WORK UNIT I. Potential impacts of petroleum exploration and development on the numbers, distribution, and status of caribou on the Arctic coastal plain.

Work Subunit Ia. Population dynamics and demographics of caribou in developed and undeveloped areas of the Arctic coastal plain.

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INTRODUCTION

In 1980, Congress directed the Department of the Interior under section 1002 of the Alaska National Interest Lands Conservation Act to conduct biological and geological studies on the coastal plain of the Arctic National Wildlife Refuge (ANWR). As a result of those studies, the 1002 area is considered the most promising onshore petroleum exploration area in the United States (Clough et al. 1987). However, the area contains important fish and wildlife habitats, including the most frequently used calving and post-calving areas for the Porcupine Caribou Herd (PCH) (*Rangifer tarandus granti*) (n = 178,000 in 1989). The Department of the Interior concluded that major impacts to the PCH could occur if a major oil discovery is located and developed (Clough et al. 1987).

The nearby Central Arctic Herd (CAH) (n = 12,900 in 1983) has been associated with petroleum development in the Prudhoe Bay region for about 20 years. Studies of the CAH (e.g., Whitten and Cameron 1983a, 1985; Dau and Cameron 1986) have revealed that development can disrupt caribou movements and displace parturient cows from traditional calving areas, raising concerns that similar effects may occur to the PCH if the 1002 area is developed. However, direct comparisons of the PCH and CAH are not possible because effects of petroleum development on the growth and dynamics of the CAH are confounded with other differences between the 2 herds such as habitat, migration, and population size.

The objectives of this study were to document herd size and growth trends, and seasonal range use patterns of the PCH and CAH. This report presents results from continued investigations of the PCH and CAH conducted from 1985-1990 by the U. S. Fish and Wildlife Service and the Alaska Department of Fish and Game (ADF&G). Population dynamics remained a research priority for the PCH throughout this period but was secondary to physiology and oilfield/caribou interaction studies for the CAH. Therefore, in some aspects, results for the PCH are more detailed and complete, and available CAH data are presented for comparison. Pertinent findings from previous studies of the PCH and CAH are incorporated so that conclusions and management recommendations are properly synthesized from all available information.

METHODS

Study area

The range of the PCH includes tundra habitats on the Arctic coastal plain and mountainous and forested habitats in northeastern Alaska, northern Yukon Territory, and northwestern Northwest Territories (Fig. 1). The vegetation, geomorphology and climate of the study area have been described by Spetzman (1959), Wiken et al. (1981) and Garner and Reynolds (1986). Winter distribution of caribou varies considerably among years, but primary wintering areas

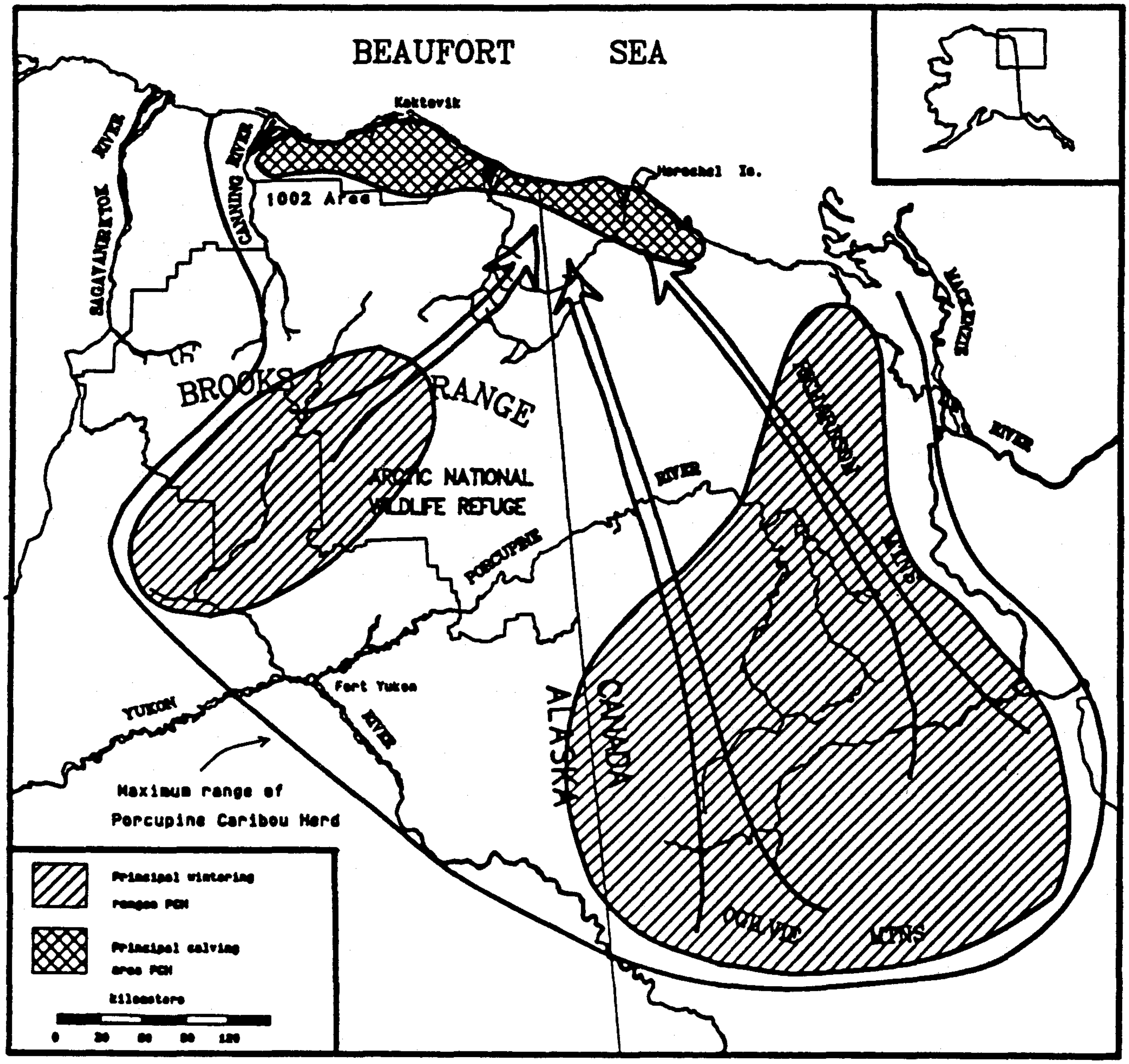

Figure 1. Range of the Porcupine Caribou Herd, in northeastern Alaska and northwestern Canada, including principal wintering areas and primary calving area.

areas include the Ogilvie and Richardson Mountains in the Yukon, and the Chandalar, Sheenjek and Coleen drainages of northeastern Alaska. Spring migration occurs within three broad corridors referred to as the Old Crow, Richardson, and Chandalar migration routes (Fancy et al. 1989). Calving occurs primarily during the first week of June on the coastal plain between the Canning River in Alaska and the Blow River in the Yukon (Thompson 1978, Garner and Reynolds 1986).

The range of the CAH is between the Colville/Itkillik Rivers and the Katakturuk River on the Arctic slope in Alaska. Primary wintering areas are in the northern foothills and mountains of the Brooks Range, although some animals occasionally winter near the coast. Calving and summer ranges are along the Arctic coast (Cameron and Whitten 1979).

Caribou Capture and Handling

Most caribou were captured on winter range in snow, a strategy which resulted in short chases. Caribou were located from a Piper supercub aircraft acting as a spotter plane for the capture helicopter. A specific animal was then chased a short distance with the helicopter and darted with a mixture of M99 (6.25 mg Etorphine hydrochloride) and 7.5 mg Acepromazine maleate fired from a Cap-Chur rifle (Palmer Chemical and Equipment Co., Douglasville, GA) into the rump or shoulder of the caribou. The antagonist M50-50 (14 mg Diprenorphine hydrochloride) was administered to effect recovery. Beginning in April 1988, all adult caribou were immobilized using a mixture of 3 mg Carfentanil citrate (Wildlife Laboratories, Fort Collins, CO) and 7.5 mg Acepromazine maleate, with Naloxone (450 mg; Wildlife Laboratories) administered as the antagonist. Thicker, winter pelage and a subdermal fat layer cushioned the impact of the dart, and cold temperatures alleviated problems with hyperthermia. We attempted to weigh each captured caribou, take a blood sample from the jugular vein, record body and antler measurements, and attach a standard VHF or satellite radiocollar (Telonics, Inc.; Mesa, Az.). We attempted to recapture collared caribou as needed every 3-5 years to replace transmitters before batteries were exhausted. Neonate calves were captured and collared on the PCH calving grounds in June 1988 using methods described by Garner et al. (1985) and Whitten et al. (1992a).

Long term observations of collared caribou from the PCH do not indicate the presence of any geographic sub-populations. Animals captured in various locations have shown similar movement and distribution patterns, and all members of the herd tend to converge during the post-calving and rut periods, and possibly more frequently. Therefore, collared caribou were assumed to be a geographically random sample of the herd, except perhaps for a short time after their initial capture (which was not a factor for any of the analyses conducted for this study). However, caribou of various sexes and ages were not captured in proportion to their occurrence in the population. Therefore, adult females captured were assumed to be representative of adult females in the herd, but the overall sample of collared caribou was not representative of the sex and age composition of the entire herd.

Tracking Caribou via Satellite

Satellite transmitters compatible with the Argos Data Collection and Location System (Fancy et al. 1988, 1989) were deployed on 41 PCH cows and 24 CAH cows between April 1985 and August 1990. Data were received monthly from Service Argos (Landover, MD) and processed as described by Fancy et al. (1988, 1989). The satellite transmitter package weighed 1.6 kg (including a VHF radio transmitter to locate the caribou from an aircraft) and had a battery life of 1 year. Individual caribou were monitored for ≤ 5 years by replacing their transmitters annually. Transmitters were programmed to operate 6 hours/day, or 6 hours/2 days, and provided 3-4 locations per day of operation. Mean location errors were 760 m for Generation 2 transmitters (68% of locations used in this study) and 480 m for newer, Generation 3 transmitters (32% of locations; Fancy et al. 1989).

Transmitters also contained sensors for monitoring the internal temperature of the unit (an approximation of ambient temperature; Pank et al. 1985) and the caribou's activity. For activity monitoring, a microprocessor in the canister determined the number of seconds each minute during which a mercury tip-switch calibrated especially for caribou was activated (Pank et al. 1987). The resulting short-term activity index, having a maximum value of 60, was a reflection of activity (i.e., lying, feeding, walking, running) during the minute prior to transmission. In addition, a long-term activity index was computed as the sum of 60-sec counts for a 24-h period (Pank et al. 1987, Fancy et al. 1988).

Location and sensor data were obtained monthly from the Argos processing center on 9-track computer tapes and processed through a series of programs for entry into the ARC/INFO and MOSS/MAPS Geographic Information Systems as described by Fancy et al. (1988). The minimum distance traveled by each caribou between two successive locations was calculated by connecting locations with straight lines. We calculated the mean daily movement rates for each caribou by summing the lengths of line segments and dividing by monthly time interval. Differences in monthly movement rates between animals of the 2 herds and years were tested by two-way analysis of variance using the General Linear Model (GLM) procedure (SAS 1985). For each caribou, we summed the distances between successive locations to obtain an estimate of the minimum distance traveled per year. We included only those caribou that were tracked over a period of 10 months or longer. Some caribou were sampled in more than one year. The estimates of minimum annual distance traveled for these animals were considered independent because previous data have shown that cows show little fidelity to wintering areas (U. S. Fish and Wildlife Service, unpubl. data), or to calving sites (Whitten et al. 1992a). Statistical comparisons were evaluated at the 95% confidence level.

Seasonal Distribution

All caribou with radio-collars were tracked from fixed-wing aircraft using standard telemetry techniques. Flights covering the entire range of the PCH were conducted 2-5 times between October and early May to determine winter distribution. CAH winter distribution was estimated from radio-collar surveys in October/November and March/April each year. Distribution of radio-collared cows at calving was determined for the PCH during survey flights over the calving grounds approximately every 1-3 days (Whitten et al. 1992a). Distribution of cows on the CAH calving grounds was determined by transect surveys (Cameron et al. 1992). PCH mid-summer distribution was determined only in conjunction with a census in July 1989, and CAH mid-summer distribution surveys were flown at least weekly during July and August.

Population Size

A photographic census (Davis et al. 1979, Valkenburg et al. 1985) of the PCH was conducted in July 1989. Formation and distribution of large post-calving aggregations was monitored by intensive aerial reconnaissance, radio-tracking, and satellite telemetry to determine when the caribou were optimally aggregated for photographing. Personnel in 3 aircraft searched the summer range of the PCH until all radio-collared caribou were located, and the areas around the radio-collared animals were searched for groups of unmarked caribou. One tracking/spotter plane then worked in conjunction with the photo plane to photograph large aggregations. The other aircraft continued to search for any unmarked caribou.

Aggregations were photographed with a Fairchild T-11 aerial camera mounted in the belly of a DeHavilland Beaver aircraft, using black and white film. Several overlapping transects were required to photograph some large groups. Transects were oriented along the long axis of each group (usually the direction of movement). We attempted to overlap photographs by approximately 30% both within and between contiguous transects to insure complete coverage. Photo scale varied from 1:1000 to 1:3000 depending on the size and configuration of each aggregation.

Caribou were counted from black and white prints (ca. 23 cm x 23 cm) using magnifying lenses and hand-held tally registers. A combination of terrain features and discernible caribou were used to determine the portion of each photo to be counted. After determining overlap, lines were drawn directly on each print to prevent caribou appearing on adjacent photos from being counted twice. A transparent acetate grid was taped to each photo, and its position marked on the photo. Numbers of calf and adult caribou were tallied separately.

Ten observers cooperated in counting the caribou on photos. Accuracy and consistency among observers were assessed by using counts from a series of reference photos which were distributed through each observer's stack of photographs. Observers did not know which photos were reference photos. A mean count across observers was calculated for each reference photo. Weighted least squares through the origin (Draper and Smith 1966) was used to estimate a correction factor for each observer (b) by fitting the model:

$$Y = bX + e$$

where Y is the mean count across observers for reference photos and X is the observer's count for that series of photos. Weighted least squares was used to adjust for heteroscedasticity, because variability was highly correlated with X (the observer's count). Each (X,Y) pair was weighted by a function that related the variance in X to the mean prior to fitting the model and estimating b.

A predicted mean count for each photo counted by a particular observer (Y) was calculated by multiplying the observed count by that observer's estimated correction factor:

$$Y = b_{hat}X$$

and the variance for this prediction was calculated as:

$$S^2(Y) = (MSE/W) + (X^2 * S^2(b_{hat})).$$

These predicted counts and their variances were summed for each observer. Observer totals were summed to estimate the number of caribou that would be counted on all the photos by an "average" observer, and a confidence interval was calculated for this estimated total count using the summed variance term with degrees of freedom calculated with Satterthwaite's (1946) approximation assuming unequal prediction variances between observers.

Estimated the instantaneous rate of increase for the PCH over the period 1979-1989 by solving the equation:

$$\ln N_t = \ln N_0 + t(\ln\lambda)$$

where N_t is the number in the population in 1989, N_0 is the number in the population in 1979, $t = 10$ years, and $\ln\lambda = r$, the instantaneous annual rate of increase.

Attempted censuses of the CAH in 1988 and 1989 could not be completed because the distribution of CAH caribou east of the Sagavanirktok River overlapped the PCH distribution. In late June 1990, an estimate of the number of CAH caribou located east of the Sagavanirktok River was attempted using a stratified random sampling procedure. However, distributions of herds once again overlapped before the sampling could be completed. The last successful photocensus of the CAH was completed in 1983. We estimated the instantaneous rate of increase of the CAH over the period 1978 - 1983 in the manner described above.

Population Composition

Porcupine Caribou Herd sex and age structure during the post-calving aggregation period was estimated from composition counts conducted in 1988 and 1989. Standard criteria such as external genitalia, relative body size, and antler development were used for classification of animals into calves, cows and bulls. Observers were flown to large aggregations by helicopter and counts were made using spotting scopes and binoculars. Because aggregations were constantly moving and changing, it was impossible to randomly select aggregations for composition sampling. Aggregations to be sampled were selected opportunistically from the coastal plain groups only. Past experience has indicated that mountain groups, which were not sampled during 1988 and 1989, are likely to be predominantly bulls. For this reason, the 1988 and 1989 post-calving composition counts were considered to be indicative of relative numbers of cows and calves, but not of overall herd structure.

Composition of the PCH was also determined in April 1990. Caribou in three large aggregations located south of Arctic Village, east of Arctic Village, and in the Ogilvie Mountains were classified by observers in a helicopter. Each aggregation was sampled by flying random transects, but intensity of sampling in each area was unknown. These three aggregations accounted for most of the herd, based on radio-collar distribution. We considered the composition of the aggregations to be representative of overall herd structure.

Productivity and Calf Survival

Annual parturition rates and survival of calves through the first month of life (i.e., through June) were determined for the PCH by surveying radio-collared caribou on the calving ground at approximately 1-3 day intervals. Pregnancy was determined through a combination of antler and udder criteria (Whitten 1991b), and the calving date was assumed to be the first time the cow was seen with a calf. After a cow had given birth, we attempted to find her daily during the first 48 hours to determine if the calf had died. At the end of June, we once again located all cows who had given birth to determine if their calves were still alive. Low level aerial surveys were flown on the calving grounds of the CAH in mid-June 1987-1990 to estimate calf:cow ratios (Cameron et al. 1992). These calf:cow ratios were used as estimates of productivity/early survival, because calves were 7-10 days old at the time of the survey.

Adult Female Survival Analyses

Nine annual survival rates of adult ($\geq$3-year-old) PCH females were determined using a Kaplan-Meier staggered entry analysis (Pollock et al. 1989). However, because radio-collars were originally deployed on PCH caribou for reasons of monitoring seasonal distribution and yearly parturition rate, and for assistance in locating all groups of caribou during photo-census attempts, there were difficulties in attempting to use these data for survival rate estimation. For instance, radio-tracking surveys were more frequent in some years and therefore intervals during each year were not always of a consistent length. In addition, some surveys did not cover the entire range of the herd. This circumstance makes it difficult to determine how many animals were really at risk during each interval (animals not heard may have been in an area not covered by the survey, they may have had inactive transmitters, or they may have emigrated out of the study area). This circumstance also makes it difficult to determine when some animals actually died (e.g., alive near the calving grounds in July, not heard on winter range in October or the following April, found dead near the calving grounds in June of the following year).

Because of these difficulties with the data set, several broad assumptions had to be made in order to estimate yearly survival rates:

1) Any animal which died during capture or was heard on mortality signal near the capture site during the survey after it was captured was considered a possible capture-induced mortality and was not included in the analysis.

2) Because < 3% of the mortality signals for adult females which were investigated on the ground came from shed collars, we considered all uninvestigated mortality signals from adult females transmitters to be coming from a dead animal and not simply a stationary, shed collar.

3) The number at risk during any interval was assumed to be all live animals with functioning radio-collars as determined by the previous survey. However, animals not heard during one or more surveys, but who were heard alive later were considered at risk during the intervening surveys.

4) Animals who were never heard from again were censored at the point at which they were last heard.

5) Deaths were assumed to have occurred between the last survey and the survey when heard dead, except in a few cases where seasonal movement patterns suggested the date of death. The caribou in the example above that was alive at calving in year 1, not heard the following October or April, and found dead on the calving grounds in June of year 2 would have been assigned a death date during the July-October interval and not the October-April interval.)

6) Animals reported killed by hunters were recorded as deaths at that time.

Survival rates were estimated beginning on 1 June of a given year and ending on 31 May of the following year. Animals were entered into the analysis at the time of their capture.

No survival analyses have been done on radio-collared CAH adults. Less effort was put into investigating suspected mortalities or into searching for missing animals, thereby compounding the problems mentioned above for the PCH data.

Harvest Information

Annual hunter harvest figures for the PCH and CAH in Alaska were compiled from records kept by the Alaska Department of Fish and Game. Harvest of the PCH in Canada was obtained from the Yukon Department of Renewable Resources.

RESULTS

Seasonal Movement Patterns

The PCH and CAH exhibited similar annual patterns in their daily rates of movement. Highest rates occurred in July and lowest rates in February or March. Differences in mean movement rates between herds and among years were compared for February, May, July, and September. We found no significant differences in movement rates between the two herds in February or July (two-way ANOVA; February $F = 0.08$; $P > 0.75$; July $F = 0.14$; $P > 0.70$). In contrast, differences in movement rates between herds were highly significant during spring and fall migration periods (May $F = 16.27$; $P < 0.001$; September $F = 49.20$; $P < 0.0001$). Between-year differences in movement rates were found for May (two-way ANOVA; $F = 5.69$; $P < 0.01$) and July ($F = 6.67$; $P < 0.005$). Movement rates during May and July in 1985 and 1986 were similar, but were significantly lower than those in 1987 (Duncan's Multiple Range Test; SAS 1985; Fig. 2).

Annual Distance Traveled

The mean annual distance traveled for 10 PCH cows (4355 $\pm$ 150 SE km) was significantly greater than that for 10 CAH cows (3031 $\pm$ 97 SE km; ANOVA; $F = 55.01$; $P < 0.0001$). Nevertheless, some CAH females moved greater total distances than some PCH cows. Greatest recorded yearly distance traveled in this study was 5055 km by a PCH cow.

Herd Status and Trend

Post-calving aggregations of the PCH were photographed during July 1989. Ten groups consisting mainly of males were photographed in the upper Sheenjek Valley on the south slope of the Brooks Range on 4 July. The remainder of the herd was located on the coastal plain between the Canning and Sadlerochit Rivers, where 9 more groups were photographed on 6 July. Extensive reconnaissance flights indicated that negligible numbers of caribou occurred outside these aggregation areas. This situation is common in the large Arctic caribou herds of Alaska at the peak of the post-calving aggregations (Davis et al. 1979, Valkenburg et al. 1985).

An initial estimate of 187,944 caribou (with a SD = 463, attributable to among observer variability in counting caribou on photos), was determined from the resulting photos. Some caribou may not have been discernable on the photographs, and the count is therefore considered a minimum of the animals actually present. However, a large portion of the CAH was mixed with PCH aggregations near the Canning River. No direct estimate of the number of these CAH caribou was possible. Based on previous estimates of CAH population size, trend, and distribution, and assuming that all caribou east of Prudhoe Bay were included in the PCH photos, the final estimate of PCH population size was adjusted downward to 178,000. This estimate indicates that the PCH has increased at an annual rate of 4.8% ($r = 0.048$) from 1979-1989 (Fig. 3).

The CAH appeared to grow rapidly in the late 1970's and early 1980's. Data available between 1978 (CAH estimated at 6000; Whitten and Cameron 1983b) and 1983 (CAH estimated at 12,900) suggested that the instantaneous rate of increase for the CAH was 15.3% ($r = 0.153$).

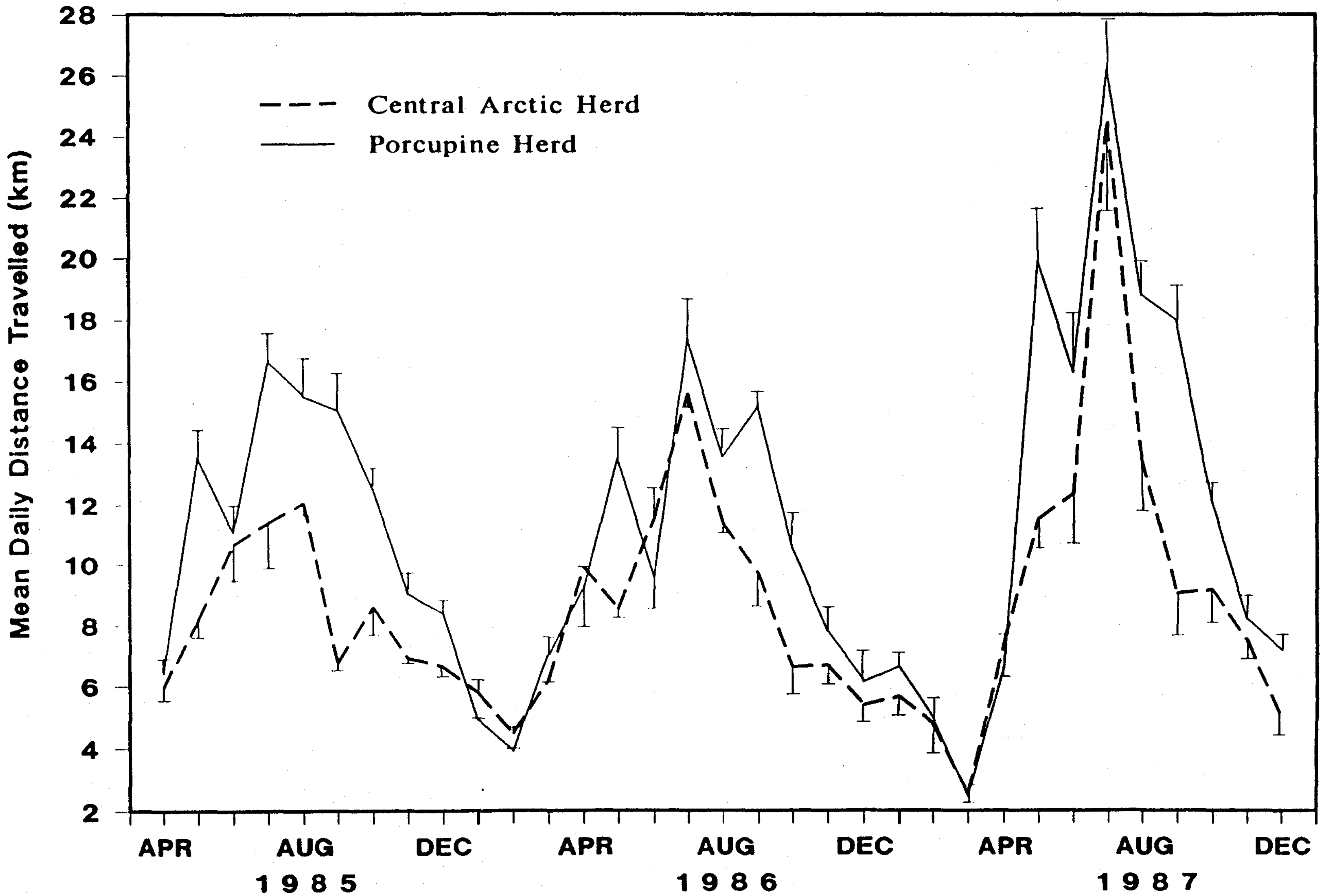

Figure 2. Mean daily distance traveled by Porcupine and Central Arctic Herd caribou, 1985-1987.

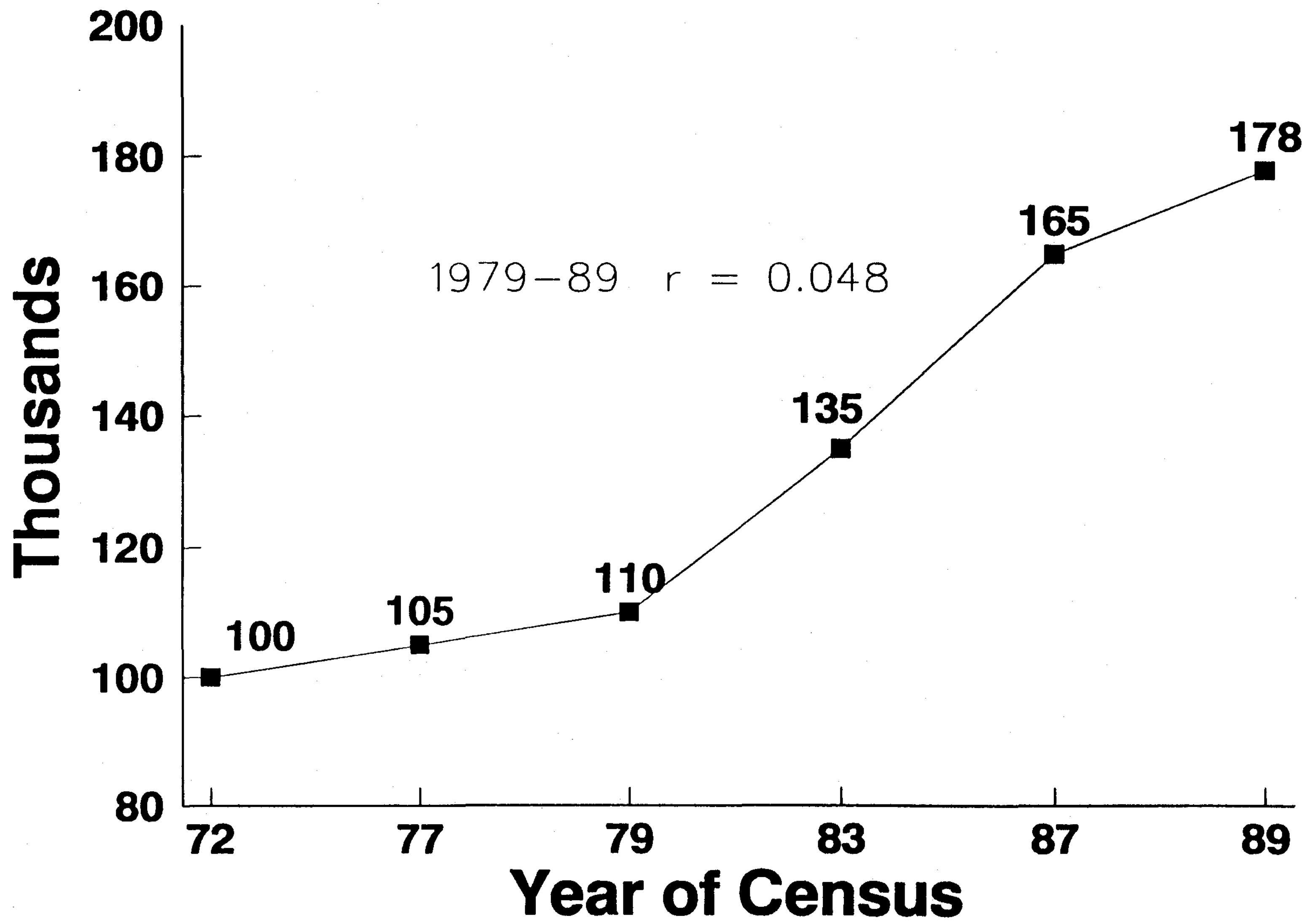

Figure 3. Photo-census results for the Porcupine Caribou Herd, 1972-1989.

Population Composition

Composition counts of the PCH during July, 1971-1990 indicated that calf:cow ratios ranged from 38:100 (1971) - 73:100 (1983) (Table 1) with a mean of 54.8 (SE = 2.6). In many years, no attempt was made to sample the entire herd or even all post-calving aggregations. Thus, although samples sizes were often large, they were not necessarily representative of the herd. During counts in 1979, 1982, 1986, and 1989 we did attempt to sample all cow/calf aggregations equally; the range in calf:cow ratios for these surveys was 43:100 - 62:100.

In April of 1990, composition of the herd was estimated by the Yukon Territorial Government, in cooperation with ADF&G; 9215 PCH caribou were classified as either calf, cow or bull. The count included 4460 cows, 1928 calves and 2827 bulls. The April bull:cow ratio was 63:100 and the calf:cow ratio was 43:100. The only previous reliable estimates of whole herd adult sex ratios were 60 bulls:100 cows in October 1980, 60:100 in July 1986, and 74:100 in July 1987.

Calf:cow ratios for the CAH were estimated in June, and calf:cow ratios for the PCH were done in conjunction with the census in July. It is expected that our calf:cow ratio estimates for the PCH would be lower than the CAH, because the PCH surveys were done one month later, and additional calf mortality is likely to occur during that time. However, a plot of CAH and PCH calf:cow ratios over time shows that although PCH estimates are lower, they are highly correlated with CAH estimates (Spearman's rank correlation; r = 0.833; $\underline{P}$ = 0.01; Fig. 4).

Productivity and Early Calf Survival

Parturition rate for radio-collared PCH cows aged 3 years or older between 1982 and 1990 ranged from 74% (1986) to 89% (1982), with a mean of 81% (Table 2; n = 437 potential calving events; some cows were sampled > 1 year) (Whitten et al. 1992a). Annual sample sizes of known age females were small for comparing age-specific natality rates. However, cumulatively, parturition among 3- and 4-year olds (43/66 = 65%) was lower than for older cows (305/371 = 82%; χ^2 = 10.06, 1 df, $\underline{P} < 0.005$). Only 2 of 62 (3.2%) 2-year-olds gave birth.

June survival for calves of radio-collared PCH cows monitored through the month of June varied from 65% (1983) to 91% (1989), with a mean of 74% (Table 3). Multiplying the June survival rate by the parturition rate would give an estimate of the calf:cow ratio among 3+ year old females expected on 1 July. The range in this estimate from 1983 to 1990 was 50:100 - 76:100 (Table 3). This estimate of July calf:cow ratios derived from radio-collared cows does not correspond closely with the calf:cow ratios estimated from composition counts (Table 1).

Productivity data for the CAH was estimated primarily from surveys of the calving grounds. These surveys were usually confined to higher density calving areas and may have overlooked areas with predominantly barren cows. Also, surveys may have occurred after the peak of calving and may have been biased by early mortality which had already occurred. Between 1978 and 1990, calf:cow ratios estimated for the entire CAH calving ground ranged from 48:100 (1989) to 91:100 (1983). Central Arctic Herd calf:cow ratios were generally lower after 1985 (Table 3). Differences between calf:cow ratios estimated for the portion of the herd that summers west of the Sagavanirktok River, in contact with oil development, and ratios estimated east of the

Table 1. Calf:cow ratios for the Porcupine Caribou Herd in post-calving aggregations during early July 1971-1990.

Year	Calves:100 Cows
1971	37.5
1972	49.1
1973	46.6
1974	67.3
1975	51.9
1976	58.2
1977	39.3
1978	67.4
1979	56.7
1980	66.7
1981	—
1982	47.2
1983	73.1
1984	—
1985	—
1986	52.4
1987	63.2
1988	54.0
1989	45.5
1990	—

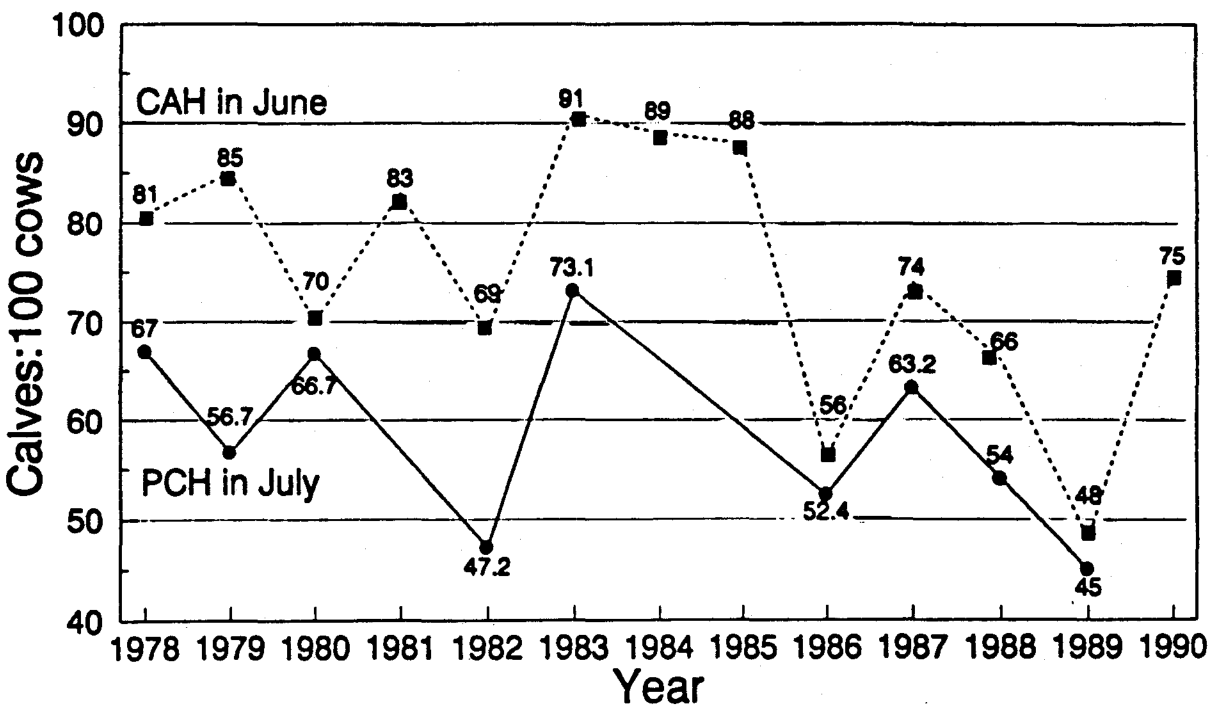

Figure 4. Calves:100 cows estimated for the Central Arctic Herd in early June, 1978-1990, and for the Porcupine Herd in early July, 1978-1989.

Table 2. **Parturition rates and June calf survival for adult (≥3-year-old) cows of the Porcupine Caribou Herd, 1982-1990. No data are available for June calf survival in 1982 and 1986.**

Year	n[a]	No. Preg.	Parturition Rate	# cows in June	Surv. Rate	Est. July calves:100 cows[b]
1982	9	8	0.89	-	—	—
1983	23	20	0.87	20	0.65	0.56
1984	31	25	0.81	25	0.84	0.68
1985	56	43	0.77	43	0.65	0.50
1986	42	31	0.74	-	—	—
1987	51	40	0.78	40	0.70	0.52
1988	91	76	0.84	71	0.71	0.57
1989	74	58	0.78	57	0.74	0.59
1990	74	61	0.82	54	0.90	0.76
Mean±SE			0.81 ± 0.02			0.74 ± 0.04

[a] n = 437 potential calving events; some cows were sampled > 1 year
[b] calculated as the product of parturition rate and June survival rate

Table 3. Calf:100 cow ratios (C:C) of the entire Central Arctic Herd calving ground, and subdivided by the area west of the Sagavanirktok River, and east of the Sagavanirktok River, during early June, 1978-1989.

	Total			West			East		
Yr.	Cows	Calves	C:C Ratio	Cows	Calves	C:C Ratio	Cows	Calves	C:C Ratio
78	426	346	81	370	307	83	56	39	70
79	833	710	85	768	658	86	65	52	80
80	356	248	70	247	166	67	109	82	75
81	1615	1333	83	896	771	86	719	562	78
82	532	368	69	532	368	69	—	—	—
83	811	738	91	811	738	91	—	—	—
84	1209	1072	89	1209	1072	89	—	—	—
85	983	867	88	983	867	88	—	—	—
86	454	254	56	454	254	56	—	—	—
87	2548	1898	74	1313	1022	78	1235	876	71
88	2387	1580	66	1277	853	67	1110	727	65
89	1475	715	48	786	278	35	689	487	71
90	5574	4176	75	4328	3203	74	1249	973	78

Sagavanirktok River, where no development exists, were small until 1989. At that time the calf:cow ratio east of the river was 63, and west of the river was 38 (Table 3). Calf:cow ratios for the western portion of the herd were lower than estimates for the eastern portion of the herd in only 3 years between 1979 and 1990 (1980, 1989, 1990; Table 3). Data on productivity of CAH radio-collared cows 1980-87 corresponded with the general trends noted from the calving ground surveys (Cameron et al. 1988).

Adult Survival

Estimates for annual survival rates of adult, female caribou of the PCH, 1982-1990 ranged from 76% (1986) - 93% (1983) with a mean of 85% (SE = 1.9; Table 4). No consistent trends in survival were evident from the data.

Table 4. Porcupine Caribou Herd annual adult female survival estimates and upper and lower bounds of 95% confidence intervals as calculated by the Kaplan-Meier product limit estimator (Pollock et al. 1989).

Year	Lower Limit	Survival	Upper Limit
1982	0.78436	0.9000	1.01564
1983	0.83888	0.9310	1.02312
1984	0.66306	0.7885	0.91394
1985	0.77136	0.8674	0.96344
1986	0.65104	0.7608	0.87056
1987	0.87914	0.9301	0.98106
1988	0.69352	0.7778	0.86208
1989	0.75822	0.8425	0.92678
1990	0.75954	0.8399	0.92026
MEAN	0.81126	0.8485	0.88574

Harvest

Between 1987 and 1990 the estimated annual harvest of the PCH ranged from about 2500 to 4500 animals (Table 5), or about 1-3% of estimated population size. Estimates of annual harvest of the CAH between 1987 and 1990 ranged from 240-381 animals (Table 6).

Table 5. Annual harvest of the Porcupine Caribou Herd, 1984-1989. Canadian harvest from Yukon Department of Renewable Resources. Harvest in Alaska obtained from Alaska Department of Fish and Game (Whitten 1991a).

	Reported				Estimated unreported			
Season	Male	Female	Unk.	Total	Alaska	Canada	Total	Total
1984-85	49	4	0	53	500-700	4,000	4,500-4,700	4,554-4,754
1985-86	52	12	1	65	500-700	4,000	4,500-4,700	4,564-4,764
1986-87	70	14	0	84	1,000-2,000	500-1,000	1,500-3,000	1,584-3,084
1987-88	106	22	1	129	<500	2,000-4,000	2,500-4,500	2,629-4,629
1988-89	82	7	0	89	<500	2,000-4,000	2,500-4,500	2,589-4,589
1989-90	104	8	0	112	500-700	2,000	2,500-2,700	2,612-2,812

Table 6. Annual harvest of the Central Arctic Herd, 1984-1989.

Season	Reported Harvest				Estimated Unreported harvest [a]	Total harvest
	Male	Female	Unk.	Total		
1984	313	55	0	368	100-200	468-568
1985	482	177	3	662	100-200	762-862
1986	311	34	0	345	100-200	445-545
1987	176	2	3	181	100-200	281-381
1988	179	7	0	255	100-200	286-386
1989	132	8	0	140	100-200	240-340

[a] Estimate by H. Golden, pers. commun.

DISCUSSION

The PCH and the CAH share some similarities in spite of their large differences in population size and migratory patterns. General patterns in daily and seasonal activity and rates of movement are similar between the 2 herds, with differences found mainly during migration periods. Thus, the mean annual distance traveled by adult females of the CAH was significantly less than the migratory PCH, although some CAH animals were observed to move as much as PCH animals during a yearly cycle.

Several factors combine to indicate that the PCH has been increasing steadily since the late 1970's. The instantaneous rate of increase of the PCH was estimated at 4.8% during the period 1979-1989. Estimates of parturition rate based on radio-collared individuals varied only between 78% and 83%, 1987-90. No trend was evident in the July calf:cow ratios estimated during composition counts 1971-1989, although the large variability in yearly estimates probably reflects annual variability in early calf survival (see also Whitten et al. 1992a, 1992b). Yearly estimates of adult female survival varied considerably, but no consistent trends were evident from data of the past 9 years.

Survival of adult females has been identified as the most important parameter affecting the rate of increase of long-lived species (Nelson and Peek 1982, Fowler and Smith 1973), and should continue to be monitored closely in the PCH. Because some animals die during or immediately following the capture and marking process, there is the potential that the capture process is traumatic enough to affect survival beyond the immediate post-capture period; the extent of such negative effects or their mechanisms are unknown. Therefore, we recognize this as a potential cause of bias in our data which would negatively affect our estimate of survival. Another potential cause of bias in our data is that lost animals that were later found dead were considered mortalities, but lost animals that may have been alive outside of the study area and were never heard from were censored. Thus, these animals were no longer considered at risk and this assumption may also bias our survival estimates negatively. Other alternatives for analyzing radio-collar data for survival estimation are being explored.

The available census data from the CAH are inadequate to detect if rate of growth of this herd is slowing. The CAH has been associated with petroleum development for approximately 20 years, and appeared to grow rapidly during the 1970's and early 1980's (Whitten and Cameron 1983b). The last census of the CAH was in 1983, and at that time the herd was estimated at 12,900. Data available between 1978 (CAH estimated at 5,800; Whitten and Cameron 1983b) and 1983 (CAH estimated at 12,900) indicated that the CAH was increasing at a rate of 15.3%. It is unlikely that this herd is still increasing at such a rate, but the available data are not sufficient to determine the observed rate of increase between 1983 and 1990.

Productivity and survival information should also yield insights into the status and trend of the CAH. However, methods of collecting population data for the CAH differed from those used in the PCH. Productivity data for the CAH are based on calf:cow ratios estimated from calving ground surveys and actually reflect conditions after some early calf mortality occurred (Fig. 4). Because of the considerable year to year variability in our estimates of calf:cow ratios, it is difficult to determine if recent calf:cow ratios are declining, or if they are simply varying within the extremes observed over the last decade. June calf:cow ratios for the entire herd decreased from 66:100 in 1988 to 48:100 in 1989 but returned to 75:100 in 1990 (Table 3). The 1989 estimate of CAH calf:cow ratio (48:100) was the lowest observed since data were collected beginning in 1978. However, the July estimate of PCH calf:cow ratio in 1989 (45.5:100) was the lowest recorded during that time period (estimates lower than 45.5 were recorded for the PCH in 1971 and 1977).

Estimates of calf:cow ratios from these 2 herds were highly correlated, and appear to have risen and fallen in synchrony since 1980 (Fig. 4). Klein (1991) discussed the increase observed in many large, migratory, caribou herds in Canada and Alaska during the 1970s and early 1980s, and hypothesized that favorable weather patterns during this period may have been partially responsible for the simultaneous increases observed. Fluctuations in Arctic weather patterns during the last several years may have played a role in shaping the similar patterns of productivity that we observed for these 2 herds. Because the ranges of the Porcupine and the Central Arctic Herd overlap, mixing often occurs during the post-calving season. It is possible that factors such as disease and parasites are also common to these 2 herds. Estimates of productivity for other Arctic caribou herds, where available, will be investigated to determine if the trend observed for the PCH and CAH was common to Arctic caribou herds over this period.

Concern exists that the segment of the CAH that summers west of the Sagavanirktok River, in contact with the development infrastructure, may be in poorer condition than the portion of the herd that summers east of the river. June calf:cow ratio estimates for that segment of the CAH associated with development west of the Sagavanirktok River were lower than ratios east of the area in 1980, 89, and 90 (Table 2). See Cameron et al. (1992) for a discussion of body condition and reproductive performance of CAH females.

MANAGEMENT IMPLICATIONS

The process of modelling the dynamics of the Porcupine Caribou population is currently underway. Accurately predicting the rate of growth or decline of a population is always an uncertain and complex procedure, and reasonable predictions can only be obtained with unbiased estimates of the input parameters. Thus, priorities for future research are to continue to estimate survival and productivity parameters through the use of radio-collared individuals.

Because survival of adult females is an important parameter driving the dynamics of long-lived species, it is desirable to maintain a sufficient sample of radio-collared PCH females to allow detection of any changes in mortality rates. The number of collared females should remain at current levels and regular tracking flights covering the entire range of the herd should be done to achieve mortality rate estimates with acceptable levels of precision. Frequent tracking flights will allow a more precise determination of rates and causes of adult mortality than is possible with the current data.

An additional priority for future research is to obtain information regarding diet composition and nutritional quality of forage during the calving and post-calving seasons. The links between habitat use, body condition, and population dynamics of the PCH have not yet been investigated. Also, information on the relationship between caribou distribution and the potential numerical and functional response of predator populations is needed. These types of information are necessary inputs to simulation models of PCH population dynamics for purposes of estimating the potential effects of an oil and gas leasing program in ANWR on the PCH.

Although parturition rates and some adult survival information are available for the PCH, comparative estimates for some parameters are lacking for the CAH due to the smaller sample sizes of marked and known age animals in this herd. Our current estimates of parturition rates and early calf survival in the CAH are based on a small sample of marked animals or the use of calf:cow ratios, and have varied greatly among the last few years. With the available data, a change in the growth rate of the CAH is very hard to detect. Further research should concentrate on obtaining better estimates of CAH population parameters. The small sample sizes currently available have restricted our ability to use some statistical analyses and limited our conclusions to the identification of trends.

Sample size of radio-collared CAH adult females should be increased to obtain better estimates of age-specific parturition rates and early calf mortality in developed and undeveloped areas of their range. By increasing frequency of relocations of collared adult females we can obtain estimates of June calf survival, comparable to those available for the PCH. Causes of perinatal as well as later calf mortality should be determined using calves of collared adult females as well as collared calves. Sex and age composition data for the CAH have been limited for some time to estimates obtained during June; reliable estimates of bull:cow ratios are also needed and necessitate sampling at a time when the bulls and cows are mixed. An accurate and precise estimate of population size of the CAH will be necessary for validation of any population model. A photocensus will be attempted again in 1992.

If productivity and survival of the CAH are both changing, we need to determine if changes are related to petroleum development in the region. It is possible that stresses associated with interaction with development could decrease chance of successful conception. A decrease in calf production and/or early calf survival might be related to factors such as contaminants, or changes in female body condition brought about by increased energy expenditure. If a cause and effect relationship exists, the exact mechanisms that determine changes in population productivity need to be determined.

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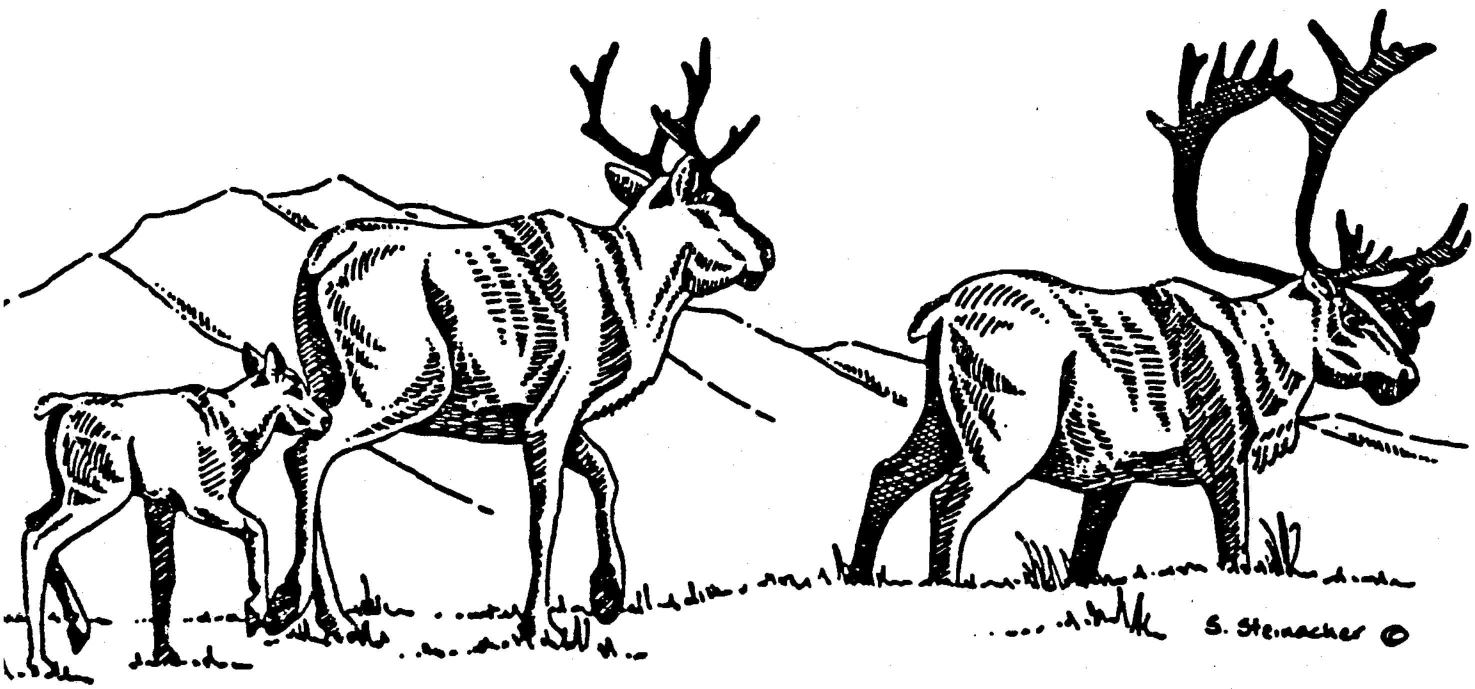

Interim Report - 1988-1990

Submitted by : Alaska Fish and Wildlife Research Center
&
Arctic National Wildlife Refuge

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