

POPULATION CHARACTERISTICS OF ALASKAN POLAR BEARS

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Abstract: A mark-recapture study of Alaskan polar bears (*Ursus maritimus*) was conducted between 1967 and 1976. Of 809 bears tagged, 147 were recaptured 1 or more times or killed by hunters. Three-year-old males and 6- and 7-year-old females were underrepresented in the captured sample. Analyses of cohort age composition over time indicated male (age 6+) and female (age 8+) annual survival rate of 0.84. Average litter size was 1.63 and breeding interval was 3.6 years. The age of first successful breeding for females was 5.4 years. For adult females, the average number of young per year was 0.45. With these fecundity estimates, the annual juvenile survival rate of 0.97 calculated from cohort data is that which is required to maintain population size.

The purpose of this study was to define population characteristics of Alaskan polar bears as a basis for developing sound management programs. Objectives were to determine population composition, reproductive rates, survival rates, and numbers and trends.

It is especially important at the present time that wildlife managers understand population dynamics of Alaskan polar bears because land ownership and land management policies in northern Alaska are changing and demand for fossil fuel located along and offshore from Alaska's north coast is increasing. Regulatory agencies also need to know population characteristics in order to assess existing regulations and proposed changes.

This paper is a report of population data, mostly from a polar bear mark and recovery program conducted by the Alaska Department of Fish and Game and the U.S. Fish and Wildlife Service for the 10 years from 1967 through 1976.

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METHODS

Polar bears located on sea ice from aircraft between 1 March and 10 May were immobilized for examination and marking by injecting phencyclidine hy-

drochloride (Sernylan) with a syringe gun from a helicopter. They were marked with ear tags, lip tattoos, and large numerals dyed on the fur (Lentfer 1968). Of a total of 809 bears captured for the first time (Table 1, Fig. 1), 94 were recaptured 1 or more times and 53 were taken by hunters. An intensive effort was made to resight marked animals during the 1976 study period.

Table 1. Distribution of 809 Alaskan polar bears captured for the first time for marking.

	Area								
	Bering Strait		Lisburne		Barrow			Barter Island	
	M	F	M	F	M	F	Unknown	M	F
1967	0	0	0	0	13	18	0	0	0
1968	5	5	20	30	24	56	0	0	0
1969	0	0	5	2	4	16	2	1	1
1970	0	0	7	20	19	34	1	0	0
1971	0	0	13	9	19	33	0	0	0
1972	0	0	25	34	33	63	0	0	0
1974	0	0	0	0	51	66	1	0	0
1975	0	0	0	0	18	20	0	19	16
1976	0	0	24	25	23	34	0	0	0
Total	5	5	94	120	204	340	4	20	17

Ages of cubs, yearlings, and 2-year-olds were usually determined by body size. Occasionally, degree of canine tooth eruption was used to distinguish yearling males from 2-year-old females. Older bears were assigned ages based on tooth cementum layering, tooth wear, body measurements, and indicators of reproductive status (Hensel and Sorensen 1980). In a few instances, not enough information was obtained to assign an age.

Reproductive status of females was determined from the condition of the vulva (infantile, turgid, open) and the mammae (nipple size and color, lactation in past or in present).

Before passage of the Marine Mammal Protection Act of 1972, Department of Fish and Game personnel

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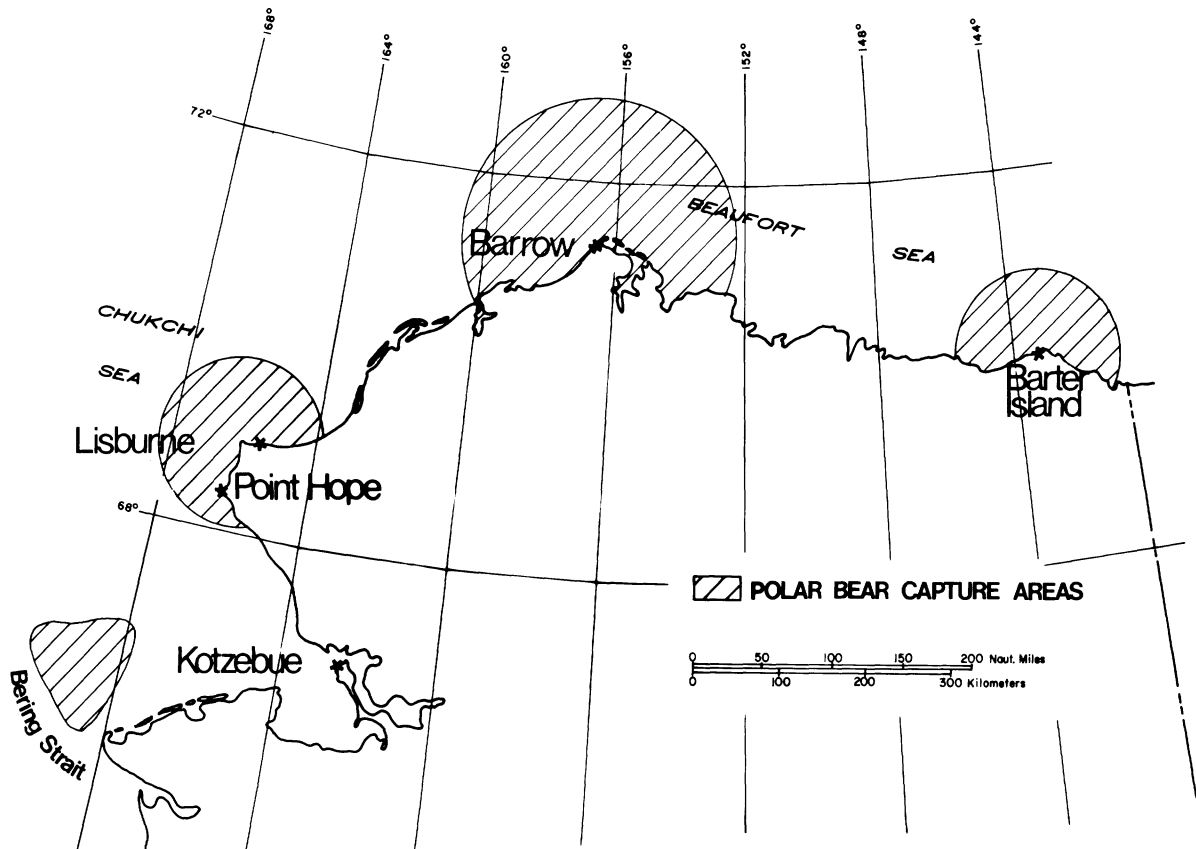


Fig. 1. Map of northern Alaska showing where polar bears were captured, 1967-76.

stationed in coastal villages to monitor hunting activity obtained polar bear testes, female reproductive tracts, teeth for sectioning, and skull measurements to relate reproductive status of individual animals to age. Incidental to Alaskan studies, testes were also obtained from bears taken on sea ice near Spitsbergen (north of Norway) during August 1967. Sections of selected testes and epididymides were examined for sperm (Lentfer and Miller 1969). Female tracts were measured and examined for placental scars and ovarian bodies.

The length of the reproductive cycle (interval between fertile breedings) was obtained by recapturing females with second litters or recapturing females without young who state in the reproductive cycle could almost definitely be determined by other means (e.g., a postlactating female paired with a mature male and in estrus when captured would be assumed to be entering another breeding cycle). A reproductive rate (average number of young produced per year per adult female) was obtained by dividing average cub litter size by length of breeding cycle.

RESULTS AND DISCUSSION

Population Composition

The best indication of polar bear population composition is a composite age structure from known or estimated ages of 378 males and 555 females captured between 1 March and 10 May from 1967 through 1976 (Table 2). That sample consisted of 32 percent litter members (cubs, yearlings, and 2-year-olds), 43 percent females 3 years old and older, and 25 percent males 3 years old and older. The data may not adequately represent some population segments, however, for the following reasons.

Relatively few cubs, compared with yearlings, were recorded because new family groups were in maternity dens during the first part of study periods. The low number of 6- and 7-year-old females is additional evidence that females with cubs were underrepresented, since at these ages substantial numbers of females have their first litters. The small number of 3-year-old males perhaps indicates dispersion of subadult males from sampling areas after family breakup. There is no reason

Table 2. Composite age structure of 933 Alaskan polar bears marked or recovered after marking, 1967-76.

Age	Male		Female		Total	
	Number	Percent	Number	Percent	Number	Percent
0	22	2.4	28	3.0	50	5.4
1	65	7.0	65	7.0	130	14.0
2	49	5.3	65	7.0	114	12.2
3	25	2.7	51	5.5	76	8.1
4	53	5.7	51	5.5	104	11.1
5	55	5.9	51	5.5	106	11.4
6	39	4.2	34	3.6	73	7.9
7	25	2.7	36	3.9	61	6.5
8	11	1.2	53	5.7	64	6.9
9	9	1.0	32	3.4	41	4.4
10	11	1.2	24	2.6	35	3.8
11	1	0.1	18	1.9	19	2.0
12	3	0.3	12	1.3	15	1.6
13	3	0.3	13	1.4	16	1.7
14	1	0.1	5	0.5	6	0.6
15+	6	0.6	17	1.9	23	2.5
Total	378	40.3	555	59.7	933	100.0

to believe that 3-year-old males were less susceptible to capture than older males. Females predominated in older age-classes because mature males tended to range farther offshore and out of sampling areas early in sampling periods, females with cubs and yearlings were protected from hunting through 1972, and hunters selected the larger males at an earlier age than females (225 males compared with 137 females killed in the Barrow area, 1967-72). Mature females and young may be slightly overrepresented in samples because family groups rather than single bears were captured for marking if the option existed.

Survival Rates

Composite annual survival rates were calculated from segments of the age structure data for each sex by using regression estimates (Seber 1973:414) and Chapman-Robson estimates (Chapman and Robson 1960). For males, these estimates were made for survival for ages 2-6 and for older than age 6. Information for males of age-class 3 was eliminated because this group was underrepresented in the samples (Table 2). For females, estimates were made of survival for ages 2-8 and for older than age 8. Information for female age-classes 6 and 7 was eliminated because they were underrepresented in the sample (Table 2). The age 6 separation point for males and age 8 separation point for females were chosen after examination of the age structures (Table 2).

The regression estimates were higher than the Chapman-Robson estimates of survival (Table 3). The

Table 3. Estimates of annual survival rates for male and female polar bears.

	Males		Females	
	Age (years) 2-6	>6	Age (years) 2-8	>8
Composite age structure estimates				
Regression	0.90	0.70	0.98	0.73
Chapman-Robson	0.69	0.63	0.70	0.64
Cohort estimates	0.97	0.84	0.99	0.84

estimate indicated that younger animals had a higher probability of survival, possibly because older age-classes were subjected to heavier hunting pressure. Males had lower annual survival rates than females in any age-class.

Both the regression and Chapman-Robson techniques assume a constant population size during the years of study. If size were not constant, the estimates would be biased. One method not subject to this bias is to calculate survival rates from cohort data. This calculation was accomplished for each sex by arranging the numbers in each age-class captured or recaptured in each year into cohorts and then calculating regression estimates of survival, using the actual number in each age-class in each year as a sample, and then calculating an average survival rate over all cohorts. This method eliminated the assumption of constant population and smoothed the data for variation in effort from year to year. For males, these estimates of survival rates were 0.97 for ages 2-6 and 0.84 for older than age 6. For females, the estimates were 0.99 for ages 2-8 and 0.84 for older than age 8 (Table 3).

Survival of young with the female is the product of the female's survival probability and the probability of loss of young from the female. Mean litter sizes of cubs, yearlings, and 2-year-olds (1.58, 1.65, and 1.47, respectively) indicated little loss of young. It is recognized that loss of entire litters would not be evident with this type of comparison. Recapture information provided 2 records of loss of young between 5 and 17 months of age; 1 was a single young and 1 was a twin. No information is yet available on cub loss from birth until cubs are first observed in April.

If the age of self-sufficiency for polar bears is assumed to be 28 months, then the annual survival rate for both male and female young would be slightly less than that of an adult female, i.e., 0.84. The resulting cohort life tables for males and females, using an equal sex ratio at birth, are given in Table 4.

Reproduction

Obtaining the number of young per adult female per

Table 4. Cohort life table for male and female polar bears from calculated annual survival rates in Table 3.

Age x	1x males	1x females	Age x	1x males	1x females
0	1000	1000	19	65	93
1	840	840	20	54	77
2	706	706	21	46	65
3	684	699	22	38	54
4	664	692	23	32	45
5	644	685	24	27	38
6	625	678	25	22	32
7	525	671	26	19	26
8	441	664	27	16	22
9	370	556	28	13	18
10	311	464	29	11	15
11	261	388	30	9	13
12	219	324	31	8	11
13	184	271	32	7	9
14	155	226	33	6	8
15	130	190	34	5	6
16	109	159	35	4	5
17	91	133	36	3	4
18	77	111			

year requires an estimate of cub litter size and of the average length of the breeding interval.

Mean litter size. — Numbers of young in litters at birth or in maternity dens have not been obtained during Alaskan studies. Litter size data for family groups captured in March, April, and early May are presented in Table 5. Mean litter sizes of cubs, yearlings, and 2-year-olds were 1.58, 1.66, and 1.47, respectively. These litter sizes are not significantly different ($p < 0.05$). Litter size was most commonly 1 or 2, but 2 family groups with 3 yearlings were observed (Table 5).

Table 5. Age-specific reproductive data for female Alaskan polar bears, 1967-76.

Age of female	Total females	Without young	With young — Age and size of litter						Vulva swollen ^a	Paired with male ^a	
			Cub		1-year-old			2-year-old			
			1	2	1	2	3	1			2
3	51	51	0	0	0	0	0	0	3	2	
4	51	50	0	1	0	0	0	0	12	5	
5	51	49	2	0	0	0	0	0	27	10	
6	34	18	5	2	5	2	0	1	11	5	
7	36	15	3	3	4	7	0	2	2	16	6
8	53	14	4	3	8	9	0	7	8	19	6
9	32	6	1	1	1	11	0	5	7	6	1
10	24	6	1	4	5	4	1	1	2	3	3
11	18	4	0	2	0	4	0	3	5	6	1
12	12	4	0	1	2	1	0	3	1	7	0
13	13	3	0	2	1	0	1	5	1	5	0
14	5	2	0	1	0	2	0	0	0	2	0
15+	17	3	0	2	2	7	0	3	0	7	2
Total	397	225	16	22	28	47	2	30	27	124	41

^aSome females with swollen vulvas were also paired with males.

Mean litter size for each age of female is shown in Table 6. This age-specific mean litter size had some tendency to increase with age of the female, although the increase was not as uniform as that noted by Stirling et al. (1975) in polar bears of the eastern Canadian Arctic. An overall mean litter size of 1.63 can be calculated from the litter size data for cubs and yearlings (Table 5).

Table 6. Age-specific litter sizes, conception rates, and production of female polar bears. Figures in parentheses are cub and yearling sample sizes.

Age of female	Mean litter size at birth	Fraction of all females successfully bred	Probability of conception ^a	Number of young per adult female per year
3		0.03	0.03	-
4	2.00 (1)	0.12	0.12	0.06
5	1.22 (9)	0.26	0.30	0.15
6	1.50 (18)	0.29	0.37	0.39
7	1.52 (23)	0.21	0.35	0.44
8	1.74 (19)	0.29	0.41	0.37
9	1.58 (12)	0.26	0.40	0.46
10	1.89 (9)	0.27	0.39	0.49
11	1.60 (5)	0.08	0.16	0.43
12	2.00 (3)	0.28	0.37	0.16
13	2.00 (4)	-	-	0.56
14+	1.92 (13)	-	-	-

^aAn estimate of the fraction of available females that actually bred.

Average length of breeding interval. — Sufficient data were obtained from 8 recaptured females to provide direct information on breeding intervals. Three had 3-year breeding cycles, 3 had 4-year breeding cycles, and 2 had at least 4-year breeding cycles. Sequential events in a normal 3-year breeding cycle, using 1970 as the year of first breeding, would consist of breeding between April and June of 1970, parturition in December 1970 or January 1971, separation from young in April 1973 when the young are about 28 months old, and breeding again that same spring. From the recapture histories of the 8 marked females, age 7 or older, an approximate mean breeding interval of 3.6 years can be calculated.

There is no evidence from Alaskan studies that young remain with the female for more than 28 months, and in a 4-year cycle the female presumably remains unbred for a year after separating from her young. Stirling et al. (1975), from studies in the Canadian section of the Beaufort Sea, cited 2 instances of 3-year-olds still with the females but stated that a 3-year breeding cycle is probably the most common. Lønø (1970) stated that in Spitsbergen, young normally separate from the female at 17 months, and a 2-year breeding cycle is the most common.

Because direct information on the breeding interval

was available from only 8 females, we examined 2 other measures of the breeding interval. One measure of the breeding interval is the inverse of the fraction of all females of each age-class that were successfully bred. For a particular age-class, 3 estimates of the fraction successfully breeding are available from the reproductive data in Table 5. For example, the fraction that successfully bred at age 5 is estimated by the fraction with cubs at age 6 (7 of 34), the fraction with yearlings at age 7 (11 of 36), and the fraction with 2-year-olds at age 8 (15 of 53). The mean of these 3 fractions, 0.26, is an estimate of the fraction of all females at age 5 that successfully bred. This fraction was calculated for each age-class (Table 6). For females at age 5 and above, this fraction varies generally in the range between 0.26 and 0.29. The inverse, or mean breeding interval, would then be between 3.85 and 3.45 years. The direct estimate from the 8 females (3.6 years) is within this range.

A second indirect measure of the breeding interval can be calculated from the probability of a female with 2-year-olds or without young conceiving in any particular year. From this probability, the fraction that conceive during the first and subsequent years that they are available for breeding can be calculated. For example, if this probability of conception was 0.40, then 40 percent of the females would have a 3-year cycle, 24 percent would have a 4-year cycle, and 14 percent would have a 5-year cycle, etc., implying a mean breeding cycle of 4.15 years. If, however, it was assumed that all females that did not breed in the first year that they were available for breeding successfully bred the next year, a 3.6-year cycle would be implied.

The probability of conception was calculated from the data in Table 5 by using the numbers of females with litters of different ages as 3 samples. For example, the probability of a female of age 5 conceiving at that age was estimated from the mean of the following fractions: females of age 6 with cubs divided by the total females of age 6 less those with yearlings or 2-year-olds (7 of 25), females of age 7 with yearlings divided by the total females of age 7 less those with 2-year-olds (22 of 32), and females of age 8 with 2-year-olds divided by the total females of age 8 (15 of 53). The mean of these fractions is 0.30, the probability of a female conceiving in her fifth year if she was single or had 2-year-old young. These probabilities of conception are present in Table 6.

For females of age 6 and above, this probability of conception ranged generally between 0.35 and 0.41. This range would imply a mean breeding interval between 4.12 and 4.42 years, or, assuming all females

breed in either the first or second year that they are available for breeding, between 3.59 and 3.65 years. These figures also confirm a mean breeding interval of approximately 3.6 years.

Mean number of young per adult female per year. — The mean number of young per adult female per year is calculated by dividing mean litter size by breeding interval. Given a range in litter size from 1.58 to 1.70 young and a range in breeding interval from 3.5 to 3.8 years, the range in number of young per adult female per year is between 0.42 and 0.49. When the best estimates of a litter size of 1.65 and a breeding interval of 3.6 years are used, the most likely number of young per adult female per year is 0.46.

Age-specific numbers of young per female are presented in Table 6. Since the fraction of all females successfully bred is the inverse of the breeding interval, the age-specific number of young per adult female is the product of litter size and the fraction of all females successfully bred in the previous age-class.

Reproductive potential of polar bears is lower than for grizzly bears (*Ursus arctos*) in Yellowstone National Park, where an average litter size of 2.24 and an average breeding interval of 3.40 years gave an average of 0.66 young per adult female (Craighead et al. 1976).

Breeding Age

Minimum breeding age for females was determined by noting their vulval condition and whether they were accompanied by young or were paired with mature males. All three criteria indicate a minimum breeding age of 3 years (Table 5).

The average minimum breeding age may be calculated from the distribution of ages of first conception that may be calculated from age-specific reproductive data in Table 5. One approach is to subtract from the number of females bred in each year of life those that were probably breeding a second time. The sum of the percentage of total first breeding at each age, times the age, results in an average age of first breeding of 5.4 years, with a distribution of ages of first breeding as indicated in Table 7.

This mean age of first breeding is substantiated by calculating age-specific rates of conception. The proportion of females with cubs, with yearlings, and with 2-year-olds constitute independent estimates of the proportion of available females that actually bred (Table 6). The mean conception rates for age-classes 3 through 6 correlate fairly closely with the percentage of females that first breed at these ages (Table 7).

Further information on the range of age of first

Table 7. Calculation of the distribution of ages of first breeding of female polar bears from Table 5.

	Age (years)						
	3	4	5	6	7	8	9
(1) Number successfully bred	3	13	33	35	22	20	13
(2) Correction for number bred second time ^a							
First bred at age 3	-	0	0	1	2	0	0
First bred at age 4	-	-	0	0	6	7	0
First bred at age 5	-	-	-	0	0	16	17
(3) Number first bred successfully							
[(1) minus (2)]	3	13	33	34	14	0	0
Percent of total	3	14	34	35	14	0	0

^a Approximately 50 percent of the females breed the same spring in which their cubs are 2 years old; the remainder delay 1 or more years.

breeding comes from histories of individual bears captured several times. The oldest age of first breeding thus documented was 7 years.

Maximum breeding age is not as well defined as minimum breeding age because fewer old animals remain in the population to provide a data base. One female estimated to be 21 years old and 2 estimated to be 18 years old were the oldest reproductively active females captured. The 21-year-old had prominent mammae and external genitalia, indicating estrus, when examined on 2 May. Both 18-year-olds had cubs, and if they bred again, could do so at age 20 after weaning 2-year-olds. Females at this age are probably approaching maximum breeding age. The oldest Alaskan polar bear captured or killed was estimated to be 25 years old.

Other workers have reported on minimum and maximum breeding ages of bears. Erickson and Somerville (1967) speculated that polar bears, like brown and grizzly bears, achieve sexual maturity when approximately 3 years old. Lønb (1970) stated that 3.5 years was the probable age of sexual maturity for female polar bears, although some do not mate until 4.5 years of age. Stirling et al. (1975), with a good data base from northwestern Canada, found a low conception rate for 3- and 4-year-old female polar bears, suggesting that sexual maturity for most females occurs at 5 years. Craighead et al. (1969) stated that female grizzly bears are not sexually mature until 4.5 years old. Hensel et al. (1969) said that female brown bears become sexually mature at 3-6 years but usually at 4 years of age.

The maximum breeding age reported by Stirling et al. (1975) for female polar bears in northwestern Canada

was 18 years. Craighead et al. (1976) reported a grizzly bear that gave birth when 22 years old and weaned young when 24 years old. They also noted that 2 females produced litters when 19 years old and stated that reproductive longevity approximates physical longevity.

Presence of mature sperm in testes and epididymides indicates that minimum and maximum ages at which males may be capable of breeding are 3 and 19 years, respectively (Lentfer and Miller 1969). Although presence of sperm indicates breeding capability, it does not show that bears as young as 3 and as old as 19 are successful breeders. An understanding of the significance of breeding by young and old animals requires study of social interactions and behavior. Male paired with mature females when captured ranged in age from 3 to 11 years.

Numbers and Trends

An attempt was made to estimate population size of polar bears in the Barrow area by using the Seber-Jolly mark-recapture procedure (Seber 1973:204). This procedure was unacceptable, however, because permanent emigration could not be assumed. Whether killed bears were included made little difference; survival rates were sometimes greater than 1.0 and birthrates were sometimes negative.

Single season mark-resighting estimates of population size in the Barrow area in 1976 were more consistent. Using a Seber-Jolly procedure, we estimated that 320 polar bears were in the study area (110 km × 110 km) between 17 March and 28 April. Estimates of the number of bears in the area in any 3-day period ranged from 15 to 57. The mark-resighting estimates indicated a rapid turnover in bears available to be captured and much movement of polar bears through the area at this time. The estimated 320 polar bears do not represent the entire population in the Barrow area, because the sample area was small and some bears probably moved through the area after 28 April.

Population trends during the sampling period from 1967 to 1976 may be inferred from comparisons of survival rate estimates derived from cohort data and age structure. Survival rate estimates calculated from cohort data are higher than those calculated from the composite age structure, indicating that the population was increasing slightly throughout the years of study.

If the survival rates given for females in Table 3 are correct, and if it is assumed that female polar bears can reproduce to at least age 21, the number of female young per mature female per year required to maintain a constant population size would be 0.213. Given an equal

sex ratio at birth, the number of young required per adult female per year would be 0.426, less than the estimated production rate of 0.48 young per adult female. Again, this calculation implied that the population was increasing.

Breeding Season

Pilot guides and tagging crews observed mature male bears starting to move south in late March, presumably for breeding, in the area north of Point Barrow. These observations are borne out by kill figures showing that the percentage of males taken north of Barrow began increasing in early April (data in Alaska Federal Aid in Wildlife Restoration polar bear reports, 1967-73).

Field observations by tagging crews between 2 March and 13 May revealed the earliest pairing of a male with a female, indicative of breeding activity, on 21 March and the latest on 10 May. Seven pairings were recorded the last week of March, 13 in April, and 1 each on 5 May and 10 May. Copulation was never observed, possibly because the observations occurred after bears had been disturbed by aircraft. The earliest and latest dates that turgid vulvas, indicative of estrus, were noted were 21 March and 10 May. However, field work was most intensive in late March and April, and there was therefore more opportunity to make observations during this period. Breeding is believed to have continued after 10 May but related activities were not observed.

In Spitsbergen, Lønø (1970) cited instances of breeding behavior by males but without copulation on 8,

10, and 26 March and observations of mating or attempted mating on 27 and 30 April, 7 May, and 20 June.

Variability in weight of testes and presence of mature sperm in testes and epididymides also aid in delineating the breeding season. Erickson (1962) weighed testes from 69 Alaskan male bears killed between 13 February and 29 April. There were no definite trends of increasing or decreasing weight during this period, and he concluded that throughout this period some males are capable of breeding. Lønø (1970) examined testes from 88 mature Spitsbergen bears, some of which were taken in most months of the year. Weights were lowest in October, November, and December. Testes increased in weights from December to March and were at about the same high level in April as in March. There were no May specimens. Weights in June had started a decline that continued to the October-December low. Weights varied considerably in both Lønø's (1970) and Erickson's (1962) samples. Specimens from 43 polar bears examined by Lentfer and Miller (1969) revealed sperm in testes and epididymides in February, March, and April, but not in August.

These observations indicate that prebreeding physiological changes begin before March and that males and females begin to pair in March. The amount of pairing increases in April. The few observations in May and a lack of observations in June and July preclude conclusions from Alaska data about the latter part of the breeding season. From histological examination of testes and ovaries from Spitsbergen bears, Lønø (1970) concluded that breeding continues through mid-July.

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