Work Subunit Ib. Effect of potential displacement of caribou from the 1002 area on mortality rates of calves

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INTRODUCTION

In 1980 the U.S. Congress set aside 600,000 hectares (1.5 million acres) of the coastal plain in the Arctic National Wildlife Refuge (ANWR) for limited oil and gas exploration. Results of that exploration program indicated a potential for significant petroleum resources, and Congress is now considering additional legislation to open those lands (commonly referred to as the 1002 area) to leasing and development (Clough et al. 1987).

The Porcupine Caribou (*Rangifer tarandrus granti*) Herd (PCH) has consistently calved at high densities in the eastern portion of the 1002 area (Garner and Reynolds 1986). Studies of the adjacent Central Arctic Herd (CAH) have found that disturbance associated with petroleum development can displace calving caribou (Dau and Cameron 1986). The Prudhoe Bay oil field has the lowest calving densities of any portion of the CAH calving grounds (Whitten and Cameron 1985), and in the Kuparuk oil field, density of calving caribou was inversely correlated with distance from development (Dau and Cameron 1986). If the 1002 area is leased, biologists, conservationists, and sport and subsistence hunters are concerned that subsequent development could displace parturient PCH caribou from the traditional calving grounds (Elison et al. 1986, Clough et al. 1987).

The objectives of this Work Subunit were to evaluate use of the 1002 area for calving by the PCH, determine causes of early calf mortality, and examine whether calf survival differed between the 1002 area and areas to which calving might be displaced. This report combines data collected from 1988-1990 with data collected during earlier baseline studies (Whitten et al. 1984, 1985, 1987).

METHODS

Study area

The primary study area was the calving ground of the PCH. This area included all north flowing drainages between the Canning River in Alaska and the Blow River in the Yukon Territory. The majority of calving by radio-collared females of the PCH occurs in this area every year. Mountains rise sharply at the southern edge of this area, about 60-80 km inland from the coast in the west, but only about 25 km inland in the east. Moderate to gentle relief foothills dominated by cottongrass (*Eriophorum vaginatum*) tussocks lie north of the mountains, and nearly flat, marshy tundra extends further north to the coast. Numerous large rivers traverse the area from south to north, characterized by open gravel bars, mat tundra vegetation on old floodplain terraces, and discontinuous stands of low riparian willows (*Salix* spp.). More detailed descriptions of the study area are given by Garner and Reynolds (1986), Felix et al. (1989), and Christiansen et al. (1990).

Calving Surveys

We attempted to observe radio-collared cows from fixed-wing aircraft at 1-3 day intervals between approximately 28 May and 30 June each year to determine date and location of calving and the fate of calves. However, in some years inclement weather prevented some cows from being relocated within 3 days of the previous location. Calving dates and neonatal survival for calves of collared cows were determined from a combination of criteria, including presence of a live calf at heel, presence or absence of hard antlers, and udder distention (Whitten 1990). Cows not showing any overt signs of pregnancy, but not obviously barren (e.g., not already possessing velvet antlers), were relocated at least weekly until 30 June to ensure that no pregnancies were missed. Cows that apparently lost calves were observed at least once more during the calving period to confirm that no calf was present.

We assumed that the first place a radio-collared cow was seen with a calf was the calving site. Calving sites of radio-collared cows between 1983 and 1990 were digitized and entered into the ARC/INFO geographic information system (GIS) for analysis of calving distribution.

Calving Distribution

We tested whether the distribution of calving sites on the coastal plain and in the foothills was random by partitioning the area into six blocks of similar size (Fig. 1) and determining the number of calving sites expected within each block if the 267 sites were evenly distributed. Blocks were delineated on the east and west by major rivers or the Alaska-Yukon border, and on the north by the coastline. The southern boundaries of the blocks were drawn where the coastal plain and foothills give rise to the mountains of the Brooks and British Ranges. The area within each block was determined using the ARC/INFO geographic information system.

Locations of PCH collared caribou during the period between early January and early April, when cows were most sedentary (Fancy et al. 1989), were classified into 1 of 3 categories (Alaska, Richardson Mountains, or Ogilvie Mountains) to determine relationships between wintering areas and calving sites. For the purpose of this analysis, all wintering locations in the Yukon that were south and west of the Porcupine and Eagle rivers were included in the Ogilvie Mountains category, whereas locations east of the Eagle River and along the axis of the Richardson Mountains were included in the Richardson Mountains category. Central Arctic Herd winter distribution was estimated from surveys of radio-collared animals in October/November and March/April each year.

Movements and Habitat Use During the Calving Period

We investigated distance moved and direction of movement of parturient females during the calving period. We monitored 42 individuals collared with satellite transmitters. We tested whether cows exhibited significantly directed movement toward calving sites using the Rayleigh test (Batschelet 1981:54).

We investigated habitat use by calving caribou by comparing locations of calving sites for all radio-collared cows from 1983-1990 with randomly-selected sites within the area bounded by the outermost calving sites (including those in the mountains, but excluding 2 cows that calved with the CAH, west of the Canning River; see Fig. 1). We excluded sites where 16 cows were first observed with a calf because the calf was estimated to be >5 days old and may have been born several kilometers away. These 16 cows were used in the calving distribution analysis above because they were located within the same block before and after calving. We determined the

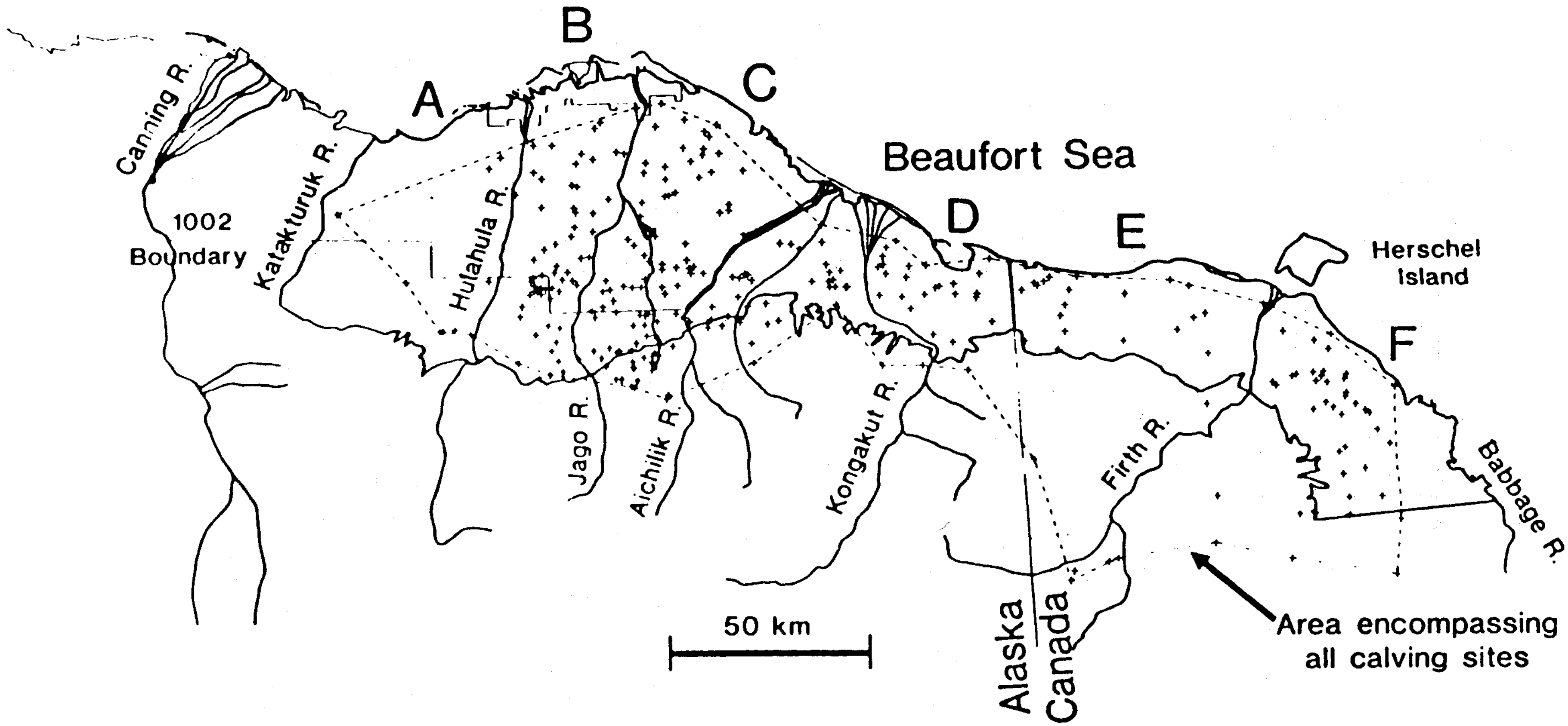

Figure 1. Calving grounds of the Porcupine Herd, showing areas used in analyses of calving distribution, calving site selection, and fidelity. Blocks A-F were used to test for random distribution of calving sites on the coastal plain. The area encompassing all sites where radio-collared cows were first observed with a calf in 1983-1990 (sites marked by crosses; area delineated by a dashed line) was used in analyses of calving site selection and fidelity.

landcover type for each calving site and random site using digital maps with a resolution (i.e., pixel size) of 50 m x 50 m in Alaska (U.S.G.S. EROS Data Center, Anchorage, AK; Garner and Reynolds 1987:60) or 100 m x 100 m in Canada (Nixon et al. 1989). Landcover maps used to determine the landcover type of each calving site were based on LANDSAT multispectral scanner data; however, the classification algorithms used for the Alaskan and Canadian portions of the calving grounds differed, thereby precluding direct comparisons of specific cover types.

Calving Site Fidelity

We determined whether individual cows showed fidelity to calving sites in different years by comparing distances between all calving sites for each radio-collared cow between 1983-1990 with a distribution of distances between random points obtained through computer simulation. The number of calving sites for each cow varied from 2-7; separate analyses were required depending on the number of calving sites included. For each cow, we calculated the shortest distance between any two calving sites, and the shortest distance connecting all calving sites. For each simulation, we generated 8000 sets (i.e., 2-7 locations) of random sites from the calving grounds (Fig. 1), and calculated the same distance parameters. Differences between cumulative frequency distributions of observed and simulated distances were compared using the Kolmogorov-Smirnov test (Sokal and Rohlf 1969:573).

Effect of Geographic Location on Calf Survival

Geographic variability in calf survival was investigated by deploying mortality-sensing transmitters on 118 calves on 2-3 June, 1988, using methods described by Garner et al. (1985). Sixty-one transmitters were deployed on calves between the Jago and Aichilik Rivers (1002 area), 16 were deployed on the coastal plain east of the 1002 area (peripheral), and 41 were deployed on calves in the foothills and mountains south of the 1002 area (peripheral). Previous experience with calf capture (Whitten et al. 1984, 1985, 1987; Garner et al. 1985) indicated that calves abandoned after capture died within 48 hr. Because inclement weather precluded observations of collared calves for 2 days following capture in 1988, and we could not distinguish between natural and capture-induced abandonment, we excluded from further analysis 14 calves that died within 48 hr of capture. Sample size was reduced to 55 collared calves in the 1002 area and 49 in the peripheral areas to the south and east. Findings in 1988 were compared with results from similar studies conducted during 1983-1985.

Earlier studies (Whitten et al. 1984, 1985, 1987, 1992) indicated that calf mortality in the PCH may be divided into two phases. We referred to death within 48 hours of birth as perinatal mortality, and death during days 3-30 after birth as post-perinatal mortality. We investigated the correlation between perinatal and post-perinatal mortality rates of calves born to radio-collared cows and the percent of parturient radio-collared cows that calved inside the 1002 boundary during 1983-89 with Spearman's rank correlation procedures. We also tested the hypothesis (Kruskal Wallis test) that post-perinatal mortality rate in years of late snow melt did not differ from the rate estimated in years of early or average snow melt.

Causes of Calf Mortality

Causes of early, or perinatal, mortality were investigated in 1989 by conducting low level aerial searches for dead or abandoned calves on the calving grounds between the Hulahula and Aichilik Rivers. Sixty-one calves were necropsied, and primary cause of death could be determined in 56 cases (Roffe 1990).

Causes of post-perinatal calf mortality were determined from collared calves in 1983-1985 and in 1988. Supplemental post-perinatal mortality data were also collected from 16 carcasses of unmarked calves which were necropsied in 1983-1985 (Whitten et al. 1992).

RESULTS

Calving Distribution

The majority of calving sites (267/321) and concentrated calving activity occurred on the coastal plain and in the foothills (Fig. 1) between the Katakturuk and Babbage Rivers. The remaining sites were widely scattered through the Brooks Range, British Mountains, and/or west of the Katakturuk River. Distribution of calving sites in 1983-90 was non-random (Table 1; $\chi^2 = 77.0$; 5 df; $\underline{P} < 0.0001$). The area between the Hulahula River and the Alaska-Canada border (blocks B, C and D, Fig. 1) contained 1.48 times as many calving sites/km^2 as expected, whereas the area east of the border (blocks E and F, Fig. 1) contained only 0.7 times as many sites as expected. Within Alaska, the coastal plain between the Aichilik River and the Canadian border is often snow-free or has mottled snow during the early calving period. In contrast, much of the area west of the Aichilik River is at higher latitude, and complete snow cover remains near the coast in most years (Eastland et al. 1989). Thus, the areas actually available for calving in most years west of the Aichilik River are smaller than those in Figure 1, and are probably more strongly selected than the data in Table 1 suggest.

The east-west distribution of calving sites was related to the herd's winter distribution (Fancy et al. 1992). Cows that wintered in the Richardson Mountains calved farther west than those that wintered in Alaska or the Ogilvie Mountains (see Fancy et al. 1992; Fig. 2). We found a significant correlation between date of arrival on the calving grounds and longitude of calving sites (early-arriving cows calved further west) for cows tracked by satellite (Spearman's rank correlation; $n = 38$; $r = 0.646$; $\underline{P} < 0.001$). However, we found no relationship between arrival date on the calving grounds and date of calving (Spearman's rank correlation; $n = 39$; $r = 0.25$; $\underline{P} > 0.20$).

Movements and Habitat Use During the Calving Period

The movements of parturient cows tracked by satellite between 1985 and 1989 averaged >10 km/d in a northwest direction during the 12-day period before calving (Table 2). Daily relocations of radio-collared cows indicated that most cows selected a calving site $\leq$3 days before their calving date. During the 6-day period beginning at calving, cows moved <5 km/d and movement direction was random. The 24-h activity index, an independent measure of caribou movement (Fancy et al. 1989), followed a pattern similar to rates of movement (Table 2).

Selection for landcover types characterized by *E. vaginatum* tussock tundra occurred in both Alaska and Canada (Table 3). In Alaska, 55% of calving sites were located in Moist Graminoid Tundra or Mesic Erect Dwarf Shrub types characterized by *E. vaginatum* (Garner and Reynolds 1987:60), whereas only 40% of the randomly-selected sites were located in these

Table 1. Distribution of 267 Porcupine Caribou Herd calving sites in 1983-1990 on the coastal plain of northeastern Alaska and northern Yukon. Blocks A-F refer to areas shown in Figure 1.

Block	% of Area	Sites Observed	Sites Expected	Ratio Obs:Exp	Selection[a] Prob.
A	21.37	11	57.1	0.19	0.032
B	15.61	66	41.7	1.58	0.259
C	19.26	70	51.4	1.36	0.223
D	16.03	65	42.8	1.52	0.249
E	12.49	18	33.3	0.54	0.088
F	15.24	37	40.7	0.91	0.149
Total	100.00	267	267	6.1	1.000

[a] Relative probability that block will be selected as a calving site; calculated as (ratio obs:exp)/6.1.

Table 2. Movement and activity of parturient Porcupine Herd caribou during 3-day intervals relative to their date of calving on the arctic coastal plain . Data collected between 1985 and 1989 using the Argos Data Collection and Location System (Fancy et al. 1989).

DAYS RELATIVE TO CALVING	n	DISTANCE MOVED (km/d) Mean ± SE	24-H ACTIVITY INDEX Mean ± SE	MEAN DIRECTION Azimuth	P
-12 to -10	42	12.8 ± 1.7	13713 ± 1270	339	***
-9 to -7	42	13.0 ± 1.5	13508 ± 1338	326	***
-6 to -4	42	11.9 ± 1.1	13469 ± 1298	303	***
-3 to -1	42	10.3 ± 1.0	11917 ± 1098	289	***
0 to +2	40	4.7 ± 0.5	8316 ± 882	290	ns
+3 to +5	41	4.2 ± 0.6	7524 ± 839	111	ns
+6 to +8	41	6.9 ± 2.3	10037 ± 1179	244	ns
+9 to +11	39	5.4 ± 0.5	11382 ± 1223	212	ns
+12 to +14	38	7.0 ± 0.7	12700 ± 1347	233	ns
+15 to +17	35	9.0 ± 1.2	14443 ± 1533	261	ns
+18 to +20	34	9.3 ± 0.9	15634 ± 1552	270	ns
+21 to +23	33	10.9 ± 1.0	16994 ± 1924	308	**
+24 to +26	30	13.9 ± 1.2	19624 ± 1999	317	ns

ns = direction not significant; Rayleigh test (Batschelet 1981:54)
** $P < 0.005$
*** $P < 0.001$

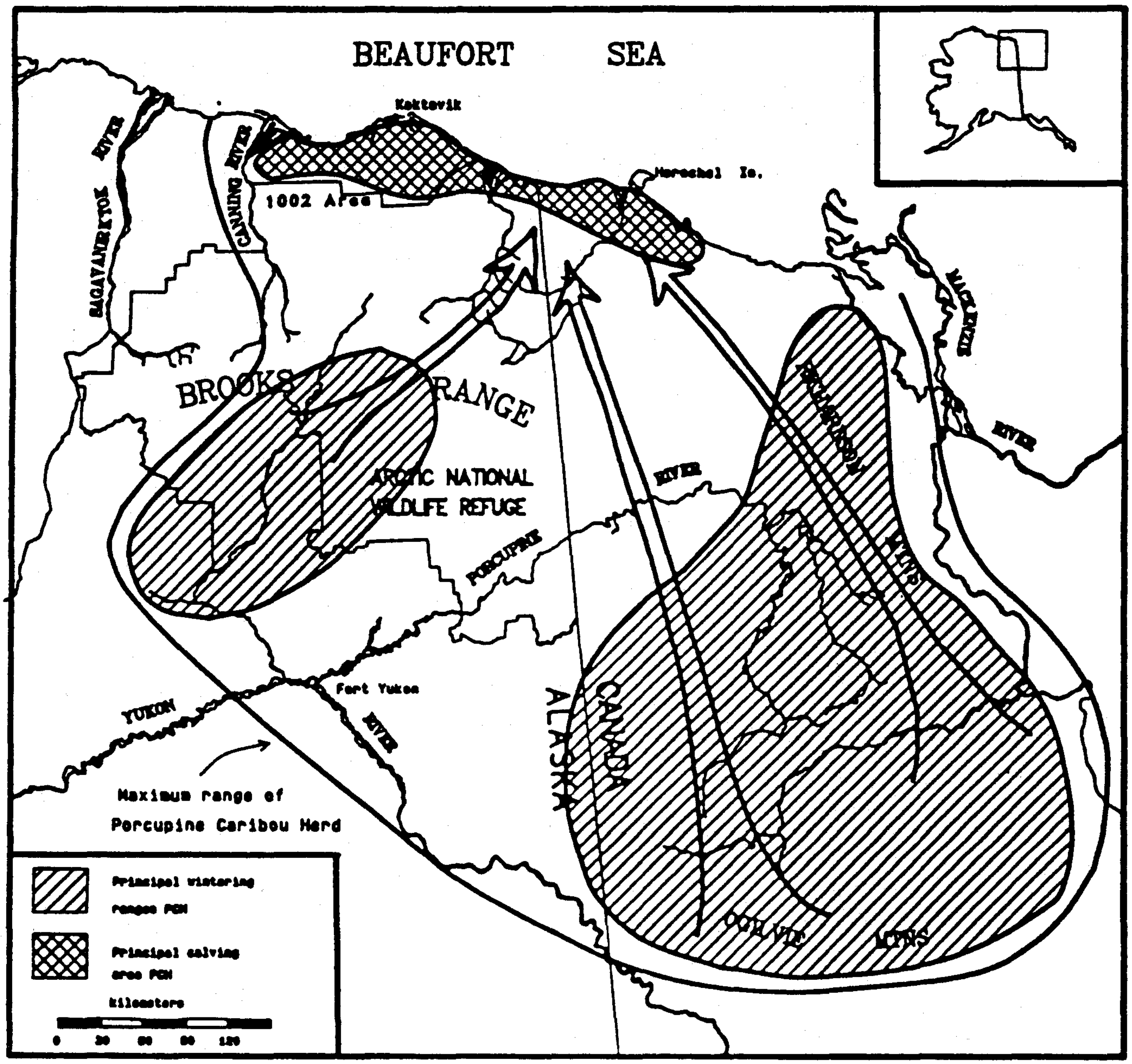

Figure 2. Locations of traditional calving area and main wintering areas of the Porcupine Caribou Herd.

types (Table 3). In Canada, 54% of calving sites were located in tussock tundra types, compared to 30% for randomly-selected sites. When landcover types in both Alaska and Canada were classified as tussock or non-tussock types, we found that a highly significant proportion of cows had their calves in tussock type vegetation. (Fisher's exact test, $P < 0.0001$).

Table 3. Percentage occurrence of landcover types at calving sites (n = 284) and randomly-selected sites (n = 277) in Alaska and Canada. No landcover data were available for the area in Canada west of the Malcolm River.

Area		Randomly-Selected Sites	Calving Sites
Alaska			
	Barren Floodplain	1.7	0.4
	Barren Scree	1.7	0.4
	Dry Prostrate Dwarf Scrub	6.9	3.0
	Moist Prostrate Dwarf Scrub	22.4	20.4
	Mesic Erect Dwarf Scrub[a]	18.4	24.3
	Moist Graminoid Tundra[a]	21.3	30.9
	Moist/Wet Tundra Complex	13.8	10.9
	Wet Graminoid	10.3	8.3
	Very Wet Graminoid	0.0	0.9
	Scarcely Vegetated	3.5	0.5
Canada			
	Dryas/Sedge	5.8	3.7
	Dense Shrub Slope	2.9	1.9
	Open Shrub Heath	12.6	20.4
	Low Shrub Tundra	1.0	0.0
	Lichen/Barren	30.1	9.3
	Tussock Tundra w/ 0-15% Shrubs[a]	10.7	22.2
	Tussock Tundra w/ 16-25% Shrubs[a]	12.6	24.1
	Tussock Tundra w/ 26-35% Shrubs[a]	6.8	7.4
	Unvegetated	16.5	7.4
	Alluvial	1.0	3.6

[a] Landcover types dominated by tussock tundra

Calving Site Fidelity

Although the PCH cows we studied consistently used the calving grounds between the Katakturuk and Babbage rivers, they did not return to the same sites on the calving grounds each year to calve (Table 4). None of the cumulative frequency distributions of distances between calving sites were different from the distributions for randomly-selected sites

Table 4. Comparisons of distances (km) (Mean ± SE, km) between calving sites of radio-collared Porcupine Caribou Herd cows on the Arctic coastal plain located in 2-7 different years with distances between randomly-selected sites. Cumulative frequency distributions of distances between calving sites and 8000 sets of randomly-selected sites were compared using the Kolmogorov-Smirnov test (Sokal and Rohlf 1969:573).

No. Years	n	Shortest Distance Between 2 Sites			Shortest Distance Connecting All Sites		
		Observed	Random	Dmax[a]	Observed	Random	Dmax
2	43	67.1 ± 49.1	93.6 ± 59.7	0.097			
3	19	27.9 ± 12.0	38.9 ± 21.7	0.266	125.0 ± 58.7	145.3 ± 55.1	0.111
4	7	26.2 ± 10.0	26.2 ± 14.3	0.202	192.8 ± 27.4	179.2 ± 48.5	0.184
5	6	17.6 ± 8.6	19.8 ± 10.7	0.145	179.6 ± 47.9	206.7 ± 43.8	0.201
6	5	7.2 ± 2.7	15.7 ± 8.4	0.297	176.3 ± 28.5	229.7 ± 41.6	0.373
7	2	5.9 ± 1.4	13.2 ± 7.1	0.424	229.1 ± 105.3	250.6 ± 42.2	0.498

[a] Kolmogorov-Smirnov test statistic; all values nonsignificant ($P > 0.10$)

(Kolmogorov-Smirnov test; $P > 0.10$). Thus, although cows often selected areas in the tussock tundra vegetation type for calving, they did not calve at the same specific location each year.

Calf Survival

Mean calf survival for 312 cows monitored through June in 1983-1990 was 73.4% (Table 5; some cows were monitored several times across years). In 1988 we compared mortality of calves born to collared cows with the mortality of a separate sample of collared calves; June mortality for calves of radio-collared cows was 31% (22/71), compared to 13% (14/104) for radio-collared calves. However, many calves may have been stillborn or may have died before we began collaring, and elimination of deaths occurring shortly after capture may account for this differential. Thus, the data from collared calves presented here pertains only to the post-perinatal period. Similar mortality rates were obtained for collared calves and calves of collared cows once the collared cow data were adjusted to exclude perinatal mortalities (Table 6).

Effect of Geographic Location on Calf Survival

In 1988 no significant difference ($\chi^2 = 0.84$; $P > 0.10$) was found between mortality of calves originally collared within the 1002 area (9/55) and those collared south and east of the 1002 area (5/49). Similarly, in 1983-85 survival rates of collared calves captured in the yearly concentrated calving area did not differ from survival rates of calves collared in peripheral areas ($\chi^2 = 0.46$, 1 df, $P = 0.50$) (Whitten et al. 1992). There was some indication that calves died at

Table 5. 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

higher elevations than those used by calves who survived ($\underline{P}$ = 0.07, Whitten et al. 1992). Location data were not obtained for surviving calves in 1988, precluding a similar analysis.

During 1983-90 the percent of radio-collared cows that calved within the 1002 area ranged from 1.6 to 69.2% (Table 7). Post-perinatal mortality of calves during the same period ranged from 0.0 to 18.0% and was inversely correlated (r = -0.76; $\underline{P}$ = 0.03) with the percent of radio-collared cows calving in the 1002 area. In particular, post-perinatal mortality was higher in years when late snow melt apparently inhibited many cows from calving in the 1002 area (1987-88 median = 19.4%; Kruskal-Wallis test; $\underline{P}$ = 0.046). During 1983-85 and 1989-90, when snow melt was early and many cows calved within the 1002 area, median post-perinatal mortality was 9.5%. Between 1983-1990, perinatal mortality ranged from 7.5 to 21.5% and was not correlated with percent of radio-collared cows calving in the 1002 area (r=0.12; $\underline{P}$ = 0.78).

Causes of Calf Mortality

Primary cause of death was diagnosed for 56 of the 61 calf carcasses found during low-level aerial searches and necropsied in 1989. These carcasses were all collected during the peak calving period when calves were very young and were assumed representative of perinatal mortality. Emaciation and malnutrition accounted for 52% of the deaths for which cause could be determined, stillbirth accounted for another 23%, 18% died of trauma, and 7% died of various other causes (Roffe 1990). Most of the trauma deaths (8/10) were attributed to predators. Our sample of calf carcasses may have been biased against predation deaths because heavily scavenged carcasses were not retrieved. Seven of the 8 calves whose deaths were attributed to predators were in good body condition. Earlier calf studies on the coastal plain indicated that 54%

Table 6. Percentage mortality of collared calves and/or calves of collared Porcupine Caribou Herd cows during late May and June, 1983-1990. Data for 1983-1985 obtained from Whitten et al. (1992). Relocations in 1986 were too infrequent to calculate mortality rates. Numbers in parenthesis are sample sizes. Range in numbers reflects uncertainty as to when calves died, and therefore uncertainty if a death was perinatal or post-perinatal.

	Calves of collared cows		Collared Calves	
Year	Overall	Post-perinatal[a]	Post-perinatal[a]	Mean post-perinatal[b]
1983	35 (20)	13-23 (15-17)	9 (59)	13.5
1984	16 (25)	9 (23)	8 (61)	8.5
1985	35 (43)	10-15 (30-32)	15 (62)	13.8
1986	--	--	--	--
1987	30 (40)	20-24 (35-37)	--	22.0
1988	29 (70)	13-28 (55-66)	13 (104)	16.8
1989	26 (58)	9-10 (47-48)	--	9.5
1990	10 (60)	0-2 (54-55)	--	1.0

[a] Post-perinatal mortality includes only those calves known to be >48 h old when last observed alive. Perinatal and possible perinatal mortalities are excluded.

[b] Mean of post-perinatal mortality rates for calves of collared cows and collared calves; if one of the mortality rates was a range, the endpoints of the range were used to calculate the mean.

Table 7. Post-perinatal mortality rates for calves of radio-collared Porcupine Caribou Herd (PCH) cows and percent of radio-collared PCH cows calving within the 1002 boundary of the Arctic National Wildlife Refuge, 1983-90.

Year	Mean Post-perinatal mortality rate[a]	Percent of radio-collared cows calving in 1002 area	Total number of radio-collared cow calving sites
1983	13.5	61.1	18
1984	8.5	36.4	22
1985	13.8	56.8	37
1986	–	–	37
1987	21.0	10.8	62
1988	16.8	1.6	52
1989	9.0	32.7	52
1990	0.0	69.2	47

[a] mean of post-perinatal mortality rate of collared calves and calves of collared cows; see Table 6

(15/28) of perinatal deaths among unmarked calves involved no predation (Whitten et al. 1992).

During the post-perinatal period 1983-85, predation was the cause of death for 13 of the 19 collared calves that died (68.4%). Of 16 unmarked calf carcasses collected during the post-perinatal period 1983-85, 13 were killed by predators (81.3%).

DISCUSSION

Distribution of PCH calving sites during 1983-90 was non-random; the area between the Hulahula River and the Canadian border was used by calving caribou 1.5 times more than expected. We hypothesize that variation in snow cover, both along migration routes and on the calving grounds, contributes to much of the annual variation in location of areas having the highest concentration of calving caribou. Snow along migration routes influences the initiation and progress of spring migration (Thompson and Roseneau 1978, Garner and Reynolds 1986, Russell et al., unpubl. data). The Chandalar and Ogilvie wintering areas are separated from the calving grounds by areas that, in many years, are covered by relatively deep, persistent snow. In contrast, the windswept ridges of the Richardson Mountains are contiguous with the coastal plain in Canada, often allowing caribou to begin spring migration and arrive on the calving grounds earlier than cows wintering elsewhere (Thompson 1978). Thus, cows wintering in the Richardson Mountains tend to calve farther west than cows wintering in Alaska or the Ogilvie Mountains, but in low snow or early snow-melt years such as 1990, all cows may arrive early and calve farther to the west than in late snow-melt years.

Porcupine Caribou Herd females did not show fidelity to specific geographic sites for calving. However, analysis of sites used for calving indicated that there is selection by parturient PCH females for sites dominated by tussock tundra. Thus, we hypothesize that the selection of a specific geographic site is modified by yearly variation in wintering sites, migration routes and amount of snow remaining on the coastal plain and foothills.

Cameron et al. (1992) found that perinatal calf survival in the CAH varied directly with the weight of females shortly after calving. Others have reported that improved nutrition in pregnant reindeer was positively correlated with calf birth weights and early calf survival (Rognmo et al. 1983). Similarly, Haukioja and Salovaara (1978) suggested that smaller calves may be more prone to early mortality than larger calves. In this study, necropsies of calves dying within 48 hours of birth (perinatal mortality) suggested inadequate nutrition of the dam and/or calf was the major factor. Seventy-five percent of unmarked calf carcasses were stillborn or died of emaciation or malnutrition. Results of earlier studies on perinatal mortality in the PCH (Whitten et al. 1992) were consistent with these results. In this study, there was no relationship detected between perinatal mortality rate and percent of cows calving in the 1002 area. This result may suggest that if inadequate nutrition of the dam is the causative factor of perinatal mortality, this inadequacy occurs prior to her arrival on the coastal plain. If this is the case, one would expect perinatal mortality rate to vary independent of yearly concentrated calving area, and instead vary as a function of winter severity or the previous year's summer weight gain.

An analysis of the fates of all calves born to radio-collared cows 1983-91 indicates that post-perinatal mortality rates were significantly correlated with proportion of cows calving outside the 1002 area. In years when deep snow persisted into June (1987-88), and large numbers of cows were apparently inhibited from calving in the 1002 area, post-perinatal mortality of calves was greater than that measured in years of early snow melt (1983-85, 89-90). Our analysis of the causes of post-perinatal mortality indicated that predation was involved in a majority of deaths. Exact predator densities on the coastal plain and in foothills areas are currently unknown. If predator densities are found to be higher outside of the traditional concentrated calving area, this factor could account for the depression in post-perinatal calf survival that was observed when calves were born primarily in the peripheral area.

Although our samples of predator-killed calves were in good body condition, it is possible that nutritionally stressed calves may be behaviorally or otherwise predisposed to predation on the coastal plain or in the foothills. It is possible that nutritional attributes of the traditional calving area may positively influence post-perinatal survival. At this point, we do not have sufficient data to evaluate the relative contribution of predation and nutrition to post-perinatal mortality. The influence of poor nutrition during summer may extend to survival of calves over their first winter (Haukioja and Salovaara 1978), and to the ability of adult females to conceive during the rut (Cameron et al. 1992). Thus, the risk of predation may be more temporally specific than the cumulative effects of poor nutrition, which may be manifested at a later point.

Although the exact, causative mechanisms are currently unknown, the relationship between post-perinatal mortality rate and calving area that was observed in this study suggests that displacement from the traditional coastal plain calving area to areas south and east has the potential to decrease survival rates of calves.

MANAGEMENT IMPLICATIONS

The 1002 area east of the Hulahula River is consistently used by calving PCH females and their offspring throughout June and July. When a greater proportion of PCH females use areas within the 1002 boundaries during calving, post-perinatal calf survival is higher than when cows calve elsewhere. The relative importance of maternal nutrition and predation, and their interaction, on the survival rates of calves is unknown. In the CAH, females that are heavier in the fall are more likely to conceive, calve earlier, and produce a viable calf (Cameron et al. 1992). This suggests that the quantity and quality of forage obtained by PCH females during the entire calving and post-calving period is likely to have a significant effect on their ability to gain weight during the summer, and to produce a viable calf the following year. In addition, although most calves killed by predators in this study were in good condition, calves born in poorer condition may be predisposed to predation, thus exacerbating the effects of poor maternal nutrition on calf survival. Therefore, studies investigating the link between calving and post-calving habitat use, weight gain, and future reproductive performance are recommended.

In addition, predator densities in the study area and rates of predation by individual bears, wolves (*Canis lupus*), and golden eagles (*Aquila chrysaetos*) on caribou are necessary to estimate the potential amount of change in calf survival rates if caribou are displaced from the traditional calving area, and the effect on the population as a whole.

Preliminary studies indicate that the historical concentrated calving area has higher quality and quantity of caribou forage than adjacent areas (Jorgenson and Udevitz 1992). In early June of 1990, the historic concentrated area had significantly higher biomass of *Eriophorum vaginatum*, an important forage species. In late June, the concentrated area had significantly higher biomass of another forage species, (*Salix planifolia*). In the full flower stage, *E. vaginatum* flowers in the concentrated area had significantly higher concentrations of nitrogen and phosphorus and lower concentrations of fiber (Jorgenson and Udevitz 1992). The rate of phenological development in the historical and 1990 concentrated calving area was slightly less than in the peripheral area. More information is needed on quantity and quality of these and other forage species in the traditional calving area versus peripheral areas.

Monitoring marked individuals to determine calving distribution and calf mortality rates during June should continue. This information will allow us to continue to evaluate the relationship between mortality rate and number of cows calving in the 1002 area, and to detect any future decline in parturition rate which may occur as the herd reaches carrying capacity.

Management plans for petroleum production in the 1002 area should acknowledge the value of the traditional calving area between the Hulahula and the Aichilik Rivers. Because studies of the adjacent CAH have shown that maternal females and calves tend to avoid areas of high human activity, including road and pipeline corridors (Dau and Cameron 1986), any petroleum development in the 1002 area should proceed cautiously. Use of the traditional calving areas within the 1002 boundaries may enhance population growth by offsetting years of naturally low calf production or survival. These types of questions are currently being addressed through simulation modelling of PCH population dynamics.

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TERRESTRIAL RESEARCH

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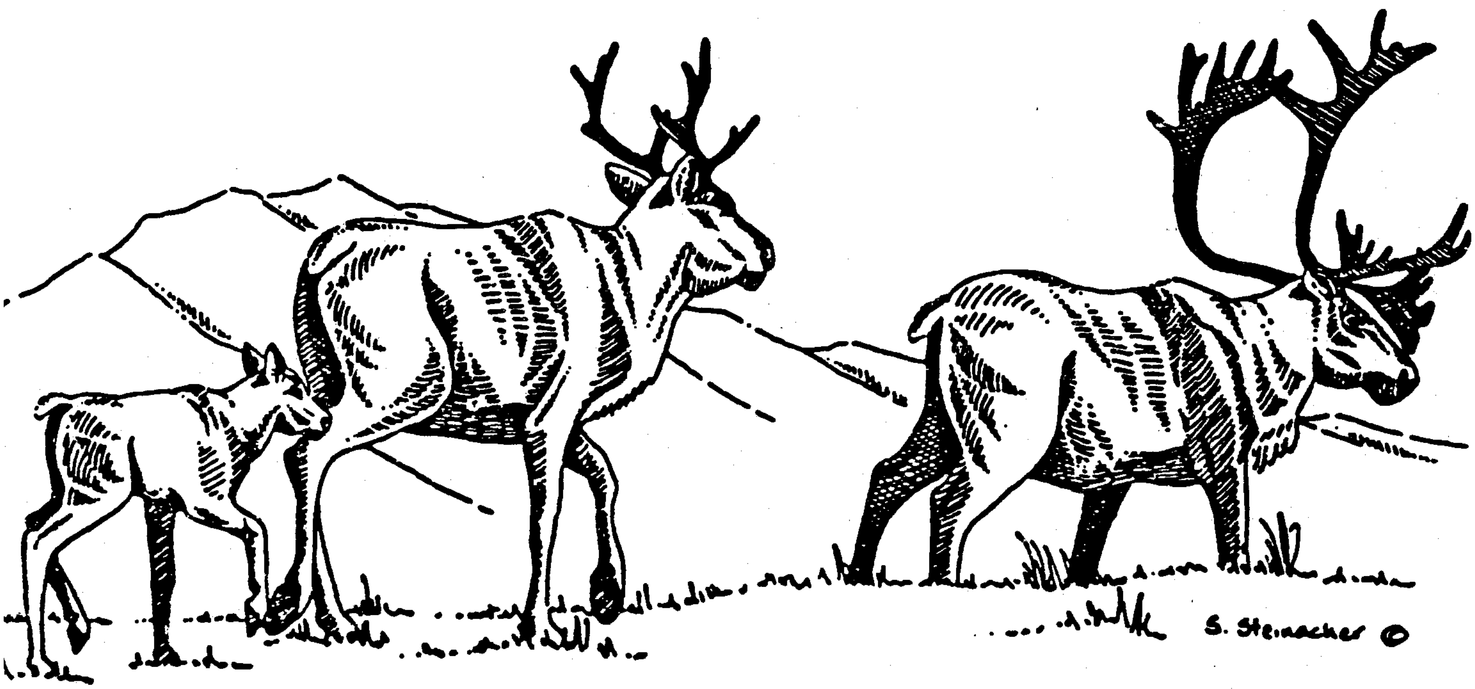

Interim Report - 1988-1990

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

RESEARCH ON THE POTENTIAL EFFECTS OF PETROLEUM DEVELOPMENT ON WILDLIFE AND THEIR HABITAT, ARCTIC NATIONAL WILDLIFE REFUGE

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