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## PRODUCTIVITY AND EARLY CALF SURVIVAL IN THE PORCUPINE CARIBOU HERD

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Abstract: Concerns have been raised that displacement from traditional calving and postcalving areas by petroleum exploration may cause increased calf mortality in the Porcupine Caribou (*Rangifer tarandus*) Herd. Consequently, we determined productivity and early calf survival by frequently locating 23–53 radio-collared cows and 59–61 radio-collared calves from 1983 to 1985. Seventy-nine to 87% of the adult females gave birth each year, and 68–90% of calves were born within, or adjacent to, a coastal plain area proposed for petroleum leasing and development. Sixteen to 35% of the calves died by 25 June. Fifty-nine to 74% of calf mortality occurred within 48 hours of birth and involved a number of causes in addition to predation. Predation was the major cause of death after the first 48 hours, and mortality increased toward higher terrain away from the coastal plain. Additional data from carcasses of unmarked calves corroborated the trends noted for radio-collared cows and calves. We conclude that if petroleum development displaces calving from the coastal plain, calf mortality likely will increase.

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The coastal plain portion of the Arctic National Wildlife Refuge has long been recognized as important calving and postcalving habitat for the Porcupine Caribou Herd (Skoog 1968, Hemming 1971), which numbered 178,000 animals in 1989. In 1980, approximately 600,000 ha of the coastal plain of the refuge were opened to limited oil and gas exploration, which indicated a potential for significant petroleum resources (Clough et al. 1987).

The southeastern portion of the area being considered for petroleum development (Fig. 1) has supported calving densities exceeding 20 caribou/km<sup>2</sup> in all but 2 years since surveys began in 1972 (Garner and Reynolds 1986; Clough et al. 1987; K. R. Whitten, Alas. Dep. Fish and Game, Fairbanks, unpubl. data). Such traditional calving areas are thought to provide better survival for young calves than other portions of the range (Bergerud 1974, Fleck and Gunn 1982, Cameron 1983). Caribou cows with young calves are sensitive to disturbance associated with human activity (de Vos 1960, Lent 1966, Bergerud 1974, Cameron 1983) and have avoided oil field developments and the Trans-Alaska Pipeline corridor in northern Alaska (Whitten and Cameron 1983, 1985; Dau and Cameron 1986). Thus, there is concern that displacement from traditional calving and postcalving areas may cause increased calf mortality and a population decline in the Porcupine Herd (Elison et al. 1986, Clough et al. 1987).

Our objectives were to estimate current rates of calf production and survival in the Porcupine Herd, and to test whether early calf survival differs between areas being considered for petroleum development and adjacent areas to which calving might be displaced.

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Fig. 1. General and intensive study areas in northern Alaska and adjacent Yukon Territory, 1983–85. Lands north and west of the 1002 boundary are being considered for petroleum leasing. A. Calving sites of radio-collared cows. B. Locations of radio-collared yearling, 2-year-old, and barren adult cows during peak of calving. Two birthsites and 8 barren cow locations within the intensive study area, and 2 birthsites and 76 barren cow locations outside the intensive study area were not mapped.

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#### STUDY AREA

The study area included all north-flowing drainages between the Canning River in Alaska and the Blow River in the Yukon Territory, Canada (Fig. 1). This area encompasses the "traditional" (as defined by Gunn and Miller 1986) calving grounds of the Porcupine Herd, where essentially all calving occurs every year. A smaller intensive study area was located in the Arctic National Wildlife Refuge north of approximately the 600 m contour level in the Brooks Range (Fig. 1). Mountains rise sharply at the southern edge of the intensive study area, about 60-80 km inland in the west, but only about 25 km inland in the east. Moderate to gentle relief foothills dominated by sheathed cottonsedge (Eriophorum vaginatum) tussocks lie north of the mountains; whereas nearly flat, marshy tundra extends along 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 description of the intensive study area is given by Garner and Reynolds (1986).

## METHODS Calving Distribution, Productivity, and Survival

Radio-collared cows captured on winter ranges were assumed to constitute a representative sample of females from the Porcupine Herd (Fancy et al. 1989). We monitored these cows during calving to determine if, when, and where calves were born, and whether those calves survived. Surveys began on 29 May 1983, 30 May 1984, and 23 May 1985, and continued until 25 June each year. After 25 June, caribou formed large, dense, and highly mobile aggregations; reliable visual data on calves of collared cows could no longer be obtained.

All radio-tracking was by fixed-wing aircraft, using standard telemetry techniques. A Piper PA-18 Super Cub was normally used, but collared caribou in more remote areas were occasionally located from a Cessna 185. Frequency of locations varied among individual caribou in relation to presumed pregnancy/parturition status, weather, and distance from the operations base in Kaktovik, Alaska.

We presumed cows with new velvet antler

growth were barren (Lent 1965, Skoog 1968, Bergerud 1976), but we relocated them after 7-10 days to confirm reproductive status. Females retaining hard antlers from the previous year were presumed to be parturient (Lent 1965, Skoog 1968, Bergerud 1976), as were those with any degree of udder distension (Bergerud 1964). Parturient females were relocated as frequently as possible to determine time and location of births. We assumed birth took place on the day a calf was first observed unless the mother had not been located for 1 or more days previously, in which case the birth was apportioned evenly among the intervening days. Presumed births (i.e., those based only on udder or antler condition of the cow) could not be dated and were not included in analyses.

Following parturition, we relocated cows at approximately 2-day intervals to monitor calf survival. Calf mortality was presumed whenever a cow known to have had a calf was later observed alone, but was always confirmed by at least 1 additional observation. Parturition and subsequent calf mortality also were presumed whenever a female showing signs of pregnancy (i.e., hard antlers or udder distension) was monitored through the calving period but never seen with a calf.

#### Spatial Variation in Calf Survival

We studied spatial variation in calf survival by placing radiocollars on newborn calves in the intensive study area. Each year calves were captured in the area with high petroleum potential and in adjacent foothills or coastal plain nearer the Canadian border (Fig. 2).

Calves were captured on foot from 4 to 8 June in 1983, 3 to 8 June in 1984, and 2 to 7 June in 1985 after using a helicopter to approach closely. Captured calves were weighed, sexed, measured (body contour length, hind foot length, and new hoof length), collared, and released in about 2–3 minutes each (Garner et al. 1985).

We aged calves using a combination of morphological characteristics (Miller et al. 1988) and new hoof growth measurements (Haugen and Speake 1958). Age calculated from new hoof growth assumed a new hoof length of 7.00 mm at birth (based on the mean measurement from 69 calves captured in 1983) and a growth rate of 0.68 mm/day (based on measurements from calves at the Univ. of Alas. in Fairbanks, 1983) (Whitten et al. 1984). When inconsistencies oc-



Fig. 2. Capture locations of collared calves, 1983–85. Dark areas represent capture sites within the area being considered for petroleum development; hatched areas represent peripheral capture sites.

curred between the 2 estimation methods, we based age on morphology (Miller et al. 1988). Ages were estimated to the nearest whole day.

Calf collars were equipped with motion-sensing "mortality" switches; after a 1-hour period with no movement, the signal rate doubled. Calves were monitored daily for mortality signals and located visually every 2 days, both to obtain location and movement data and to ensure that all deaths were rapidly detected even if agitation of the collar by predators or scavengers prevented the mortality switch from operating. We investigated mortality signals immediately, and sites were visited as soon as possible, usually within a few hours and never more than 24 hours after detection. Carcasses were collected for postmortem examination, and any signs of predation of scavenging were recorded. Cause of death was determined following methods described by Garner et al. (1985).

Carcasses of unmarked calves were aged, weighed, measured, and necropsied similar to those of collared calves. All unmarked carcasses came from the intensive study area, but the area never was searched thoroughly and carcasses were collected only when a helicopter was conveniently nearby. Because of these potential sampling biases, we used information from unmarked calf carcasses only to elaborate qualitatively on trends noted for collared calves or calves of collared cows.

#### Data Analysis

Depending on the type of data, we used Chisquare contingency analysis to test for differences in proportions, or *t*-tests for differences in means. When data did not meet the assumptions necessary for conducting *t*-tests, we used the nonparametric Wilcoxon 2-sample test. We used logistic regression (Lee 1980) to determine whether capture area, year, sex, or size (hind foot length and mass) were significant correlates of the fate of collared calves.

We also tested spatial variation in calf mortality by comparing latitude, longitude, and elevation of sites where calves died with sites where calves survived. Because of potential lack of independence in serial locations of individual calves, 1 location/calf was randomly selected for each population (survival or mortality), and the mean per population was calculated and then resampled with replacement in a bootstrap test (Efron 1982) for calf mortality. We considered *P*-values  $\leq 0.10$  to be significant rather than the more often used P < 0.05 because Type II errors would be more costly than Type I errors when our goal was to determine whether development poses a threat to a wildlife resource (Kempthorne 1979). We report actual *P*-values and provide biological justifications so readers can make their own judgments when  $0.05 \leq P \leq 0.10$ .

#### RESULTS

#### Distribution of Parturient versus Barren Cows

All radio-collared females used the traditional calving area during the calving period in 1983-85. Parturient females calved mainly in the intensive study area (Fig. 1A, Table 1). Barren cows tended to remain in mountainous areas south and east of the intensive study area or on the coastal plain in Canada (Fig. 1B, Table 1), and some did not arrive on the calving grounds until nearly 25 June. No yearling females were pregnant in any year, and only 1 2 year old gave birth (but the calf died within 24 hr); whereas 79-87% of the adult females were pregnant each year (Table 1). A higher proportion (67%;  $\chi^2$  = 66.1, 1 df, P < 0.0005) of adult cows (i.e.,  $\geq 3$ years old) than of yearlings and 2 year olds (13%)used the intensive study area in Alaska. Among adult cows, the parturition rate was higher (92%;  $\chi^2 = 15.53, 1 \text{ df}, P < 0.0005$ ) in the intensive study area than elsewhere (60%). Seventy-six percent of the births among collared cows occurred in the intensive study area (90%, 68%, and 74% in 1983, 1984, and 1985, respectively).

# Timing of Births and Temporal Patterns of Calf Mortality

Newborn calves were observed from 27 May to 24 June. Calving chronology was similar in all years, and 83–92% of the births occurred before 10 June.

Most early (perinatal) calf mortality occurred within 48 hours of birth. Among calves born to radio-collared cows, perinatal mortality was associated with 18–23% (range reflects uncertainty in timing of calf mortality due to gaps in relocation data) of births (n = 88) and 59–74% of deaths (n = 27) prior to 25 June. Perinatal mortality apparently was less common in the intensive study area (16–18% of births) than elsewhere (24–38% of births) (Table 1). If undetermined causes of deaths were assumed not

	Within intensive study area <sup>a</sup>						Outside intensive study area				
-	Barran	Porturiont	· · · · · · · · · · · · · · · · · · ·	Calf deaths		Barren	Parturiant	Calf deaths			
	females	females	<48 hr	>48 hr	Total	females	females	<48 hr	>48 hr	Total	
Yearlings											
1983	5	0	0	0	0	28	0	0	0	0	
1984	0	0	0	0	0	14	0	0	0	0	
1985	3	0	0	0	0	14	0	0	0	0	
Total	8	0	0	0	0	56	0	0	0	0	
2 yr olds											
1983	1	0	0	0	0	5	0	0	0	0	
1984	3	0	0	0	0	25	0	0	0	0	
1985	1	1	1	0	1	8	0	0	0	0	
Total	5	1	1	0	1	38	0	0	0	0	
3+ yr olds											
1983	2	18	3 - 4	2 - 3	6	1	2	0-1	0-1	1	
1984	1	17	0	2	2	5	8	2	0	2	
1985	3	31	7	3	10	8	11	3-5	0-2	5	
Total	6	66	10-11	7-8	18	14	21	5 - 8	0–3	8	

Table 1. Distribution and productivity of radio-collared cows, and calf mortality from birth through 25 June 1983–85, Porcupine Caribou Herd, northeastern Alaska and adjacent Yukon Territory.

<sup>a</sup> The proportion of  $\geq$ 3-year-old females and the parturition rate among  $\geq$ 3-year-old females were higher (Chi-square tests, *P* < 0.005) within the intensive study area. If the higher estimates for <48-hour calf deaths are used, the <48-hour death rate was lower (Chi-square test, *P* = 0.054) in the intensive study area.

to be perinatal, the perinatal mortality rate in the intensive study area was not different ( $\chi^2 = 0.59$ , 1 df, P = 0.44), but if all these deaths were assumed to be perinatal, the rates differed ( $\chi^2 = 3.71$ , 1 df, P = 0.054).

Late-born calves experienced higher ( $\chi^2 = 4.39$ , 1 df, P = 0.036) mortality than calves born during or before the peak calving period; 4 of 8 calves born after 10 June died, versus 12 of 67 (19%) born on or before 10 June. Three of the late-born calves were perinatal mortalities, and 1 died within 3 days.

#### **Overall Calf Survival Rates**

Because yearling and 2-year-old females made essentially no contribution to calf production, calf survival rates were calculated for adult cows only. Survival rates through 25 June were 65% in 1983, 84% in 1984, and 65% in 1985 (Table 2). For the combined sample, survival was 70%.

### Adjustment of Collared Calf Data for Suspected Capture-induced Mortality

Fifty-six of 212 (26%) calves were separated from their mothers during capture; 26 (12%) remained apart for up to several hours but eventually were reunited. Nevertheless, 28 calves (13%) were permanently abandoned during or shortly after capture, and 2 more (1%) were dead the day after capture before it could be determined if they had rejoined their mothers. Nineteen of the permanently abandoned calves remained separated from the time of capture; 3 were separated at capture, joined a cow several hours later, and were subsequently abandoned permanently; and 6 stayed with their mothers for several hours after capture before being abandoned. No calf that was alone the day after capture ever reunited with its mother, and all permanently abandoned calves died; 4 were killed by predators, 20 died of exposure and/or starvation, and 4 were sacrificed, which also allowed their collars to be reused. No doubt some natural abandonment of neonates occurred, but we could not distinguish it from capture-induced abandonment. Therefore, the 30 calves that were either dead or had not reunited with a cow by the day after capture were eliminated from further analyses. Abandoned calves did not differ from other collared calves in sex ( $\chi^2$  = 0.54, 2 df, P = 0.76), mass (t = 1.30, 206 df, P= 0.20), or length (t = 1.38, 207 df, P = 0.17), but were younger (Wilcoxon 2-sample test, Z =-1.69, P = 0.09) and had shorter hind feet (t = 2.11, 209 df, P = 0.04) (Table 3).

#### Age and Sex Composition of Collared Calves

Calves were captured during the peak calving period each year when they would have been

			Calves of colla	ared cows				
	Dea	ths					Collared calve	s <sup>a</sup>
	<48 hr <sup>b</sup>	>48 hr	Births	Мо	ortality rate <sup>c</sup>	Deaths	No. captured	Mortality
Yr	(A)	(B)	(C)	Overall	>48 hr	(D)	(E)	rated
1983	3–5	2-4	20	0.350	0.765-0.867	5	59	0.085
1984	2	2	25	0.160	0.087	5	61	0.082
1985	10 - 12	3–5	42	0.349	0.100-0.156	9	62	0.145

Table 2. Comparison of mortality rates among collared calves versus calves of collared adult cows in the Porcupine Caribou Herd from birth through 25 June 1983–85, northeastern Alaska and adjacent Yukon Territory.

<sup>a</sup> Possible capture-induced mortalities excluded.

<sup>b</sup> Also includes 1 calf born after 10 June in 1983 which lived <72 hours.

 $^{c}$  Overall mortality rate is (column Å + column B)/column C; >48-hour mortality rate is column B/(column C - column A).

<sup>d</sup> Mortality rate is column D/column E.

<7 days old and mostly <3 days old. Mean estimated ages of captured calves (excluding abandoned calves) were similar in all years (2.7 days in 1983, 2.0 days in 1984, and 2.5 days in 1985). Sex composition (Table 3) also was similar in all years ( $\chi^2 = 1.67$ , 2 df, P = 0.43) and did not differ (1983:  $\chi^2 = 0.44$ , 1 df, P = 0.51; 1984:  $\chi^2 = 1.33$ , 1 df, P = 0.25; 1985:  $\chi^2 = 0.26$ , 1 df, P = 0.61) from unity.

#### Survival of Collared Calves

Our univariate logistic regression analyses indicated that survival of collared calves through 25 June did not vary with capture area ( $\chi^2 =$ 0.46, 1 df, P = 0.50), year ( $\chi^2 = 1.45$ , 2 df, P =0.48), sex ( $\chi^2 = 0.04$ , 1 df, P = 0.85), body contour length ( $\chi^2 = 0.12$ , 1 df, P = 0.74), hind foot length ( $\chi^2 = 1.97$ , 1 df, P = 0.16), or mass ( $\chi^2 = 1.04$ , 1 df, P = 0.31). Survival rates for sexes combined were 92% in 1983, 92% in 1984, and 85% in 1985 (Table 2). The overall survival estimate for the pooled data set was 90%. Mortality was highest shortly after capture and gradually decreased through time in 1983 and 1984, but remained fairly constant through June in 1985.

Six of 20 (30%) intact carcasses of unmarked calves weighed  $\leq 5$  kg, compared with 4 of 207 (2%) that were captured, collared, and weighed (Whitten et al. 1984, 1985, 1987). The unmarked calves of low birth-mass all died at  $\leq 2$ days, and none were killed by predators. Therefore, smaller body measurements may have been associated with perinatal deaths, which were effectively excluded from the collared calf sample. Of the 4 collared calves that had masses <5kg at capture, none were apparent capture mortalities, but 2 died during June, and 1 died in late July or August. Only 1 survived >1 year. Therefore, even among calves that survived the perinatal period, those with the lowest birth masses had higher mortality.

#### Causes of Calf Mortality

Both perinatal and non-perinatal mortality involved a number of causes besides predation by golden eagles (Aquila chrysaetos), grizzly bears (Ursus arctos), and wolves (Canis lupus). Because of the small sample of calves of radiocollared cows for which cause of death was known and because of the potential biases in the unmarked calf carcass data, the contribution of predation to perinatal mortality was difficult to assess. However, it appeared that predation was not the predominant cause of perinatal mortality (Table 4). Data from radio-collared calves indicated that predation was the primary cause of non-perinatal mortality, and this was corroborated by the unmarked calf carcass collection (Table 4).

Deaths in which predation was judged not to be a factor (n = 26 in Table 4) involved mostly intact carcasses, although 9 (8 perinatal and 1 non-perinatal) suffered minor scavenging by glaucous gulls (*Larus hyperboreus*) or jaegers (*Stercorarius* spp.). Most deaths attributed to predators (38/41) showed signs of bleeding or hemorrhaging around wounds, and in many instances the predator was observed. One perinatal calf killed by an eagle was made susceptible to capture by a broken leg. Some carcasses of animals killed by predators also were scavenged by other species.

#### Spatial Variation in Calf Survival

There was no relationship between calf survival and longitude (P = 0.45) within the intensive study area. However, sites where col-

				Fem	iales					Ma	les		
		Liv	eda	Di	eda	Aband	loned <sup>b</sup>	Liv	eda	Di	da	Aband	oned <sup>b</sup>
	Yr	¥	SE	£	SE	£	SE	Ŧ	SE	4	SE	Ŧ	SE
Mass (kg)	1983	6.6	0.16	7.7	0.52	6.4	0.50	7.4	0.19	6.3	1.40	6.9	0.85
ò	1984	6.7	0.18	6.7	0.64	6.6	0.31	7.3	0.22	5.6	1.50	6.8	0.28
	1985	7.3	0.20	7.1	0.70	8.9	0.00	7.7	0.23	7.1	0.41	7.9	0.72
Hind foot length	1983	33.5	0.33	34.5	1.26	32.8	0.33	34.0	0.24	33.0	3.00	32.8	0.47
(cm)	1984	33.6	0.26	33.8	0.88	33.2	0.60	34.3	0.28	31.8	1.75	33.7	0.49
	1985	34.2	0.33	33.7	0.33	34.5	0.00	34.8	0.22	33.7	0.51	34.7	1.45
Body contour	1983	80.4	0.92	82.3	2.91	79.8	1.14	81.0	0.85	80.5	5.50	77.0	2.65
length (cm)	1984	80.2	0.94	80.5	3.50	81.0	2.02	82.8	0.84	75.5	4.50	80.8	1.31
) D	1985	86.4	1.19	83.7	2.91	92.0	0.00	86.3	1.17	85.3	2.92	87.7	2.84
Age (davs)	1983	2.6	0.18	3.7	0.33	1.8	0.40	2.8	0.24	2.0	1.00	2.5	0.50
0	1984	2.0	0.22	2.0	0.38	1.8	0.31	2.0	0.16	1.5	0.50	1.7	0.30
	1985	2.6	0.18	2.0	0.00	3.0	0.00	2.4	0.19	2.5	0.28	2.7	0.33
Sample size	1983	28		3		9		24		61		4	
	1984	23		З		9		33		63		10	
	1985	26		3		I		27		9		c	

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	Perinatal	(<48 hr)	Non-perinatal (>48 hr-25 Jun)		
Cause of mortality	Calves of collared cows	Unmarked calf carcasses	Calves of collared cows	Collared calves	Unmarked calf carcasses
Predation					
Eagles		6	2	7	8
Bears		5		2	2
Wolves		2		2	2
Uncertain				2	1
Nonpredation					
Exposure	1				
Starvation/pneumonia	1	3			2
Disease		3		1	
Stillbirth		2			
Trampling		1			
Drowning				1	
Uncertain		6		4	1
Mortality rate	18-23%	N/A	8-12%	10%	N/A

Table 4. Causes of calf mortality for the Porcupine Caribou Herd from birth through 25 June 1983-85, coastal plain of the Arctic National Wildlife Refuge, Alaska.

lared calves died were farther south (i.e., toward the mountains; P = 0.10) and thus at higher elevations (P = 0.07) than sites used by surviving calves. Sites where death occurred by predation tended to be higher than other death sites, but the difference was not significant (t = 1.23, 17 df, P = 0.24) (Table 5).

Supplementary information from unmarked calves corroborated the relationship between elevation and calf mortality. Carcasses showing signs of predation tended to occur in higher terrain ( $\bar{x} = 236.9$  m, n = 26); whereas deaths in which predation was not involved tended to be at lower elevations ( $\bar{x} = 182.3$  m, n = 16). Deaths attributed to predators among calves born to collared cows occurred at 171 m and 304 m, while non-predation deaths were at 100 m and 195 m.

### DISCUSSION

About 75% of the calves in the Porcupine Herd were born in the intensive study area during 1983–85. This area comprises only about 25% of the overall area used for calving. Long-term records indicate that high-density calving occurs regularly in this same vicinity (Garner and Reynolds 1986).

For a number of reasons, calf mortality calculated from the disappearance of calves from collared cows was higher than for collared calves (Table 2). Most deaths among calves born to collared cows occurred within 48 hours of birth. Thus, some mortality had undoubtedly occurred before we began capturing calves, and the further elimination of collared calves that survived <24 hours effectively removed any perinatal mortality from the collared calf data set. Ozoga and Clute (1988) similarly concluded that mortality of white-tailed deer (Odocoileus virginianus) fawns was underestimated when based on collared fawn samples alone in a population where many fawns died at <48 hours old and before they could be captured. Our sample of collared calves did not include late-born calves,

Table 5. Mean elevations (m) of live locations and death sites of collared calves in the intensive study area, Arctic National Wildlife Refuge, Alaska, June 1983–85.

			Death sites	
	Live locations	Nonpredation	Predation	All
Mean elevation (m) <sup>a</sup>	238.5 <sup>b</sup>	235.2	380.6	334.7
SE°	10.9	78.3	71.5	55.9
Sample size	$179^{d}$	6	13	19

<sup>a</sup> A mean elevation was calculated for each animal, then all animals were averaged.

<sup>b</sup> Differed (*t*-test, P < 0.10) from death sites.

<sup>c</sup> SE among animals, i.e., using the average for each animal. <sup>d</sup> Includes locations for calves that died later.

<sup>a</sup> Includes locations for calves that died later

which had a high mortality rate in the collared cow sample.

When the data from collared cows were adjusted to exclude perinatal deaths, the resulting mortality rates were more similar to the data from collared calves (Table 2). The 2 data sets still are not directly comparable because the collared cow data reflect conditions over the entire calving area; whereas the collared calves came only from the most heavily used portion. Nevertheless, the similarity suggests that when capture-induced abandonment was taken into account, collared calves were not further predisposed to mortality compared with unmarked calves. All captures were within the high-density calving area, and all collared calves remained within that area throughout our study period each year. We therefore conclude that while the collared calf data may not necessarily reflect overall population productivity and survival, they are representative of non-perinatal calf mortality patterns in the intensive study area.

Tracking records for collared cows indicate that little movement occurs for several days after calves are born (Fancy et al. 1989). Thus, capture sites for collared calves, which were mostly <3 days old when captured, were likely near actual birth sites. There were no clear differences in non-perinatal mortality based on where calves were born. However, annual sample sizes of calves captured in the potential leasing area versus peripheral habitats were inadequate to detect small differences, and extensive movements of cows and calves during mid- and late June resulted in redistribution of study animals such that the capture groups did not remain separate and distinct. The effect of birth location on mortality was therefore modified by where calves moved after birth, and mortality sites for collared calves were farther south and higher in elevation than locations where calves survived. Data from unmarked calf carcasses and from the calves of collared cows showed similar relationships between elevation and predator-related mortality. These elevated areas provide better year-round habitat for predators, as well as alternative prey resources, such as moose (Alces alces), Dall's sheep (Ovis dalli), Arctic ground squirrels (Spermophilus parryii), and ptarmigan (Lagopus spp.) (Garner and Reynolds 1986). Thus, as calves either remained in or moved to higher terrain, they were exposed to more predators, the chief mortality factor after the first 24-48 hours of life.

Perinatal mortality also appeared to be higher outside the historic high-density calving area, although uncertainty in timing of some deaths makes this result somewhat tenuous. Perinatal mortality in the intensive study area included a high proportion of deaths not attributed to predation, and that may have been related to maternal condition. Barren females, females in poor condition, and first time breeders tend to lag behind healthier and more experienced cows in migrations toward calving areas (Skoog 1968, Parker 1972), and young or unhealthy mothers may produce nonviable calves (Verme and Ullrey 1984). Therefore, at least some of the higher perinatal mortality in areas removed from the high-density calving area may have been due to inherent attributes of the females that went there.

In addition, the relative abundance of predators outside or peripheral to the historic highdensity calving area, which affected non-perinatal mortality, also could have affected perinatal mortality. Newborn calves are relatively helpless and unable to outrun predators. Barren-ground caribou calves <3 days old were over 3 times more likely to die than were calves 4-7 days old in the Beverly Herd in Canada, and most of the mortality there was from wolf predation (Miller et al. 1985, 1988). Wolves sometimes killed young calves in greater numbers than what was actually consumed. Bears also were more successful at killing calves <3days old in Denali National Park in Alaska (Adams et al. 1988). Multiple kills of newborn calves by both wolves and bears have been observed in this and other studies on the calving grounds of the Porcupine Herd (K. Whitten, Alas. Dep. Fish and Game, Fairbanks, pers. observ.). Golden eagle densities on some winter ranges have increased in response to prey abundance (Craig et al. 1984), suggesting that nonbreeding birds could potentially be attracted to high numbers of calves displaced from the coastal plain. Because young calves may be particularly vulnerable to surplus killing, calf mortality may rise disproportionately to predator abundance where high densities of neonatal calves and predators coincide.

#### MANAGEMENT IMPLICATIONS

Most calving occurred in a small portion of the overall calving range. Calf mortality was low in the low-elevation, low-relief coastal plain portion of the high-density calving area that may be opened to petroleum development. Uncertainties regarding the timing, location, and amount of development make it difficult to predict what the effects on caribou might be. Nevertheless, available data are sufficient to predict that, if displacement of calving onto higher terrain to the south and east resulted from development, calves would be exposed to more predators and increased mortality.

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# POPULATION REDUCTIONS AND GENETIC VARIABILITY IN BLACK-TAILED PRAIRIE DOGS

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Abstract: Black-tailed prairie dogs (Cynomys ludovicianus) have been subjected to intense population reduction efforts over much of their range, often resulting in scattered, remnant colonies, and possibly resulting in altered genetic characteristics. Consequently, I examined the relationships between population size reductions and the amount of genetic variability in black-tailed prairie dogs at Wind Cave National Park, South Dakota, where a wide range of colony sizes and past management histories existed. Blood samples were collected from 377 prairie dogs at 8 colonies, and were analyzed using starch-gel electrophoresis. Colonies varied in size from <20 individuals, at colonies that had been through recent population bottlenecks as the result of control efforts, to thousands of individuals at colonies that were relatively unmanaged. Mean heterozygosity values within populations ranged from 0.027 to 0.040, but showed no relationship to the severity of recent population reduction. Allele frequencies at all loci were heterogeneous among colonies and  $F_{sT}$  (fixation index) values were moderate to high (mean  $F_{sT}$  = 0.115), indicating moderate to high levels of genetic differentiation among colonies. Genetic divergence was as much as 4 times greater among colonies that had undergone recent population bottlenecks than among colonies that were relatively unmanaged. Current prairie dog management practices at Wind Cave National Park were not found to decrease the level of genetic variability in prairie dog populations, probably because of rapid recovery from low population sizes and occasional successful immigration.

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Black-tailed prairie dogs are indigenous to North American shortgrass prairies, originally occurring in large colonies that often contained millions of individuals (Clark 1979). Due to putative, but questionable (Coppack et al. 1983), interference with ranching and agricultural practices, prairie dogs have been eliminated from large portions of their original range (Koford 1958). On some state and federal lands, attempts to reduce black-tailed prairie dog populations to manageable levels, while still maintaining viable populations, have resulted in scattered, remnant colonies (e.g., Issue identification for prairie dog manage.: Nebr. Natl. For. and related range manage. in Conata Basin and Scenic Basin: Buffalo Gap Natl. Grassland, unpubl. rep., For. Serv., Chadron, Nebr., 1986). These colonies are smaller and more isolated than natural populations, and therefore may have altered genetic characteristics.

During the 1920's and 1930's, the U.S. Bureau of Biological Survey and local ranchers conducted wide-scale shooting and poisoning operations with the goal of complete extermination of prairie dogs from the area that now comprises

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