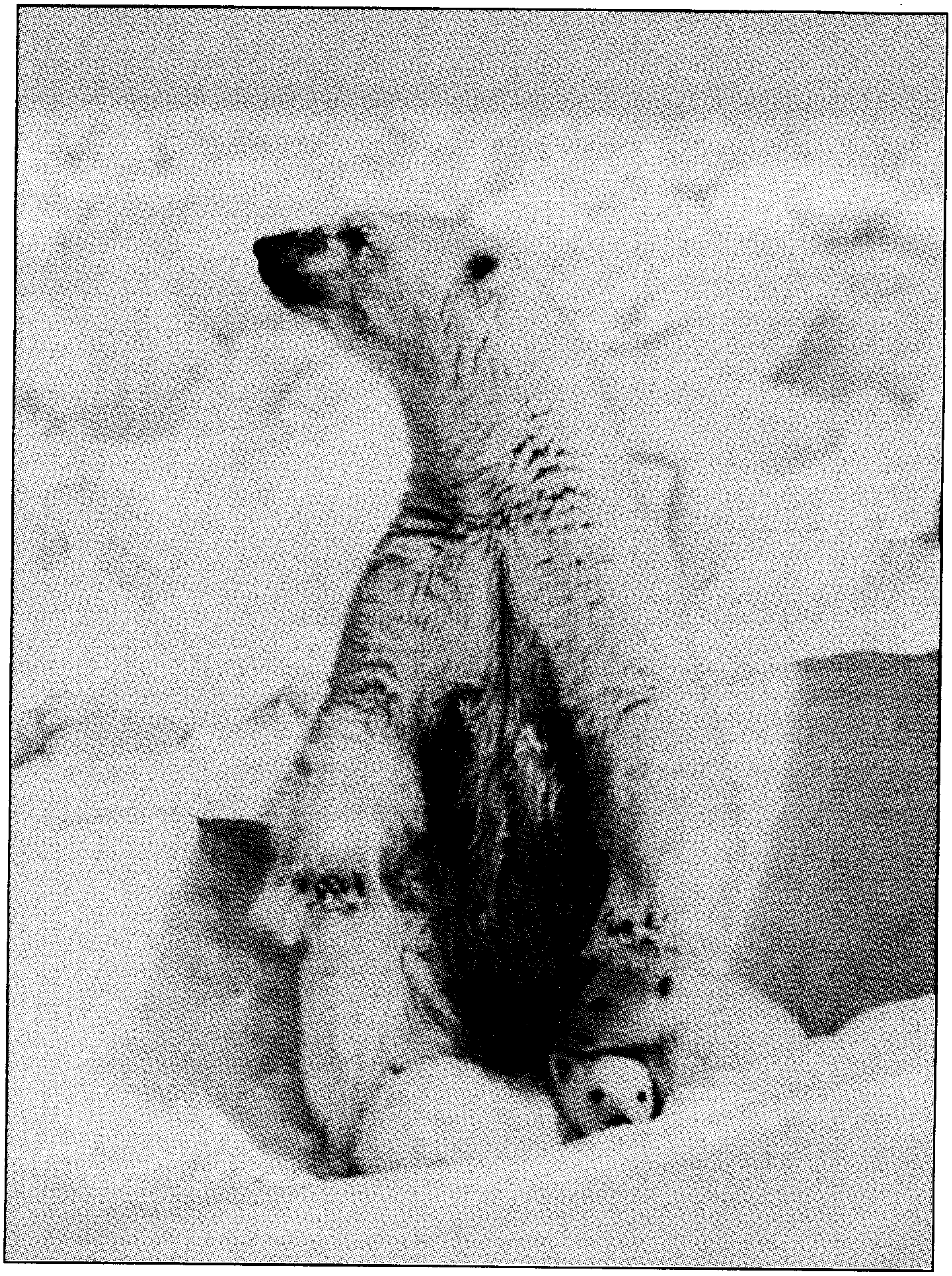
8804

Polar Bear ——— *Ursus maritimus*

STEVEN C. AMSTRUP, *U.S. Fish and Wildlife Service, 1011 E. Tudor Road, Anchorage, Alaska 99503*
and
DOUGLAS P. DEMASTER,* *Marine Mammal Commission, 1625 I Street, N.W., Washington, D.C. 20006*

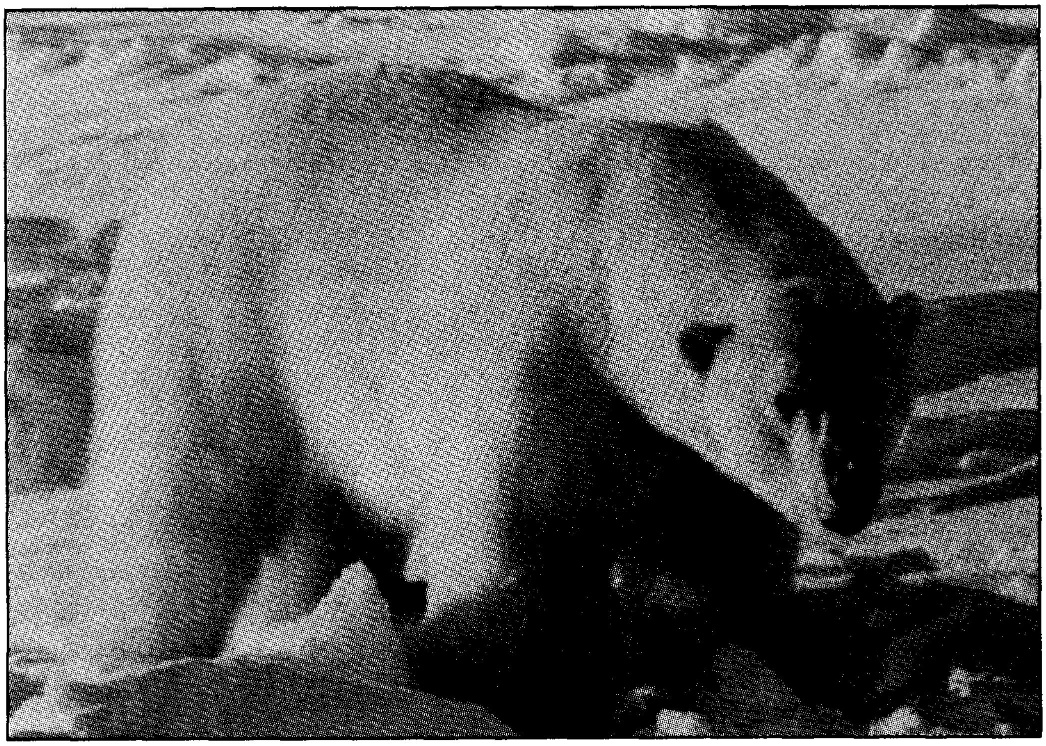
*Current address: U.S. Department of Commerce, NOAA, National Marine Fisheries Service, Southwest Fisheries Center, P.O. Box 271, La Jolla, California 92038.

Lentfer, Jack W., editor. 1988. *Selected Marine Mammals of Alaska: Species Accounts with Research and Management Recommendations.* Marine Mammal Commission, Washington, D.C.



Photograph by Steven C. Amstrup

Polar Bear _Ursus maritimus_



Photograph by Steven C. Amstrup

Polar bears (*Ursus maritimus*) are long-lived, late-maturing carnivores that have relatively low rates of reproduction and natural mortality. Their populations are susceptible to disturbance from human activities, such as the exploration and development of mineral resources or hunting. Polar bear populations have been an important renewable resource available to coastal communities throughout the Arctic for thousands of years.

BIOLOGY, LIFE HISTORY, AND HABITAT REQUIREMENTS

Distribution and Movements

Polar bears inhabit most ice-covered seas of the Northern Hemisphere. They are circumpolar in distribution and have been reported as far north as 88°N latitude (Stefansson 1921, Papanin 1939). They occur as far south in the eastern Bering Sea as St. Matthew Island and the Pribilof Islands (Ray 1971), and are commonly found within 300 km of the Alaskan coast of the Chukchi and Beaufort seas, from Bering Strait to the United States-Canada border (Frame 1969; Amstrup, unpubl. data). Polar bears in the Chukchi Sea make extensive north-south migrations in relation to the position of the southern edge of the pack ice.

In winter and spring polar bears are commonly found in three distinct types of ice: shorefast ice with deep snow drifts along pressure ridges, the floe edge, and areas of moving ice with 7/8 or more ice cover (Stirling *et al.* 1981). In the western Canadian Arctic, subadult females and adult females with young cubs generally prefer shorefast ice, possibly because of the absence of large adult males in this type of habitat. Other classes of bears seem to prefer the floe edge and moving ice; 87% of all bear sightings in spring in the western Canadian Arctic were made on the floe edge and moving ice (Stirling *et al.* 1975). Lentfer *et al.* (1980) indicated that the pattern of distribution in the western Canadian Arctic may not apply off the coast of Alaska, where mature males tend to range far offshore in the early spring and move toward the coast as the breeding season progresses. Off the coast of Alaska, Lentfer (unpubl. data) and Amstrup (unpubl. data) found numerous subadults and females with young cubs in drifting ice and along the floe edge and suggested that neither of these two components of the Alaskan population prefers shorefast ice during the spring.

When ice forms in the fall, polar bears that have spent the summer on drifting ice north of Alaska move to the south. By late fall they are distributed seaward of the Beaufort and Chukchi seacoasts, and normally occur during the winter as far south as Bering Strait. In some years the bears range south of St. Lawrence Island. Polar bears are more abundant along the Alaskan coast in years when winds bring old ice near shore. As the ice breaks up and recedes north in spring and early summer, the bears move north. They remain on the drifting pack ice through the summer. Little is known of their distribution on the pack ice in Alaska during the summer (Lentfer 1972).

Lentfer (1974*a*) hypothesized that Alaska has two relatively discrete polar bear populations. He proposed that a line extending northwest from Point Lay, Alaska, separates the western and northern populations in Alaska. Ocean currents and movements of the ice may be partly responsible for this apparent separation (Lentfer 1971*a*). Bears in the northern population remain west of Banks Island, Canada, and east of a point near Point Barrow which has yet to be defined (Amstrup, unpubl. data).

Information concerning the concentration of mercury residue in liver and muscle tissues from bears captured in the western and northern areas supports the hypothesis that polar bears in Alaska are not a single, homogeneous population (Lentfer 1987). In addition, the studies by Manning (1971), Lentfer (1974*a*), and Wilson (1976) on skull and body size of polar bears in Alaska support this interpretation. However, this interpretation was not supported by information on the incidence and severity of *Trichinella* larva infestation in polar bear masseter muscle, which do not vary geographically in Alaska (Lentfer 1976*a*).

There are no physical barriers to prevent polar bears from moving across international boundaries. However, information from mark-recapture studies indicates that polar bears tend to be recaptured in the general area where they were originally marked. Mark-recapture studies indicate that animals move between Alaska and the mainland coast of western Canada, but not between Alaska and the rest of Canada, Greenland, and Svalbard (Lentfer 1974*a*, 1983; Stirling *et al.* 1975, 1981; Amstrup *et al.* 1986). At least three instances of movements between Alaska and the U.S.S.R. have been reported (Lentfer 1983). At present there is insufficient information to determine the significance of such movements.

Stirling *et al.* (1977*a*) reported that the only recovery of a significant number of bears in Alaska that had been marked in Canada followed unusual weather conditions in the springs of 1974 and 1975, when ice conditions were such that the numbers of ringed seals and bearded seals in the Beaufort Sea were severely reduced. Lentfer (1983) reported that bears marked in Alaska were recovered in Canada in 1973 and 1976, but not in 1974 and 1975. Population estimates for polar bears in the Beaufort Sea were found to be significantly lower between March 1974 and March 1975 than in the previous or subsequent 3 years (DeMaster *et al.* 1980). DeMaster *et al.* suggested that the change in numbers of bears was related to relative abundance of ringed seals and bearded seals. These data suggest that the distribution and abundance of polar bears in the Beaufort Sea are influenced by the number and availability of seals.

Recent radio-tracking studies indicate considerably more movement of animals within the Beaufort Sea than did previous studies (Amstrup 1986). Polar bears radio-tagged off the coast of Alaska between Point Barrow and Barter Island were later located as far east in the Canadian Beaufort Sea as Cape Bathurst, Northwest Territories. Movements of radio-tagged bears also occurred in the opposite direction, from the Canadian Beaufort to Point Barrow. The explanation for the apparent difference in the results of mark-recapture studies and radio-tracking studies is most likely related to the ability to follow a bear's movements between seasons as opposed to obtaining data mainly in the spring of each year.

In summary, the available evidence indicates that polar bears off the coast of Alaska are not part of a single, well-mixed population. Polar bears between the vicinity of Point Barrow and Cape Bathurst seem to constitute a single management unit. Polar bears found west of Point Barrow constitute at least one additional management unit. Some movements, documented by tag returns and radio-tracking, have been reported between the western Beaufort Sea and the Chukchi Sea, and between the U.S.S.R. and Alaska. However, such movements appear to be the exception rather than the rule. Amstrup (unpubl. data) hypothesized that atypical movement of Beaufort Sea bears to points west of Point Barrow during the winter of 1985–86 was related to ice conditions and prevailing currents that carried bears west of their former ranges.

Population Size

Sound estimates of the abundance of polar bears in Alaska or trends in population levels currently do not exist. This is related to a number of factors. As stated previously, the degree to which local populations are discrete is not fully understood. In addition, the probability of sighting a bear is related to habitat type, and even under ideal sighting conditions many bears are not seen (Stirling *et al.* 1975). For example, it is much easier to detect a bear along the floe edge than in heavily ridged pack ice. At present there is no way *a priori* to stratify a survey to account for differences in ice type in different areas. Finally, the density of polar bears is low enough that logistic constraints generally preclude surveying at a level of effort that will provide meaningful population estimates or indices of abundance (see Eberhardt 1978).

In spite of these difficulties, progress has been made in estimating abundance or population trends. Initial efforts involved strip surveys with fixed-wing aircraft. Tovey and Scott (1957) reported that trophy hunters in 1956 and 1957 sighted 255 bears while searching 26,515 km^2, or an average sighting rate of 1 bear per 104 km^2. Searches were conducted from the villages of Point Hope, Wales, Lisburne, and Point Barrow. Working from a slightly larger data base for 1956–58, Scott *et al.* (1959) reported that polar bear trophy hunters saw 1 bear per 138 km^2. These density estimates were based on an average aircraft speed of 167 km/hour and a 0.40-km strip width. From 1959 through 1969, airborne hunters saw 1 bear per 147 km^2 (Amstrup *et al.* 1986) during flights similar in pattern to those reported by Tovey and Scott (1957). Amstrup *et al.* (1986) recognized that many bears were probably missed and that coverage was not random.

From a density of 1 bear per 104 km^2 and available habitat along the Alaskan coastline of 208,000 km^2, Tovey and Scott (1957) estimated that there were roughly 2,000 polar bears in Alaska. The estimate of available habitat was based on the average distance from the coastline (121 km) of bear sightings by hunting guides in aircraft. Radiotelemetry studies by Amstrup (1986) indicate that polar bears occupy a strip 280 km wide along the coast of Alaska; using this figure and an average density of 1 bear per 104 km^2 results in a total population estimate of 4,600 animals. Amstrup's estimate of the average width of area used by polar bears off the coast of Alaska is likely to be low, because it is based primarily on the distribution of females in the Beaufort Sea. Lentfer (pers. commun.) reported finding a significant number of polar bears in the Chukchi Sea beyond 280 km from the coast.

During 3,096 hours of flying in Alaska between 1966 and 1984, Amstrup *et al.* (1986) recorded 1,147 polar bear observations. Following the procedure of Scott *et al.* (1959), the approximate density of bears was 1 bear per 150 km^2. Amstrup *et al.* (1986) estimated polar bear densities in the Chukchi Sea to be 1 bear per 75–211 km^2.

Amstrup *et al.* (1986) provided a comprehensive review of polar bear sighting and mark-recapture data. From multiyear mark-recapture data they estimated a mean of 1,776 animals (SE = 274) for the Beaufort Sea population of Alaska and Canada between 1972 and 1983. Estimates ranged from 1,186 to 3,527, depending on the survival rate assumed. The estimated standard error was calculated as the square root of the sum of variances for each population estimate divided by the square of the sample size (Amstrup *et al.* 1986: table 1). The estimated density of bears in this area was 1 bear per 197 km^2. DeMaster *et al.* (1980) estimated a population size of 1,170–1,800 polar bears in the western Canadian Arctic, in a study area of roughly 172,000 km^2, using a multiyear mark-recapture technique. These data give a density estimate of 1 bear per 96–147 km^2. Because such estimation procedures are sensitive to changes in adult survival, they may yield less accurate estimates than it appears. Gilbert (1985) and Lentfer *et al.* (1980) reported that population estimates based on multiyear mark-recapture programs in Alaska were not reliable because it was not possible to assume that once animals left the study area they would not return (see Seber 1973:204).

Amstrup *et al.* (1986) reviewed the results of five single-season mark-recapture estimates of population size. In the first of these, Gilbert (1976, 1985) attempted to estimate numbers of polar bears in a 111-km by 111-km area north of Point Barrow. The density of bears was estimated over a 5-week period (17 March to 28 April). The Schnabel method produced an estimate of 320 bears or 250 groups (*i.e.*, an adult female with cubs is counted as one group). The Jolly-Seber method produced an estimate of 17 to 150 individuals or 13 to 45 groups. Using these estimates gives a density range of 1 bear/38 km^2 to 1 bear/725 km^2. Other single-season estimates ranged from 1 bear/129 km^2 to 1 bear/211 km^2 (Amstrup *et al.* 1986).

Amstrup *et al.* (1986) suggested that densities of polar bears in the Chukchi Sea are similar to those in the Beaufort Sea. At present, the most accepted estimate for the total population of polar bears in Alaska is 3,000–5,000 animals. The density of bears has probably never exceeded 1 bear per 137–240 km^2.

The only published estimates of Alaskan polar bear population trends are in Lentfer *et al.* (1980) and Amstrup *et al.* (1986). Lentfer *et al.* indicated that the population of polar bears around Point Barrow between 1967 and 1976 was increasing. This determination was based on a comparison of survival rates from a cohort of animals and from a composite age structure. Neither the variance of the survival rates nor the level of significance between the two estimates was given. In addition, the authors reported that the results of a population simulation based on the observed rates of reproduction and survival indicated that the population was increasing between 1967 and 1976. (See sections on Reproduction and Survival for a review of these data.) The rate of increase was not reported.

Amstrup *et al.* (1986) suggested that the numbers of polar bears in Alaska in 1956 and 1984 were similar. However, they indicated that the population may have declined in the late 1950s and early 1960s in response to hunting pressure, recovered during the mid- and late 1970s, and has been stable since then. Amstrup *et al.* (1986) discussed numerous possible biases and shortcomings in existing data. Disproportionate sampling of some sex and age groups and radical annual variations in small sample sizes required lumping of data in ways which could be misleading. The fact that populations in Alaska were not stable during the sampling period was also a source of possible error. Eberhardt (unpubl. data) suggested some of these problems could be reduced if only adult animals were considered. However, that approach would require a greater sampling intensity.

Trophic Ecology

Seals are the primary prey of polar bears throughout their range, although other marine mammals, birds, and vegetative foods may also be consumed (Lono 1970, Freeman 1973, Russell 1975, Stirling and Smith 1975, Heyland and Hay 1976, Stirling and Archibald 1977). Polar bears in the Alaskan Arctic prey primarily on ringed seals (*Phoca hispida*) and to a lesser extent on bearded seals (*Erignathus barbatus*). Eley (unpubl. data) examined the remains of 71 pinnipeds killed by polar bears in Alaskan waters; 65 (93%) were ringed seals, 5 (6%) were bearded seals, and 1 was a walrus (*Odobenus rosmarus*). Bearded seals constituted 11-19% of the identifiable prey in the western Canadian Arctic (Stirling and Archibald 1977, Smith 1980). Walruses are not considered to be an important component of the polar bear diet (Kiliaan and Stirling 1978; Fay 1982; Eley, unpubl. data). Instances of polar bears killing beluga whales (*Delphinapterus leucas*) have been reported (Degerbøl and Freuchen 1935, Kleinenberg *et al.* 1964, Freeman 1973, Heyland and Hay 1976), but belugas are not considered an important component of the polar bear diet.

Stirling and Archibald (1977) reported that over 50% of ringed seals taken by polar bears on fast ice in the western Canadian Arctic and the High Arctic during periods of high ringed seal productivity were young-of-the-year. In years of low ringed seal productivity in the western Arctic, young-of-the-year ringed seals were not taken by polar bears. In addition, consumption of carcasses differed between the two study areas. The difference was thought to be related to the relative availability and productivity of ringed seals. Similar studies have not been done in Alaska.

Age-specific differences in hunting success rates have been reported by Stirling and Latour (1978) for the central Canadian High Arctic. Cubs of any age were not observed to be successful at taking seals in the spring of the year. During the summer the success rate of 2-year-olds was similar to that of adults. Young-of-the-year and yearlings were less successful than adults. The authors suggested that the poor hunting ability of cubs in the spring is related to their inability to break through the layer of snow that covers birth lairs and breathing holes at that time. They also suggested that cubs abandoned prior to the normal weaning age of 2.5 years would likely not survive.

The energetics of polar bear predation on ringed seals was discussed by Stirling and McEwan (1975), Best (1977), and Hurst *et al.* (1982). Stirling and McEwan estimated that in the Canadian Arctic 80% of ringed seals taken by polar bears are less than 2 years old. Similar studies have not been reported for Alaska. A young-of-the-year ringed seal is worth about 60,000 kcal to a polar bear. Over 70% of these calories are in fat deposits. These authors reasoned that, when seals are readily available, polar bears may eat only the skin and blubber of their prey because, at least for subadults and females with cubs, smaller animals may be interrupted at kills by larger animals. This places a premium on getting as many calories as quickly as possible from a kill. Best (1977) determined that most polar bears could consume up to 20% of their own body weight in less than 30 minutes and that, on average, a polar bear would need to kill a ringed seal every 6.4 days to maintain its body weight.

Polar bears have few natural enemies; however, walruses and wolves (*Canis lupus*) have been observed to kill polar bears. Reports of polar bears being killed by walruses are generally related to polar bears being injured, and subsequently dying, while making an unsuccessful attempt to take a walrus (Kiliaan and Stirling 1978). Wolves have been observed to take polar bear cubs in the Hudson Bay area (Ramsay and Stirling 1984), but this is thought to be uncommon in other areas because the ranges of these species generally do not overlap.

Denning

Female polar bears enter maternity dens, which they excavate in snow, by late November; the young are born in late December or early January (Harington 1968). In most areas of the Arctic, family groups leave the dens in late March or early April. Female polar bears are quite sensitive to outside disturbances during this period (Belikov 1976, Lentfer and Hensel 1980, Amstrup 1986). Movement of bears from dens before cubs are able to walk or withstand ambient temperatures results in loss of cubs. Similarly, the successful rearing of polar bears in captivity requires a relatively undisturbed denning environment.

The density of maternity dens varies geographically (see Behavior section in DeMaster and Stirling 1981). The largest concentrations of dens are found on Wrangel Island in the Soviet Union (Uspenskii and Kistchinskii 1972), on some of the islands of the Svalbard Archipelago north of the Norwegian mainland (Larsen 1985), and near the west coast of Hudson Bay in Canada (Jonkel *et al.* 1972; Stirling *et al.* 1977*b*). Several other areas where bears consistently den have also been identified; *e.g.*, west coast of Banks Island (Stirling *et al.* 1975) and on Gateshead Island (Schweinsburg *et al.* 1984), both in Canada. In Alaska and along the western edge of Banks Island, maternity dens are thought to be sparsely distributed along the coast (Stirling *et al.* 1975, Lentfer 1976*b*, Lentfer and Hensel 1980). Lentfer and Hensel (1980) reported more dens on land and shorefast ice between the Colville River and the Canadian border than elsewhere. They suggested that this may be related to the onset of ice formation along the north coast of Alaska, which often first occurs near the Canadian border and progresses westerly. It is also probably related to the greater topographic relief found along this section of the coast. Polar bears need deep, compacted snow drifts from which they can excavate snow dens, and suitable drifts are less common on the flatter terrain of the western Arctic coast of Alaska.

Lentfer (1975) reported the first confirmed instance of polar bears denning on drifting sea ice of the Beaufort Sea. A den was found approximately 165 km from the coast in multiyear pack ice. Lentfer and Hensel (1980) reported locations on drifting ice north of Alaska of 93 litters of young-of-the-year recently out of dens. The mean distance from the coast was 77 km and the range was 7–278 km. Many had emerged from the dens so recently and were so far offshore that their dens most likely had been on the drifting ice. However, Lentfer (1975) and Lentfer and Hensel (1980) suggested several reasons why denning by polar bears on the sea ice may not be as successful as denning on land. Recent radio-tracking studies indicate that denning in multiyear pack ice in the Alaskan Beaufort Sea may be the rule and not the exception (Amstrup 1986). In the winters of 1983 and 1984, 26 radio-tagged bears were followed to maternity den sites. Only four of these sites were on land. One of the den sites was not pinpointed; the remaining 21 dens were on pack ice. In addition, several other radio-tagged bears assumed to be pregnant were last seen moving in a northerly and westerly direction in the late summer toward the multiyear pack ice. In 1985, 21 of 23 polar bears were followed to maternity den sites on pack ice (Amstrup, unpubl. data). Larsen *et al.* (1980) reported that 90% of all polar bear tracks observed in the vicinity of the FRAM I expedition (about 83°N latitude) were those of females with small cubs. Given the distance from land, it is likely that these females had also denned on multiyear pack ice.

For the 3 years 1983–86, 83% of the maternity dens found in the Alaskan Beaufort Sea were on pack ice. However, it is not clear if this was always the case or if human disturbance has altered the distribution of denning in Alaska. Stirling *et al.* (1975) suggested that Native hunters along the mainland coast of the western Canadian Arctic may have displaced polar bears from denning in this area. Leffingwell (1919) documented the removal of many bears from maternity dens along the north coast of Alaska in the early 1900s.

Reproduction

Geographical differences in litter size, litter production, and the onset of maturity seem to exist, especially between Hudson Bay and all other populations (Stirling *et al.* 1977*b*). Therefore, estimates of these parameters from populations other than those in the Chukchi or Beaufort seas may not be reliable.

In Alaska the mean litter size of young-of-the-year, yearlings, and 2-year-olds between March and April was 1.68, 1.66, and 1.51, respectively (Lentfer 1976*b*). The litter size at birth is not known. Lentfer *et al.* (1980) reported no significant difference in litter size with age of the cubs and an average litter size of 1.63 cubs per litter ($N = 115$, $SE = 0.05$); data on 2-year-olds were not included. Given the discrete nature of the data and the current low level of sampling, it is unlikely that differences in litter size with age of less than 10% will ever be detected. The authors indicated that litter size may increase with the age of the female, but the age-specific sample sizes were small. DeMaster and Stirling (1983) suggested that young-of-the-year litters are not randomly sampled, because these litters are generally, and illogically, reported to be smaller than yearling litters. Lentfer *et al.* (1980) reported that females with young-of-the-year may have been undersampled because field studies started each year before emergence of females and cubs from dens. DeMaster and Stirling (1983) speculated that the average litter size at birth in Alaska is probably very close to 2.0. The median and modal litter size in Alaska, and for most populations of polar bears (excluding Hudson Bay), is 2.0. The average size in the fall for young-of-the-year litters in Alaska has not been reported, but in Canada is 1.53 (Ramsay and Stirling 1982).

The probability of parturition (defined as the proportion of mature females that are accompanied by young-of-the-year; Furnell and Schweinsburg 1984) in Alaska is 0.13 (Lentfer *et al.* 1980; referred to as "fraction which successfully bred"). This rate is the lowest reported litter production rate for polar bears and is likely an artifact of undersampling adult females with young-of-the-year. A similar bias seems to exist for the western Canadian Arctic, where the parturition rate for females 5 years old and older was 0.19 (Stirling *et al.* 1975: table 4). In both areas more yearling litters were observed than young-of-the-year litters. The parturition rate for polar bears 5 years old and older in the central Canadian Arctic was 0.31 (Furnell and Schweinsburg 1984) and in western Hudson Bay was 0.56 (Ramsay and Stirling 1982). In both of these areas the number of young-of-the-year litters was greater than the number of yearling litters.

Adult female polar bears in most areas are "available" for breeding in the spring if they are not accompanied by young-of-the-year or yearlings. Therefore, the fraction that bred successfully the preceding year can be estimated as the number of adult females with young-of-the-year divided by the number of adult females without yearlings or 2-year-olds. The resulting estimate of breeding success for polar bears 8 years old and older in Alaska is 0.34 (Lentfer *et al.* 1980: table 5); in the western Canadian Arctic, 0.61 (Stirling *et al.* 1975: table 4); and in the central Canadian Arctic, 0.67 (Furnell and Schweinsburg 1984: table 3). Breeding success of 5-, 6-, and 7-year-olds in Alaska was 0.04, 0.28, and 0.29, respectively (Lentfer *et al.* 1980); and in the central Canadian Arctic was 0.27, 0.43, and 0.58, respectively. These data are consistent with the hypothesis that females with young cubs were undersampled in the Alaskan study.

Because females with young-of-the-year are generally undersampled, age-specific estimates of the parturition rate are usually based on the number of x-year-old females with young-of-the-year and $x + 1$-year-old females with yearlings (see Stirling *et al.* 1975 and Lentfer *et al.* 1980). Because estimates made in this manner assume that survival of cubs is near unity, which it probably is not, and the age distribution is stationary, the estimates are likely to be low. Therefore, where possible, the parturition rate should be estimated from the proportion of mature females with young-of-the-year litters (see Furnell and Schweinsburg 1984). Ramsay and Stirling (1988) discussed use of data on yearlings in estimating rates of reproduction.

A number of authors have used the reciprocal of the average number of years between breeding as an independent estimate of the rate of parturition. Lentfer (1976*b*) and Lentfer *et al.* (1980) estimated an average reproductive interval of 3.1 years ($N = 8$) and 3.6 years ($N = 8$), respectively, for polar bears in Alaska. Ramsay and Stirling (1982) reported an average reproductive interval of 3.2 years ($N = 11$) for Hudson Bay. Taylor (pers. commun.) pointed out that using the average reproductive interval underestimates the average probability of parturition over all age classes because primaparous females are "available" for breeding at a higher rate than older females. (See Goodman [1984:167] for formula for an unbiased estimator.) However, because the fraction of females that successfully breed is an increasing function of age, the significance of the bias toward underestimation should be minimal.

Lentfer *et al.* (1980) reported an average age of first reproduction in Alaska of 6.4 years, with a range of 4–8 years. Stirling *et al.* (1975) suggested that the maximum litter production rate is not reached until age 6, but that in the western Canadian Arctic some 4- and 5-year-olds produce litters. In both of these studies, the findings may be overestimates of the true age of first reproduction because of the undersampling of females with young cubs. The onset of litter production in the central Canadian Arctic, Hudson Bay, the High Arctic, and southeast Baffin Island occurs at 5 years of age (Stirling *et al.* 1980, 1984; Ramsay and Stirling 1982; Furnell and Schweinsburg 1984). (See Ramsay and Stirling [1988] for a comprehensive review of reproductive rates of polar bears in Canada.)

The maximum reported age of reproduction for polar bears in Alaska is 18 years. The oldest bear captured or killed in Alaska was estimated to be 29 years old (Schliebe, unpubl. data). The oldest reported female with cubs in the western Canadian Arctic was 19 years old. Ramsay and Stirling (1988) concluded that reproductive senescence occurs at 20 years of age.

The mean number of female cubs produced per female per year (hereafter referred to as the reproductive rate), assuming that the adult female survives from one census period to the next, has been calculated differently by different authors. This has created problems in comparing rates of reproduction by area. Given the type of information that is available, the following estimate is proposed as being the most useful estimate of the reproductive rate [m(x)] of an x-year-old female in Alaska (Eberhardt, pers. commun.):

$$m(x) = (0.5)(\text{litter size}_x)/(\text{reproductive interval}_x)$$

A range of reproductive rates for females age 8 and older in Alaska can be calculated from the following: mean litter size, 1.63 (Lentfer *et al.* 1980) and 1.98 (DeMaster and Stirling 1983); reproductive interval, 3.1 (Lentfer 1976*b*) and 3.6 (Lentfer *et al.* 1980).

Using these estimates gives a range of 0.23 to 0.32 cubs per mature female per year.

Taylor *et al.* (1986) have proposed a more detailed model for estimating age-specific rates of reproduction. The model

$$m(x) = (\%\ \text{available}_{x-1})\ (\text{litter production rate}_x/\text{available})\ (\text{litter size}_x),$$

assumes that females that lose litters of young-of-the-year and yearlings will be available to breed the following breeding season. However, because of the previously mentioned sampling biases in the Alaska data base, this model is not recommended at this time. Clearly, future data collections in Alaska must be designed to overcome current deficiencies in estimates of reproductive parameters.

Survival

Meaningful estimates of age-specific survival of polar bears are not available. This is because (1) estimates of survival are confounded by movements of polar bears; (2) sample sizes from mark-recapture studies are typically too small to provide sound estimates; (3) local densities of bears can fluctuate greatly from year to year (Amstrup *et al.* 1986: table 5) and, therefore, it is not possible to assume a stable age distribution or a constant population rate of change; and (4) in Alaska, monitoring of the Native harvest and collection of specimens from bears taken by Natives has not been consistent since 1972 and sample sizes have been relatively small.

Two publications report on survivorship of polar bears in Alaska. Estimates of survival by Lentfer *et al.* (1980) and Amstrup *et al.* (1986) were based on composite age-structure analysis (*i.e.*, regression analysis, Chapman–Robson). Survival estimates by Lentfer *et al.* were also based on a cohort analysis.

Lentfer *et al.* reported age- and sex-specific differences in rate of survival. Survival estimates for adult females ranged between 0.64 and 0.84. Survival estimates for adult males were similar. Survival estimates for males 2–6 years old and females 2–8 years old were between 0.69 and 0.99. The Chapman–Robson estimates were consistently less than the regression and cohort estimates. The authors stated that the cohort estimates of survival were not biased by changes in population size during the study (1967–76). According to Seber (1973) this is only true if the probability of capture is constant. If the population was increasing in the 1970s (Amstrup *et al.* 1986) and given that the number of bears captured in Lentfer *et al.*'s study did not increase significantly over time (Lentfer *et al.* 1980: table 1; $r = 0.34$, slope $= 4.68$, $P < 0.5$), the probability of capture would have been decreasing during the study period. If the number of animals captured per year was constant and if the population was increasing, an estimate of survival based on a cohort analysis is biased by the factor, 1/(discrete rate of growth). In addition, there is evidence that females with young-of-the-year may be undersampled (see Reproduction). If females aged 5 to 8 can be expected to have more young-of-the-year litters than any older age classes, then these ages would be undersampled.

Amstrup *et al.* (1986) reported a mean rate of survival for bears 1 year old and older of 0.88 (range = 0.87–0.89), which is close to estimates of the survival rate for bears in the western Canadian Arctic (DeMaster *et al.* 1980) and the central Canadian Arctic (Furnell and Schweinsburg 1984). The estimated mortality rate, 0.12, includes both natural mortality and hunting-related mortality. It is necessary to assume that the population size was constant in using a regression analysis or the Chapman–Robson method. If, as was stated previously, the population was increasing, then the estimates of survival reported by Amstrup *et al.* are negatively biased.

Survival estimates for yearlings ranged between 0.70 and 0.75 (DeMaster and Stirling 1983). This estimate was based on the change in litter size from litters of yearlings to 2-year-olds. The data were from Alaska, the western Canadian Arctic, the central Canadian Arctic, and Baffin Island.

The average annual polar bear harvest in Alaska has declined since passage of the Marine Mammal Protection Act of 1972, although there may have been a relative increase in the number of cubs and females with cubs that are taken. Between 1925 and 1953 the mean reported number of polar bear hides shipped from Alaska was 117 (Amstrup *et al.* 1986). In 1954, 1955, and 1956 the estimated annual kill was 100, 128, and 135, respectively, and 128, 250, and 162 bears were reported killed in 1958, 1959, and 1960, respectively (Amstrup *et al.* 1986).

Between 1961 and 1972 the number of polar bears taken annually in Alaska ranged from 148 to 405 and averaged 260 (Lentfer 1973, Amstrup *et al.* 1986). Seventy-five percent of these animals were males. During these years cubs and females with cubs were protected, hides and skulls had to be presented to an Alaska Department of Fish and Game agent within 30 days of the date of kill, and bag limits for sport hunters were enforced. Residents were allowed to take bears for food at any time without a permit and without limit provided aircraft were not used (Lentfer 1971*b*).

The Marine Mammal Protection Act of 1972 prohibited the hunting of polar bears in Alaska except by Alaska Natives for subsistence purposes. Under the Act the Native take was not restricted by age, sex, or number of animals, except that the take must be in a nonwasteful manner. From 1973 to 1976 an average of 45 female bears were harvested per year (Amstrup *et al.* 1986). For the years 1980–85 the reported polar bear take ranged from 89 to 292 and averaged 135 (Schliebe 1986). The harvest composition was 54% males, 30% females, and 16% unknown sex. The ratio of males to females was 64:36. The average age of the unknown-sex bears was substantially below that of animals of known sex, possibly indicating a hunter tendency to forget the sex of younger (dependent) animals. Females with cubs and their cubs comprised 16% of the harvest. Annual harvests averaged 38 animals (28%) from the Beaufort Sea and 97 animals (72%) from the Chukchi and Bering seas. The annual average age ranged from 6.2 to 10.4 for females and from 4.6 to 7.0 for males.

At present it is not possible to determine what proportion of the total mortality rate (*i.e.*, 12%) is caused by hunting. Reliable estimates of the population size and the percentage of males in the population are not available for 1960–72 when reliable information on the harvest exists. More recently, although reliable estimates of the Beaufort Sea population exist, estimates of the Native take are not exact. If the number of bears in the mainland Beaufort Sea population is 2,000 (Amstrup *et al.* 1986), and if the current harvest in this region is approximately 50 bears per year (Schliebe 1986), then harvest currently accounts for 21% of the total mortality. Losses due to crippling are thought to be low but have not been determined, and the degree to which hunting mortality and natural mortality are compensatory is unknown. New information and a more thorough analysis of the existing information are required to adequately understand the influence of hunting on polar bears in Alaska.

MANAGEMENT

Some historical accounts suggest that Yankee whalers and subsistence hunters may have extirpated local populations of polar bears in Alaska. Prior to 1900, polar bears occupied St. Matthew Island. Unlike most of Alaska's polar bears, many of these individuals spent the summer on land instead of remaining with the sea ice as it retreated to the north. Polar bears in Hudson Bay and some parts of the Canadian Arctic archipelago still follow this lifestyle. Commercial hunters in search of seal skins and whale oil eliminated polar bears from St. Matthew Island by the early 1900s (Hanna 1920). In addition, overwintering commercial whalers along with local residents may have reduced the number of bears that once denned in the Canning River region of Alaska (Leffingwell 1919).

With the exception of the take by commercial hunters at St. Matthew Island, polar bears were taken primarily for subsistence purposes and for the sale of hides by Natives hunting with dog teams through the 1940s. Guided hunting by aircraft started in the late 1940s and continued until stopped by the State of Alaska in 1972.

In 1961 the State of Alaska made it mandatory that hunters present polar bear skins for sealing and examination. The average annual take between 1960 and 1972 was 260 animals (Lentfer 1973, Amstrup *et al.* 1986). Between 1961 and 1972 the state regulations provided a preference for subsistence hunters and protected cubs and females with cubs. During this period trophy hunters were allowed to hunt only during late winter and spring. Although some undocumented take occurred (Lentfer 1971), information on the manner of take, area of take, and age and sex composition of the known take is available for this period (Lentfer 1973).

In 1972 the Marine Mammal Protection Act vested management with the federal government. Under the Act, only Natives are allowed to take polar bears. The Act removed restrictions on the taking of cubs and females with cubs and the mandatory reporting requirement of the state's management program. The only restriction on Native take is that it must be done in a nonwasteful manner. The Act allows the federal government to restrict the take by Natives only if the polar bear population is determined to be depleted.

Most Native hunters did not become familiar with the change in management regulations for some time following the passage of the Marine Mammal Protection Act (Lentfer 1985). Therefore, cubs and females with cubs were not taken in the early 1970s to the extent that they are taken now. Several other factors also contribute to variability between years in the vulnerability of different age and sex classes of bears and the total number of animals harvested by subsistence hunters. First, the cessation of the use of aircraft for hunting polar bears may have allowed the number of animals along the coasts of Alaska to increase. Second, in some years ice conditions tend to concentrate bears along the coast. Third, an apparent tendency for females with young cubs to occupy nearshore areas during the fall makes them more vulnerable to hunting. In addition, polar bears are often attracted to carcasses of whales or other marine mammals taken by Beaufort Sea subsistence hunters. Finally, pregnant females may return to historic denning sites in the fall. These factors and unexplained variations in the availability of bears to hunters cause considerable concern about the potential for harm to polar bears in Alaska under the existing management regime.

In recognition of the polar bear's increasing vulnerability to human activities, the five nations within whose boundaries polar bears occur negotiated the

International Agreement on Conservation of Polar Bears. The Agreement, negotiated in 1973 and ratified in 1976, prohibits the taking of polar bears from aircraft or large motor vessels or in areas where they have not been taken by traditional means in the past. This prohibition creates a *de facto* sanctuary in the central Arctic basin. A resolution appended to the Agreement requests governments to prohibit the taking of cubs or females with cubs and hunting in denning areas during periods when pregnant females are moving into them or are denning. Another resolution requests governments to establish an international system of identifying hides to effectively control the trafficking of illegal hides. (See Lentfer [1974*b*] and Stirling [1986] for more comprehensive reviews.) Finally, the Agreement requires each of the signatory nations to conduct a research program and to coordinate management and research for populations that overlap jurisdictional boundaries.

Each of the five signatory nations has implemented a management program to protect polar bears and their environment. The Soviet Union ended all hunting of polar bears in 1955. The only reported taking of polar bears in the U.S.S.R. since then has been a few cubs taken each year for public display. In 1970 Norway severely reduced the taking of polar bears in the Svalbard area. In 1973 a complete ban on the taking of polar bears in Svalbard, except for defense of life and property, was established. Denmark has eliminated commercial hunting of polar bears in Greenland, and only subsistence hunting by Native residents is allowed. This hunting is further restricted by the requirement that hunters use only traditional means (which does not include motorized vehicles). In most areas of Canada female bears and their young are protected by specific statutes and by season closures. The harvest is regulated by a quota system administered cooperatively by various jurisdictions operating in each village that has access to polar bears. Reporting is mandatory. Compliance with quotas, seasons, and other biologically founded regulations is assured because of economic incentives provided by the legal sale of hides and management of a limited trophy guiding industry for maximum benefit of the local hunters and trappers. The United States chose to implement the polar bear agreement with the provisions of the Marine Mammal Protection Act. The Act, which went into effect in 1973, prohibits the hunting of polar bears by other than Indians, Aleuts, or Eskimos. However, no restrictions on the number, sex, or age of animals taken by Natives were imposed.

The current harvest monitoring program of the U.S. Fish and Wildlife Service began in November 1980 (Schliebe 1986). Twenty villages are included in the program, and each is visited monthly. Information on the age, sex, and reproductive condition of each animal taken is collected. Between 1973 and 1980, information on the harvest of polar bears in Alaska was not systematically collected. The Service has published proposed regulations which authorize mandatory reporting requirements.

Recognizing the absence of protection for female polar bears with cubs in Alaska, the Polar Bear Specialist Group affiliated with the International Union for the Conservation of Nature and Natural Resources passed a resolution in August 1985 calling for swift action among the users of polar bears in Alaska and Canada to establish voluntary restrictions that will protect female polar bears and their young. The Polar Bear Group further called for voluntary measures to be followed as soon as possible by legal protection.

Progress on the first point was made 4 April 1986 when the Fish and Game Management Committee of the North Slope Borough resolved that Alaskan hunters should not shoot cubs or females with young. This group further resolved to collaborate with the Inuit hunters of Canada to ensure that harvests of polar bears do not exceed the replacement rate of this population. Passage of the resolution was followed in September 1986 by an agreement for cooperative management between the North Slope Borough Fish and Game Management Committee and the Inuvialuit Game Council. Among other things, this cooperative management agreement calls for:

1. Establishing harvest limits
2. Protection of females and cubs
3. Protection of pregnant females
4. Protection of denning bears
5. Management system to regulate the number of polar bears harvested to comply with harvest limit allocations
6. Reporting system to collect critical information from harvested polar bears
7. Protection of important polar bear habitat

This is a positive step with the potential to afford the necessary protection of polar bears in the area of North Slope Borough jurisdiction; *i.e.*, from the Canada border westward to Cape Seppings between Point Hope and Kivalina. Similar stipulations should apply where polar bears occur outside of the North Slope Borough.

CONSERVATION ISSUES AND DATA GAPS

The conservation of polar bears in Alaska depends primarily upon two things. First, to insure adequate space for critical life functions of feeding and reproduction, habitats of special significance to bears must be identified and protected. Second, to maintain viable polar bear populations, human activities that directly or indirectly alter the numbers of polar bears occupying available habitat must be controlled. To determine the effectiveness of programs designed to protect critical habitats and to control human activities, monitoring programs must be developed and implemented.

Habitat Preservation

The mobility of polar bears combined with the fact that much of their habitat consists of sea ice results in unusual problems in identifying important habitat. The most obvious and identifiable habitats important to polar bears are maternity denning areas because reproductive effort there can most easily be altered. Areas where open water or active ice persists through the winter and early spring are important habitats for feeding.

The potential to adversely impact denning bears due to disturbance in or around dens has been demonstrated (Stirling *et al.* 1975, Belikov 1976, Lentfer and Hensel 1980). The actual degree to which denning polar bears in Alaska are disturbed is not known at this time. This is partly related to the unknown significance of pack ice denning. Lentfer and Hensel (1980) reported locations of 35 dens, 5 on drifting ice and 30 on land or shorefast ice. They also reported a significant number of newborn cubs so far from land that they likely emerged from dens on drifting ice. More recently, only 17% ($N = 76$) of dens located in Alaska by radiotelemetry were on land. Concern has been raised over the potential for displacing females from historically important denning areas by either hunting or industrial activity (Stirling *et al.* 1984). It is therefore critical to determine the significance of offshore denning and how successful such denning is relative to onshore denning.

Less is known about habitat preference for polar bear feeding than is known about denning, but it seems clear that individual bears show a great deal of site fidelity at certain times of the year. The importance of polynyas, areas where ice consistently breaks up and makes open water and newly refrozen areas available for much of the winter, is well established (Stirling and Cleator 1981). In general, areas that contain polynyas may be the most important marine habitats in the Arctic (Stirling and Cleator 1981). Recent studies have shown that polar bears spend the majority of their time in a band extending from the shore leads that parallel the coast of Alaska out to approximately 200 km offshore. The ice in this zone is generally more active and has more open water and refreezing areas than either shorefast ice or heavy pack ice to the north. The effect of human activities, such as seismic exploration or shipping, in these areas on either polar bears or their prey is unknown. In addition, concern has been expressed that contamination of ice, water, food species, and bears themselves by oil or other toxic chemicals may increase as human activities increase in the Arctic over the next few decades. (See Stirling and Calvert [1983] for a comprehensive review.) Acute exposure to such compounds can be fatal (Øritsland *et al.* 1981). However, the long-term effects of lower levels of such contamination are not known (Stirling and Calvert 1983).

Nonconformance to Polar Bear Agreement

Under the current management regime an unlimited number of polar bears, of any age and either sex, may be taken by Native hunters. As stated earlier, Native hunters of the North Slope Borough may voluntarily restrict the taking of cubs or females with cubs. It is not clear if hunters from the west coast of Alaska (*i.e.*, outside of the North Slope Borough) will voluntarily protect cubs and females with cubs. Currently there are no seasonal or area closures to protect pregnant females as recommended by the Agreement on Conservation of Polar Bears. The status of implementing mandatory reporting requirements is unclear. Therefore, though moving in the right direction, the U.S. management program for polar bears is not in compliance with the Polar Bear Agreement.

Canada has developed a quota system by village. The taking of cubs and females with cubs is banned, and seasonal closures protect pregnant females. The maximum allowable take has been estimated to equal 5% of the local population per year. Taylor *et al.* (1986) determined that a population of 4,000 animals (roughly the size of the polar bear population in Alaska) can sustain a harvest of no more than 80 adult females per year. Amstrup (1986) estimated that for the Beaufort Sea population as few as 56 adult females may be recruited into the population each year.

The average polar bear harvest in Alaska has declined since passage of the Marine Mammal Protection Act. However, available evidence indicates, at least for the Beaufort Sea population, that the annual loss of females is currently about the maximum allowable. The recently passed resolution of the North Slope Borough recommending against the taking of cubs or females with cubs may reduce their vulnerability. However, a mandatory harvest monitoring program for all villages is needed to verify the number, sex, age, and location of bears taken. In addition, efforts to convey biological concepts to user groups must be expanded.

Population Discreteness

Recent evidence indicates that polar bears north of Alaska and in the western Canadian Arctic constitute a single management unit. The degree of separation between bears in Alaska and the U.S.S.R. is not known at this time. Given the current level of take by Natives in Alaska and Canada, it is essential that management of polar bears in the Beaufort Sea be coordinated between the two countries. Moreover, because there may be limited movement of animals between the Beaufort and Chukchi seas, the significance of such movements must be determined. It is likely that such movements are associated with unusual weather conditions and, therefore, research programs will have to be designed to accommodate the variability in annual ice conditions.

Interactions with People

Polar bears sometimes pose a threat to or attack people living and working in the Arctic (Schweinsburg 1976, Guravich 1980), and this often results in bears being killed. Stenhouse (1983) and Bromley (1985) summarized ways to minimize bear–human interactions. Camps should not be located in areas of active ice, near shore leads, or on points of land where ocean currents might deposit carcasses of marine mammals. Food and garbage in camps and villages should be handled so as not to attract bears. Workers new to the Arctic should be indoctrinated on bear behavior and procedures to use if confronted by a bear. A bear that comes into a camp or settlement should not be allowed to become habituated and lose fear of humans, but should be thoroughly frightened and, if possible, driven several kilometers away with a snow machine or helicopter. Close encounters can be prevented by use of trip-wire alarm systems and tied dogs which bark at the sight or scent of bears. Efforts should continue to develop reliable, nonlethal methods to deter bears.

Monitoring Programs

The effectiveness of a management program in controlling the adverse effects of human activities on polar bears in Alaska can only be evaluated relative to specific management goals, *e.g.*, to maintain the population at or above the level of maximum net productivity. The population is currently thought to be within this range. However, techniques sensitive enough to detect other than very large changes in the size of the Alaskan population have not been developed. Traditional survey approaches have proven unreliable and expensive because of the low density of bears on the sea ice. Mark-recapture programs are expensive and slow to provide information on changes in population size. Catch per unit effort indices of abundance have lacked suitable precision to be reliable. The U.S. Fish and Wildlife Service is currently trying to develop a survey technique that takes advantage of weather conditions that tend to concentrate animals in a relatively narrow band offshore. Such a survey may take place only once every few years, but may provide an adequate basis for evaluating the effectiveness of various management activities. Before any type of population monitoring program is adopted it should be evaluated in terms of what level of change could be detected, given a particular level of effort (Holt *et al.* 1986).

MANAGEMENT RECOMMENDATIONS

1) Manage in Conformity with Polar Bear Agreement. — Simulation models suggest polar bear populations are extremely sensitive to harvesting of adult females. In addition, pregnant or post-parturient polar bears often occur closer to human settlements than other components of the population. Cubs and females with cubs, therefore, need greater protection than other age and sex classes. The current North Slope Borough resolution recommending against the taking of cubs or females with cubs is a positive step. The recommendation should be extended to villages outside the jurisdiction of the North Slope Borough. In addition, fall hunting should be restricted to protect pregnant females returning to traditional denning areas. Females and cubs in dens should be protected. Efforts to minimize disturbance from hunting and industrial activities in areas critical for denning and feeding should be continued and, where necessary, increased.

2) Monitor Changes in Population Size. — Industrial activities and hunting may adversely affect polar bears in Alaska. Therefore, it is necessary to monitor changes in population size over time. Present survey techniques cannot provide a valid index of abundance. Ongoing research efforts must lead to the development of new survey methodologies. Once developed, surveys should be conducted on a regular basis.

3) Make Harvest Reporting Mandatory. — Because polar bear populations are sensitive to the removal of adult females, sex and age composition and size of the harvest must be known in order to determine whether a particular level of harvest will adversely affect a population of polar bears. This is best done by a mandatory reporting program whereby hunters are required to present hides for sex determination and skulls for measurements and collection of a tooth. The responsible management agency should be required to analyze and report results of the previous year's harvest monitoring program within the first 6 months of the following year.

4) Reduce Bear–Human Interactions. — The nature, magnitude, and trend of bear-human interactions over the past 20 years should be determined.

Education programs should be implemented in problem areas. When bears are killed as nuisance animals, the agency responsible for management should review the circumstances. The effectiveness of available detection and deterrent systems for Alaska must be evaluated. Efforts to develop more reliable deterrents should continue. These activities should be coordinated with those of the Northwest Territories, Canada.

*5) **Protect Polar Bear Habitat and Populations.*** — Several agencies of the state and federal governments have resource management responsibilities that can affect polar bear habitat and populations. Land and ocean activities should be regulated and other management activities coordinated and conducted so that polar bear habitat and populations are not adversely affected.

RESEARCH RECOMMENDATIONS

In order to be most effective, future polar bear research must proceed in the following order. First, the populations in question must be defined. One cannot discuss population size, trend, or other population parameters until one knows what the population is. Then, the important parameters such as survival, recruitment, and age composition must be determined. Distribution patterns and feeding and other behaviors must also be understood because they may introduce bias into estimates of life history parameters. Finally, survey and index techniques that take these considerations into account can be developed. Specific research recommendations and suggestions are as follows.

*1) **Define the Populations In and Adjacent to Alaska.*** — Information on the degree to which polar bears in the eastern and western Beaufort Sea and the Chukchi and Beaufort seas mix indicates that animals in the former, but not the latter, constitute a single management unit. Therefore, management agencies in the United States and Canada must coordinate their individual management strategies to conserve polar bears in this area. At present, however, there is insufficient information to determine the degree to which animals in the Beaufort and Chukchi seas constitute discrete stocks. Therefore, telemetry studies should be expanded to include instrumenting and tracking an adequate sample of animals in the Chukchi and Bering seas and at the interface of the Beaufort and Chukchi seas.

In addition to telemetry studies, the feasibility of using levels of contamination of various pollutants to define stock discreteness should be tested. Initial studies by Lentfer (1976*a*, 1987) were informative, but recent refinements in this approach need to be incorporated into a research project. Specimen material can be easily obtained as part of the harvest monitoring program. Therefore, the only significant cost of such a project would be for the chemical analysis.

Analyses of nuclear and mitochondrial DNA can also be used to define population discreteness. The U.S. Fish and Wildlife Service is currently testing the value of such analyses, as well as investigating the potential for using different types of algae that are found in the hair of polar bears to augment other studies on stock discreteness of Alaskan polar bears.

*2) **Describe Relationships between Polar Bears, Seals, and Sea Ice.*** — Distribution of polar bears is tied closely to the condition and distribution of sea ice. However, effects of ice drift patterns, topography, and lead development on polar bear movements and distribution are not clearly understood. In order to understand the movements and distribution of polar bears well enough that meaningful surveys of population trend and size can be conducted, the relationships between polar bears and movements and condition of ice must be better understood. Therefore, information on ice formation, movement, and distribution should be obtained, along with information on polar bear movements and activities. Correlations between polar bears and sea ice should then be developed.

Also not understood are predator-prey relationships between polar bears and their principal food species—ringed seals and bearded seals. Distribution and abundance of ringed seals in different ice types are not well known, nor is the manner in which polar bears hunt seals in the various kinds of ice. Some information obtained under laboratory conditions on dietary requirements of polar bears, when combined with ringed seal population estimates, suggests that estimated numbers of polar bears could require more seals than are available. There is clearly a need to describe relationships between polar bears, seals, and sea ice as a basis for understanding polar bear ecology and designing meaningful population and trend surveys.

*3) **Refine Population Parameters.*** — Detecting significant trends in polar bear abundance, reproduction, and survival, if possible, will likely require a time series of at least 8 or 10 years (Gerrodette 1987). Therefore, to avoid unnecessary population declines, population monitoring will have to be augmented by projecting population trends from current estimates of various life history parameters and harvest data, including total kill and age and sex composition. At a minimum, information on the average reproductive interval, the recruitment rate to age 6, and the adult survival rate are needed. With improved information on these life history parameters, existing models can be used to predict how the population will change over the next few years and how a particular change in management strategy might affect this projection. At this point, polar bear management lacks adequate information, not an adequate model to analyze the data. Concurrent with this analysis should be a sensitivity analysis of the modeling results.

At present, satellite telemetry offers the most promising approach to understanding the population dynamics of polar bears in Alaska. Ideally, recently emerged adult females with young-of-the-year or females with 2-year-olds could be radio-tagged and followed over time until the reproductive cycle has been completed. Such an approach will provide data on the reproductive interval, cub survival, and adult survival, as well as information on important habitats and movement patterns. A preliminary analysis will be necessary to determine what sampling level provides adequate precision. The U.S. Fish and Wildlife Service is currently conducting and plans to continue research to refine population parameters.

Eberhardt's (pers. commun.) recent analysis of the available information on the population dynamics of Alaskan polar bears indicates that females in Alaska have lower rates of parturition, an older age of first reproduction, and a smaller average litter size than do populations of polar bears in Canada. The reasons for these differences are not obvious. For example, Lentfer *et al.* (1980) suggested that young cubs were undersampled in the first few years of their study. It is possible that this bias could be removed by a number of stratification strategies. In addition, DeMaster (pers. commun.) performed a preliminary analysis of the Alaskan polar bear data base in 1980 and found over 20 cases where the length of the reproductive interval could be estimated from information on the presence or absence of cubs. Eberhardt reported that the adult rate of survival required to produce a stationary population level is at least 0.975, given various rates of recruitment. An adult survival rate of 0.975 or greater may be unrealistic; yet Amstrup *et al.* (1986) suggested that polar bear populations in the 1970s were probably increasing in Alaska and are currently likely to be stable. Therefore, a comprehensive analysis of the existing information should be undertaken to determine the likelihood of sampling biases in the data, geographic differences in various life history parameters, or long-term trends in the population.

4) Determine Significance of Denning on Pack Ice. — Radio-tracking is providing insight into the potential significance of denning on pack ice. However, the suitability of pack-ice denning relative to mainland denning has not been determined. Telemetry studies should continue over the next few years to determine areas critical to successful denning.

Telemetry studies should be expanded to determine the degree to which human activities such as shipping may disrupt animals denning in the pack ice. If it is found that denning on pack ice is significantly less successful than denning on land, research should immediately be directed toward determining the factors that may be responsible for the abandonment of what may have been traditional denning habitat on land.

5) Develop Index of Population Abundance. — After population boundaries have been defined, methods for assessing trends in the population should be developed. The U.S. Fish and Wildlife Service started research in fiscal year 1986 to develop an index of population abundance. A number of possible methods have been tested, but so far none have proven both practical and reliable. It is probable that knowledge gained from telemetry and tagging studies could be used to develop more efficient survey techniques. In fiscal year 1987 the Service began testing the feasibility of line and strip transect surveys from fixed-wing aircraft when bears are concentrated along a relatively narrow band of active ice because of weather conditions. If one of these survey methods appears promising, the level of population change that can be detected relative to a given level of effort should be determined. A panel of experts should be convened to review proposed methodology.

ACKNOWLEDGMENTS

We are especially grateful to Jack W. Lentfer, Scott L. Schliebe, Robert J. Hofman, and Caleb Pungowiyi for substantive and editorial contributions. Dale L. Taylor, David R. Cline, Ian Stirling, Lee L. Eberhardt, Richard J. Hensel, and Matthew Iya also reviewed and commented on the report.

REFERENCES CITED

AMSTRUP, S. C.
1986. Research on polar bears in Alaska, 1983-1985. Pages 85-115 *in* Polar bears: Proceedings of the Ninth Working Meeting of the IUCN/SSC Polar Bear Specialist Group, 9-11 August 1985, Edmonton, Alberta, Canada. Int. Union Conserv. Nature and Nat. Resour., Gland, Switzerland.

AMSTRUP, S. C., I. STIRLING, AND J. W. LENTFER.
1986. Past and present status of polar bears in Alaska. Wildl. Soc. Bull. 14(3):241-254.

BELIKOV, S. E.
1976. Behavioral aspects of the polar bear, *Ursus maritimus.* Pages 37-40 *in* M. R. Pelton, J. W. Lentfer, and G. E. Folk, eds. Bears—their biology and management. IUCN Publ. New Ser. 40.

BEST, R. C.
1977. Ecological aspects of polar bear nutrition. Pages 203-211 *in* R. L. Phillips and C. Jonkel, eds. Proceedings of the 1975 Predator Symposium. Univ. Montana, Missoula.

BROMLEY, M.
1985. Safety in bear country: a reference manual. Northwest Territ. Dep. Renewable Resour. 24pp.

DEGERBØL, M., AND P. FREUCHEN.
1935. Mammals. Rep. 5th Thule Exped. 1921-24, 2(4-5):109.

DEMASTER, D. P., M. C. S. KINGSLEY, AND I. STIRLING.
1980. A multiple mark and recapture estimate applied to polar bears. Can. J. Zool. 58:633-638.

DEMASTER, D. P., AND I. STIRLING.
1981. *Ursus maritimus.* Mamm. Species 145:1-7.
1983. The estimation of survival and litter size of polar bear cubs. Int. Conf. Bear Res. Manage. 5:260-263.

EBERHARDT, L. L.
1978. Appraising variability in population studies. J. Wildl. Manage. 42:207-238.

FAY, F. H.
1982. Ecology and biology of the Pacific walrus, *Odobenus rosmarus divergens* Illiger. N. Am. Fauna 74. 279pp.

FRAME, G. W.
1969. Occurrence of polar bears in the Chukchi and Beaufort seas, summer, 1969. J. Mammal. 53: 187-189.

FREEMAN, M. M. R.
1973. Polar bear predation on beluga in the Canadian Arctic. Arctic 26:163-164.

FURNELL, D. J. AND R. E. SCHWEINSBURG.
1984. Population dynamics of central Canadian Arctic island polar bears. J. Wildl. Manage. 48(3): 722-728.

GERRODETTE, T.
1987. A power analysis for detecting trends. Ecology 68(5):1364-1372.

GILBERT, J. R.
1976. Single season estimates of polar bear numbers using mark-resighting methods. Internal rep., U.S. Fish and Wildl. Serv., Denver Wildl. Res. Center, Denver, Colo. 17pp.
1985. Evaluation of methods to estimate polar bear population size. Unpubl. manuscr., U.S. Fish and Wildl. Serv., Anchorage, Alaska. 18pp.

GOODMAN, D.
1984. Statistics of reproductive rate estimates, and their implications for population projection. Reproduction in whales, dolphins and porpoises. Int. Whaling Comm., Spec. Issue 6:161-174.

GURAVICH, D.
1980. Protecting bear and man in the Arctic. Exxon 19(3):16-21.

HANNA, G. D.
1920. Mammals of the St. Matthew Islands, Bering Sea. J. Mammal. 1:118-122.

HARINGTON, C. P.
1968. Denning habits of the polar bear. Can. Wildl. Serv. Rep. 5:1-30.

HEYLAND, J. D., AND K. HAY.
1976. An attack by a polar bear on a juvenile beluga. Arctic 29:56-57.

HOLT, R. S., T. GERRODETTE, AND J. B. COLOGNE.
1986. Research vessel survey design for monitoring dolphin abundance in the eastern tropical Pacific 1986-1990. Internal rep., U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southwest Fish. Center, La Jolla, Calif. 20pp.

HURST, R. J., M. L. LEONARD, P. D. WATTS, P. BECKERTON, AND N. A. ØRITSLAND.
1982. Polar bear locomotion: body temperature and energetic cost. Can. J. Zool. 60:40-44.

JONKEL, C. J., G. B. KOLENOSKY, R. J. ROBERTSON, AND R. H. RUSSELL.
1972. Further notes on polar bear denning habits. Pages 142-158 *in* S. Herrero, ed. Bears—their biology and management. IUCN Publ. New Ser. 23.

KILIAAN, H. P. L., AND I. STIRLING.
1978. Observations on overwintering walruses in the eastern Canadian High Arctic. J. Mammal. 59:197-200.

KLEINENBERG, S. E., A. V. YABLOKOV, B. M. BEL'KOVICH, AND M. N. TARASEVICH.
1964. Beluga (*Delphinapterus leucas*): investigation of the species. Akad. Nauk SSSR, Moscow. 454pp. (Transl. from Russian by Israel Prog. Sci. Transl., 1969, 376pp. Avail. Natl. Tech. Inf. Serv., TT67-51345.)

LARSEN, T.
1985. Polar bear denning and cub production in Svalbard, Norway. J. Wildl. Manage. 49:320-326.

LARSEN, T., C. JONKEL, AND C. VIBE.
1980. Satellite radio-tracking of polar bears between Svalbard and Greenland. Int. Conf. Bear Res. Manage. 5:230-237.

LEFFINGWELL, E.
1919. The Canning River region, northern Alaska. U.S. Geol. Surv. Prof. Pap. 109. U.S. Gov. Print. Off., Washington, D.C. 247pp.

LENTFER, J. W.
1971*a*. Polar bear report. Alaska Dep. Fish and Game, Pittman-Robertson Proj. Rep. W-17-4 and W-17-5. 22pp.
1971*b*. The effects of ocean currents and ice movement on polar bear activity. Alaska Dep. Fish and Game, Pittman-Robertson Proj. Rep. W-17-2 and W-17-3. 11pp.
1972. Polar bear—sea ice relationships. Pages 165-171 *in* S. Herrerro, ed. Bears—their biology and management. IUCN Publ. New Ser. 23.
1973. Polar bear report. Alaska Dep. Fish and Game, Pittman-Robertson Proj. Rep. W-17-4 and W-17-5. 24pp.
1974*a*. Discreteness of Alaskan polar bear populations. Proc. Int. Congr. Game Biol. 11:323-329.
1974*b*. Agreement on conservation of polar bears. Polar Record 17(108):327-330.
1975. Polar bear denning on drifting sea ice. J. Mammal. 56:716-718.
1976*a*. Environmental contaminants and parasites in polar bears. Alaska Dep. Fish and Game, Pittman-Robertson Proj. Rep. W-17-4 and W-17-5. 22pp.

1976*b*. Polar bear reproductive biology and denning. Alaska Dep. Fish and Game, Pittman-Robertson Proj. Rep. W-17-3 and W-17-4. 22pp.

1983. Alaskan polar bear movements from mark and recovery. Arctic 36(3):282-288.

1985. The polar bear. Pages 27-36 *in* J. J. Burns, K. J. Frost, and L. F. Lowry, eds. Marine mammals species accounts. Alaska Dep. Fish and Game Tech. Bull. 7.

1987. Mercury in polar bears from Alaska. J. Wildl. Dis. 23:338-341.

LENTFER, J. W., AND R. J. HENSEL.
1980. Alaskan polar bear denning. Pages 101-108 *in* C. J. Martinka and K. L. McArthur, eds. Bears—their biology and management. Fourth International Conference on Bear Research and Management. U.S. Gov. Print. Off., Washington, D.C.

LENTFER, J. W., R. J. HENSEL, J. R. GILBERT, AND F. E. SORENSEN.
1980. Population characteristics of Alaskan polar bears. Pages 102-115 *in* C. J. Martinka and K. L. McArthur, eds. Bears—their biology and management. Fourth International Conference on Bear Research and Management. U.S. Gov. Print. Off., Washington, D.C.

LONO, O.
1970. The polar bear (*Ursus maritimus* Phipps) in the Svalbard area. Nor. Polarinst. Skr. 149. 103pp.

MANNING, T. H.
1971. Geographical variation in the polar bear, *Ursus maritimus* Phipps. Can. Wildl. Serv. Rep. 13. 27pp.

ØRITSLAND, N. A., F. R. ENGELHARDT, F. A. JUCK, R. J. HURST, AND P. D. WATTS.
1981. Effect of crude oil on polar bears. Environmental Studies No. 24. Northern Affairs Program, Northern Environmental Protection Branch, Indian and Northern Affairs, Canada. 268pp.

PAPANIN, I.
1939. Life on an ice-floe. Hutchinson, London. 240pp.

RAMSAY, M. A., AND I. STIRLING.
1982. Reproductive biology and ecology of female polar bears in western Hudson Bay. Nat. Can. (Que.) 109:941-946.

1984. Interactions of wolves and polar bears in northern Manitoba. J. Mammal. 65(4):693-694.

1988. Reproductive biology and ecology of female polar bears (*Ursus maritimus*). J. Zool. (Lond.): in press.

RAY, C. E.
1971. Polar bear and mammoth on the Pribilof Islands. Arctic 24:9-19.

RUSSELL, R. H.
1975. The food habits of polar bears of James Bay and southwest Hudson Bay in summer and autumn. Arctic 28:117-129.

SCHLIEBE, S. L.
1986. Alaska polar bear Native subsistence harvest, 1980-1985. Pages 117-131 *in* Polar bears: Proceedings of the Ninth Working Meeting of the IUCN/SSC Polar Bear Specialist Group, 9-11 August 1985, Edmonton, Alberta, Canada. Int. Union Conserv. Nature and Nat. Resour., Gland, Switzerland.

SCHWEINSBURG, R. E.
1976. More research needed to minimize conflicts between men and polar bears. Oilweek 15:54-55.

SCHWEINSBURG, R. E., W. SPENCER, AND D. WILLIAMS.
1984. Polar bear denning area at Gateshead Island, N.W.T. Arctic 37(2):169-171.

SCOTT, R. F., K. W. KENYON, J. L. BUCKLY, AND S. T. OLSON.
1959. Status and management of the polar bear and Pacific walrus. Trans. N. Am. Wildl. Conf. 24:366-373.

SEBER, G. A. F.
1973. The estimation of animal abundance. Hafner Press, New York. 506pp.

SMITH, T. G.
1980. Polar bear predation of ringed and bearded seals in the land-fast sea ice habitat. Can. J. Zool. 58(12): 2201-2209.

STEFANSSON, V.
1921. The friendly Arctic. Macmillan, New York. 361pp.

STENHOUSE, G.
1983. Bear detection and deterrent study, Cape Churchill, Manitoba. N.W.T. Wildl. Serv. File Rep. 44. 59pp.

STIRLING, I.
1986. Research and management of polar bears, *Ursus maritimus*. Polar Record 23(143):167-176.

STIRLING, I., D. ANDRIASHEK, AND W. CALVERT.
1981. Habitat preferences and distribution of polar bears in the western Canadian Arctic. Final rep. to Dome Petroleum Ltd., Esso Resources Canada Ltd., and Canadian Wildlife Service. 49pp.

STIRLING, I., D. ANDRIASHEK, P. LATOUR, AND W. CALVERT.
1975. The distribution and abundance of polar bears in the eastern Beaufort Sea. Dep. Environ., Victoria, B.C., Beaufort Sea Tech. Rep. 2. 59pp.

STIRLING, I., AND W. R. ARCHIBALD.
1977. Aspects of predation of seals by polar bears. J. Fish. Res. Board Can. 34(8):1126-1129.

STIRLING, I., W. R. ARCHIBALD, AND D. P. DEMASTER.
1977*a*. Distribution and abundance of seals in the eastern Beaufort Sea. J. Fish. Res. Board Can. 34:976-988.

STIRLING, I., AND W. CALVERT.
1983. Environmental threats to marine mammals in the Canadian Arctic. Polar Record 21(134):433-449.

STIRLING, I., W. CALVERT, AND D. ANDRIASHEK.
1980. Population ecology studies of the polar bear in the area of southeastern Baffin Island. Can. Wildl. Serv. Occas. Pap. 44. 32pp.

1984. Polar bear (*Ursus maritimus*) ecology and environmental considerations in the Canadian High Arctic. Pages 201-222 *in* R. Olson, F. Geddes, and R. Hastings, eds. Northern ecology and resource management. Univ. Alberta Press, Edmonton.

STIRLING, I. AND H. CLEATOR.
1981. Polynyas in the Canadian Arctic. Can. Wildl. Serv. Occas. Pap. 45. 73pp.

STIRLING, I., C. JONKEL, P. SMITH, P. ROBERTSON, AND D. CROSS.
1977*b*. The ecology of the polar bear along the western coast of Hudson Bay. Can. Wildl. Serv. Occas. Pap. 33. 69pp.

STIRLING, I., AND P. B. LATOUR.
1978. Comparative hunting abilities of polar bear cubs of different ages. Can. J. Zool. 56(8):1768-1772.

STIRLING, I., AND E. H. MCEWAN.
1975. The caloric value of whole ringed seals (*Phoca hispida*) in relation to polar bear (*Ursus maritimus*) ecology and hunting behavior. Can. J. Zool. 53:1021-1027.

STIRLING, I., AND T. G. SMITH.
1975. Interrelationships of Arctic Ocean mammals in the sea ice habitat. Proc. Circumpolar Conf. North. Ecol. (Ottawa, Can.) 2:129-136.

TAYLOR, M. K., D. P. DEMASTER, F. L. BUNNELL, AND R. E. SCHWEINSBURG.
1986. Sustainable harvest of polar bears (*Ursus maritimus*). Internal rep., Wildl. Serv., Yellowknife, Northwest Territ.

TOVEY, P. E., AND R. F. SCOTT.
1957. A preliminary report on the status of polar bears in Alaska. Unpubl. manuscr., U.S. Fish and Wildl. Serv. 11pp. [8th Science Conf., Anchorage, Alaska.]

USPENSKII, S. M., AND A. A. KISTCHINSKII.
1972. New data on the winter ecology of the polar bear (*Ursus maritimus*) on Wrangel Island. Pages 181-197 *in* S. Herrero, ed. Bears—their biology and management. IUCN Publ. New Ser. 23.

WILSON, D. E.
1976. Cranial variation in polar bears. Pages 447-453 *in* M. R. Pelton, J. W. Lentfer, and G. E. Folk, eds. Bears—their biology and management. IUCN Publ. New Ser. 40.

PERSONAL COMMUNICATIONS AND SOURCES OF UNPUBLISHED DATA

T. J. Eley, U.S. Fish and Wildlife Service, Anchorage, Alaska.

J. W. Lentfer, Polar Bear Project Leader (retired), Alaska Department of Fish and Game, Juneau, Alaska.

S. L. Schliebe, U.S. Fish and Wildlife Service, Anchorage, Alaska.

M. K. Taylor, Northwest Territories Wildlife Service, Yellowknife, N.W.T., Canada.