ice type, length and timing of the hunting season, and weather and sea state during the hunting season, can all influence hunting success. Recent harvest levels are lower than historical levels but it is not clear if this represents reduced hunting effort. Harvest levels must be assessed within the context of the best available information on walrus population size, weather and climate, and political, economic, and social conditions of subsistence hunters in Alaska and Chukotka.

Cooperative Agreements have been developed annually between the USFWS and the Eskimo Walrus Commission since 1997 to facilitate the participation of subsistence hunters in activities related to the conservation and management of walrus stocks in Alaska. This co-management process is on-going. Ensuring that harvest levels remain sustainable is a goal shared by subsistence hunters and resource managers in the U.S. and Russia. Achieving this management goal will require continued investments in co-management relationships, harvest monitoring programs, international coordination, and research.

CITATIONS

Acquarone, M., E.W. Born, and J.R. Speakman. 2006. Field metabolic rates of walrus (*Odobenus rosmarus*) measured by doubly labeled water method. Aquatic Mammals 32: 363-369.

Born, E. W., M. Acquarone, L.Ø. Knutsen, and L. Toudal. 2005. Homing behaviour in an Atlantic walrus (*Odobenus rosmarus rosmarus*). Aquatic Mammals 31: 23-33.

Born, E.W. and L.Ø. Knutsen. 1997. Haul-out and diving activity of male Atlantic walruses (*Odobenus rosmarus rosmarus*) in NE Greenland. Journal of Zoology 243: 381-396.

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

Burn, D.M., M.A. Webber, and M.S. Udevitz. 2006. Application of airborne thermal imagery to surveys of Pacific walrus. Wildlife Society Bulletin 34(1):51-58.

Burn, D., M.S. Udevitz, S.G. Speckman, and R.B. Benter. 2009. An improved procedure for detection and enumeration of walrus signatures in airborne thermal imagery. International Journal of Applied Earth Observation and Geoinformation 11:324-333.

Chapskii, K.K. 1936. The walrus of the Kara Sea. Results of an investigation of the life history, geographical distribution, and stock of walruses in the Kara Sea. Transactions of the Arctic Institute 67:1-124.

Chivers, S.J. 1999. Biological indices for monitoring population status of walrus evaluated with an individual-based model. Pages 239-247, *In* Garner, G.W., S.C. Amstrup, J.L. Laake, B.F.J. Manly, L.L. McDonald, and D.G. Robertson (eds.), Marine Mammal Survey and Assessment Methods. A. A. Balkema, Rotterdam, 287 pp.

DeMaster, D.P. 1984. An analysis of a hypothetical population of walruses. Pages 77-80, *In* F.H. Fay and G.A. Fedoseev (eds.), Soviet American Cooperative Research on Marine Mammals, vol. 1, Pinnipeds. NOAA Technical Report, NMFS 12, 104 pp.

Estes, J.A., and J.R. Gilbert. 1978. Evaluation of an aerial survey of Pacific walruses (*Odobenus rosmarus divergens*). Journal of the Fisheries Research Board of Canada 35:1130 1140.

Estes, J.A., and V.N. Gol'tsev. 1984. Abundance and distribution of the Pacific walrus (*Odobenus rosmarus divergens*): results of the first Soviet American joint aerial survey, autumn 1975. Pages 67-76, *In* F.H. Fay and G.A. Fedoseev (eds.), Soviet American Cooperative Research on Marine Mammals, vol. 1, Pinnipeds. NOAA Technical Report, NMFS 12, 104 pp.

Fay, F.H. 1957. History and present status of the Pacific walrus population. Transactions of the North American Wildlife Conference 22:431-445.

Fay, F.H. 1982. Ecology and Biology of the Pacific Walrus (*Odobenus rosmarus divergens*). North American Fauna 74. U.S. Fish and Wildlife Service, Washington, DC., 279 pp.

Fay, F.H., B.P. Kelly, P.H. Gehnrich, J.L. Sease, and A.A. Hoover. 1984. Modern populations, migrations, demography, trophics, and historical status of the Pacific walrus. Final Report R.U. #611. NOAA Outer Continental Shelf Environmental Assessment Program, Anchorage AK., 142 pp.

Fay, F.H., B.P Kelly, P.H. Gehnrich, J.L. Sease, and A.A. Hoover. 1986. Modern populations, migrations, demography, trophics, and historical status of the Pacific walrus. U.S. Department of Commerce, NOAA, Outer Continental Shelf Environmental Impact Assessment Program, Final Reports of Principal Investigators 37: 231-376. NOAA, National Ocean Service, Anchorage, Alaska.

Fay, F.H., B.P. Kelly, and J.L. Sease. 1989. Managing the exploitation of Pacific walruses: a tragedy of delayed response and poor communication. Marine Mammal Science 5:1-16.

Fay, F.H., J.J. Burns, S.W. Stoker, and J.S. Grundy. 1994. The struck-and-lost factor in Alaskan walrus harvests. Arctic 47(4):368-373.

Fay, F.H., L.L. Eberhardt, B.P. Kelly, J.J. Burns, and L.T. Quakenbush. 1997. Status of the Pacific walrus Population, 1950-1989. Marine Mammal Science 13(4):537-565.

Fay, F.H. and S.W. Stoker. 1982a. Analysis of reproductive organs and stomach contents from walruses taken in the Alaskan native harvest, spring 1980. Final Report contract 14-16-0007-81-5216. U.S. Fish and Wildlife Service, Anchorage, Alaska. 86pp.

Fay, F.H. and S.W. Stoker. 1982b. Reproductive success and feeding habits of walruses taken in the 1982 spring harvest, with comparisons from previous years. Eskimo Walrus Commission, Nome, AK. 91pp.

Fedoseev, G.A. 1979. Material on aerovisual observations on distribution and abundance of ice forms of seals, walruses, and migrating whales in the ice of the Bering Sea in spring 1979. Pages 17-44 in Scientific Investigations of Marine Mammals in the Northern Part of the Pacific Ocean in 1978 and 1979. All-Union Scientific Investigational Institute of Marine Fisheries and Oceanography (VNIRO), Moscow. In Russian.

Fedoseev, G.A. 1984. Present status of the population of walruses (*Odobenus rosmarus*) in the eastern Arctic and Bering Sea. Pages 73-85, *In* V.E. Rodin, A.S. Perlov, A.A. Berzin, G.M. Gavrilov, A.I. Shevchenko, N.S. Fadeev, and E.B. Kucheriavenko (eds.), Marine Mammals of the Far East. TINRO, Vladivostok.

Fedoseev, G.A., and V.N. Gol'tsev. 1969. Age-sex structure and reproductive capacity of the Pacific walrus population. Zoological Journal 48:407-413.

Fedoseev, G.A., and E.V. Razlivalov. 1986. The distribution and abundance of walruses in the eastern Arctic and Bering Sea in autumn 1985. VNIRO, Magadan Branch. Mimeo report, 7 pp.

Fedoseev, G.A., E.V. Razlivalov, and G.G. Bobrova. 1988. Distribution and abundance of ice forms of pinnipeds on ice of the Bering Sea in April and May 1987. Pages 44-70 in Scientific Investigations of Marine Mammals in the Northern Part of the Pacific Ocean in 1986 and 1987. All-Union Scientific Investigational Institute of Marine Fisheries and Oceanography (VNIRO), Moscow. In Russian.

Garlich-Miller, J., and C.V. Jay. 2000. Proceedings of a workshop concerning walrus survey methods. USFWS R7/MMM Technical Report 00-2, 92 pp.

Garlich-Miller, J.L., L.T. Quakenbush, and J.F. Bromaghin. 2006. Trends in age structure and productivity of Pacific walruses harvested in the Bering Strait region of Alaska, 1952-2002. Marine Mammal Science 22:880-896.

Gilbert, J.R. 1986. Aerial survey of Pacific walrus in the Chukchi Sea, 1985. Mimeo report, 43 pp.

Gilbert, J.R. 1989a. Aerial census of Pacific walruses in the Chukchi Sea, 1985. Marine Mammal Science 5(1):17-28.

Gilbert, J.R. 1989b. Errata: Correction to the variance of products, estimates of Pacific walrus populations. Marine Mammal Science 5(4):411-412.

Gilbert, J.R. 1999. Review of previous Pacific walrus surveys to develop improved survey designs. Pages 75-84, *In* Garner, G.W., S.C. Amstrup, J.L. Laake, B.F.J. Manly, L.L. McDonald, and D.G. Robertson (eds.), Marine Mammal Survey and Assessment Methods. A. A. Balkema, Rotterdam, 287 pp.

Gilbert, J.R., G.A. Fedoseev, D. Seagars, E. Razlivalov, and A. LaChugin. 1992. Aerial census of Pacific walrus, 1990. USFWS R7/MMM Technical Report 92-1, 33 pp.

Gol'tsev, V.N. 1976. Aerial surveys of Pacific walrus in the Soviet sector during fall 1975. Procedural Report TINRO, Magadan, USSR. 22 pp. Translated by J.J. Burns and the U.S. State Department.

Gjertz, I., D. Griffiths, B.A. Krafft, C. Lydersen, and Ø Wiig. 2001. Diving and haul-out patterns of walruses *Odobenus rosmarus* on Svalbard. Polar Biology 24: 314-319.

Hills, S., and J.R. Gilbert. 1994. Detecting Pacific walrus population trends with aerial survey —a review. Transactions North American Wildlife and Natural Resource Conference.

Jay, C.V., S.D. Farley, and G.W. Garner. 2001. Summer diving behavior of male walruses in Bristol Bay, Alaska. Marine Mammal Science 17:617-631.

Jay, C.V., P.M. Outridge, and J.L. Garlich-Miller. 2008. Indication of two Pacific walrus stocks from whole tooth elemental analysis. Polar Biology 31:933–943.

Johnson, A., J. Burns, W. Dusenberry, and R. Jones. 1982. Aerial survey of Pacific walrus, 1980. U.S. Fish and Wildlife Service, Anchorage, AK. Mimeo report, 32 pp.

Kavry, V.I., A.N. Boltunov, and V.V. Nikiforov. 2008. New coastal haulouts of walruses (*Odobenus rosmarus*) – response to the climate changes. Pages 248-251, *In* Collection of Scientific Papers from the Marine Mammals of the Holarctic V conference, Odessa, Ukraine, 14-18 October 2008.

Kochnev, A.A. Personal Communication. Head of Laboratory of Marine Mammals Study, ChukotTINRO, Pacific Research Institute of Fisheries and Oceanography, P.O. Box 29, Anadyr, Chukotka, 689000, Russia.

Kochnev, A.A., N.V. Kryukova, A.A. Pereverzev, and D.I. Ivanov. 2008. Coastal haulouts of the Pacific walruses (*Odobenus rosmarus divergens*) in Anadyr Gulf (Bering Sea), 2007. Pages 267-272, *In* Collection of Scientific Papers from the Marine Mammals of the Holarctic V conference, Odessa, Ukraine, 14-18 October 2008.

Krogman, B.D., H.W. Braham, R.M. Sontag, and R.G. Punsley. 1979. Early spring distribution, density, and abundance of the Pacific walrus (*Odobenus rosmarus divergens).* Final Report, Contract No. R7120804, NOAA Outer Continental Shelf, Environmental Assessment Program, Juneau Project Office, Juneau, AK. 47 pp.

Krylov, V.I. 1965. Determination of age, rate of growth, and analysis of the age structure of the catch of the Pacific walrus. Pages 210-211, *In* E.N. Pavlovskii, B.A. Zenkovich, S.E. Kleinenber, and K.K. Chapskii (eds.), Morskie Mlekopitaiushchie. Nauka, Moscow.

Krylov, V.I. 1968. On the present status of stocks of the Pacific walrus and prospects of their rational exploitation. Pages 189-204, *In* V.A. Arsen'ev and K.I. Panin (eds.), Lastonogie Severnoi Chasti Tikhogo Okeana. Pischevaya Promyshlennost', Moscow.

Lydersen, C., J. Aars, and K.M. Kovacs. 2008. Estimating the number of walruses in Svalbard from aerial surveys and behavioral data from satellite telemetry. Arctic 61:119-128.

Mansfield, A.W. 1959. The walrus in the Canadian Arctic. Fisheries Research Board Canada, Circular 2, 13 pp.

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

Meier, W., J. Stroeve, and F. Fetterer. 2007. Whither Arctic sea ice? A clear signal of decline regionally, seasonally and extending beyond the satellite record. Annals of Glaciology 46:428-434.

NMFS. 2005. Revisions to Guidelines for Assessing Marine Mammals Stocks. 24 pp. Available at: *http://www.nmfs.noaa.gov/pr/pdfs/sars/gamms2005.pdf*

Overland, J.E., and M. Wang. 2007. Future regional Arctic sea ice declines. Geophysical Research Letters 34:L17705, doi: 17710.11029/12007GL03808.

Overpeck, J.T., M. Sturm, J.A. Francis, D.K. Perovich, M.C. Serreze, R. Benner, E.C. Carmack, F.S. Chapin III, S.C. Gerlach, L.C. Hamilton, L.D. Hinzman, M. Holland, H.P. Huntington, J.R. Key, A.H. Lloyd, G.M. MacDonald, J. McFadden, D. Noone, T.D. Prowse, P. Schlosser, and C. Vörösmarty. 2005. Arctic system on trajectory to new, seasonally ice-free state. EOS Transactions 86(34):309-316.

Ovsyanikov, N.G., L.L. Bove, and A.A. Kochnev. 1994. Causes of mass mortality of walruses on coastal haulouts. Zoologichesky Zhurnal 73:80-87.

Ovsyanikov, N.G., I.E. Menyushina, and A.V. Bezrukov. 2008. Unusual Pacific walrus mortality at Wrangel Island in 2007. Pages 413-416, *In* Collection of Scientific Papers from the Marine Mammals of the Holarctic V conference, Odessa, Ukraine, 14-18 October 2008.

Scribner, K.T., S. Hills, S.R. Fain, and M.A. Cronin. 1997. Population genetics studies of the walrus (*Odobenus rosmarus*): a summary and interpretation of results and research needs. *In* A.E. Dizon, S.J. Chivers, and W.F. Perrin (eds.), Molecular Genetics of Marine Mammals. Marine Mammal Science, Special publication 3:173-184.

Sease, J.L. 1986. Historical status and population dynamics of the Pacific walrus. Univ. Alaska, Fairbanks. Thesis, 213 pp.

Sease, J.L., and D.G. Chapman. 1988. Pacific walrus (*Odobenus rosmarus divergens*). Pages 17-38, *In* J.W. Lentfer (eds.), Selected Marine Mammals of Alaska: species accounts with research and management recommendations. Marine Mammal Commission, Washington, D.C. NTIS PB88-178462.

Speckman, S.G., V.I. Chernook, D.M. Burn, M.S. Udevitz, A.A. Kochnev, A. Vasilev, C.V. Jay, A. Lisovsky, R.B. Benter, and A.S. Fischbach. In prep. Estimated size of the Pacific walrus population, 2006.

Stroeve, J., M.M. Holland, W. Meier, T. Scambos, and M. Serreze. 2007. Arctic sea ice decline: Faster than forecast. Geophysical Research Letters 34.

Stroeve, J., M. Serreze, S. Drobot, S. Gearheard, M.M. Holland, J. Maslanik, W. Meier, and T. Scambos. 2008. Arctic sea ice extent plummets in 2007. EOS Transactions, AGU 89:13-20.

Udevitz, M.S., J.R. Gilbert, and G.A. Fedoseev. 2001. Comparison of method used to estimate numbers of walruses on sea ice. Marine Mammal Science 17:601-616.

Udevitz, M.S., D.M. Burn, and M.A. Webber. 2008. Estimation of walrus populations on sea ice with infrared imagery and aerial photography. Marine Mammal Science 24(1):57-70.

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 pp.