Effects of a road system on caribou distribution during calving

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Abstract: In winter 1981 - 82, a 29-km road system was built in a high-use caribou (*Rangifer tarandus granti*) calving area near Milne Point, Alaska. Aerial surveys of this area were conducted annually during the calving period for 4 years before and 4 years after road construction. Effects of the road system on the distribution of caribou were investigated by comparing survey data obtained during these two periods. The 41 400-ha study area was partitioned into 40 quadrats; after construction (1982 - 85), significantly fewer caribou were observed within quadrats encompassing the present road system than before construction (1978 - 81). The area within 6 km of the road system was stratified into six 1-km intervals, and differences in the distribution of caribou among those strata were examined using linear regression analysis. After construction, the density of maternal females was positively correlated with distance, whereas no such relationship was apparent before construction. Density of nonmaternal adults was unrelated to distance during both periods. The results suggest that a local displacement of maternal caribou has occurred in response to roads and associated human activity.

Key words: caribou, calving, roads, disturbance.

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Introduction

The Central Arctic Herd (CAH) is a distinct subpopulation of ca. 13 000 caribou (*Rangifer tarandus granti*) (as of 1983; W. Smith, unpublished data) that ranges the Arctic Slope of Alaska between the Canning and Colville Rivers. Seasonal movements are principally north-south between wintering areas in the Brooks Range and calving grounds/summer range on the Arctic Coastal Plain (Cameron and Whitten, 1979).

In winter 1981 - 82, CONOCO, Inc. built 29 km of gravel road as the initial phase of petroleum development within the Milne Point Production Unit (Fig. 1). This complex is approximately centered on one of two known CAH calving concentration areas (Whitten and Cameron, 1985). In winter 1984 - 85, a single pipeline 35 cm in diameter and approximately 1.8 m above ground was erected adjacent to the Milne Point Road, and a 300-person housing facility was constructed. Human activity and traffic levels near Milne Point were low in June 1983 and 1984 (<10 vehicles per day; 1 active drill rig), moderate in 1982 (10 - 100 vehicles per day; 2 active drill rigs), and high in 1985 (>200 vehicles per day; 3 active drill rigs).

The objective of this study was to determine the effects of roads and associated activity on the local distribution of caribou, especially maternal females, in this high-use calving area. We compared the distribution of caribou within this region during the four years before construction of the road system (1978 - 81) with that during the four years after construction (1982 - 85).

Methods

The study area is ca. 45 km northwest of Prudhoe Bay, lying north of the West Sak Road between the Oliktok Road and Kuparuk River

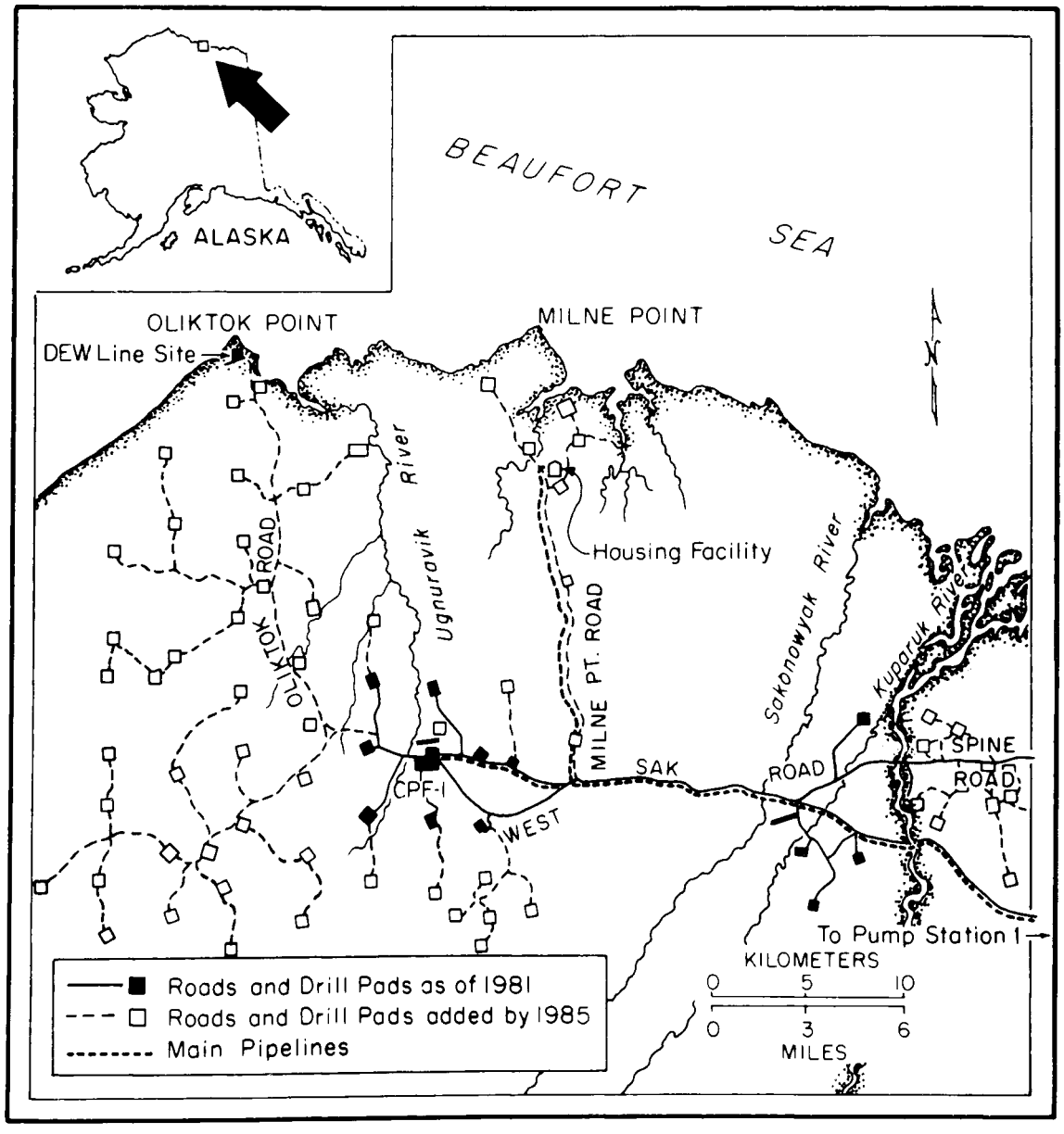

Fig. 1. The Milne Point study area and surrounding region, with roads and gravel pads as of 1981 and 1985.

(Fig. 1). Terrain ranges from sea level to 25 m elevation. Vegetation is typical of the Arctic Coastal Plain (Wahrhaftig, 1965) and similar to that described for the Prudhoe Bay region (Neiland and Hok, 1975; Webber and Walker, 1975).

Aerial surveys of the study area (Whitten and Cameron, 1985; Cameron *et al.*, 1985) were conducted annually between 10 and 14 June 1978 - 85, within a few days after the majority of CAH calving had occurred. North-south strip transects spaced at 3.2 km were flown by helicopter, and observers searched within 1.6 km of the transect center line. For each group of caribou observed, we recorded map location, group size, and sex/age composition.

The study area was partitioned into 40 quadrats of 1036 ha each (Fig. 2). Median percentages of caribou observed within the seven quadrats that include the present road system (i.e., «road quadrats») were compared between the pre- and postconstruction periods using the

Mann-Whitney test; the Z test statistic is reported when ranks were tied (Conover, 1980).

The area within 6 km of the present roads was then stratified into six 1-km distance intervals, excluding portions of strata that were closer to the West Sak Road (Fig. 1), and the data were examined to determine whether the assumptions for linear regression analysis were satisfied (Neter and Wasserman, 1974). Square root transformations eliminated the correlations between means and variances of caribou density within strata. Linear regressions describing caribou density as a function of distance from roads were fit using the full and reduced model approach (Neter and Wasserman, 1974) to examine differences within and between the two four-year periods. Linear models for 1978 - 81 and 1982 - 85 were fit simultaneously and compared through analysis of variance (ANOVA).

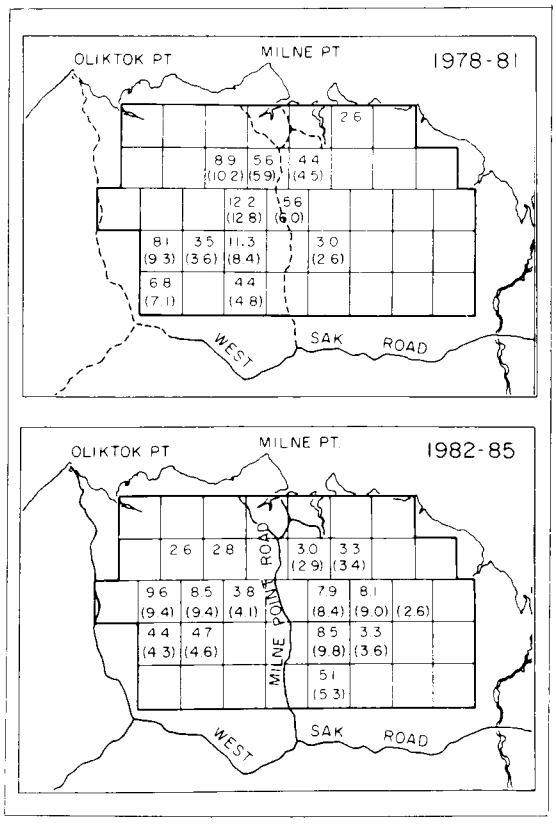

Fig. 2. Distribution of 1036-ha quadrats in the study area (see Fig. 1) preferred by caribou (calves, in parentheses) during calving, 1978 - 81 and 1982 - 85. The occurrence of caribou is expressed as a percentage of the total observed in all 40 quadrats; only those percentages exceeding 2.5% (the percentage of the total area for each quadrat) are shown.

During the surveys, we did not distinguish between maternal and nonmaternal females. Therefore, to describe the distribution of maternal females, the above analyses based on total number of caribou were repeated using number of calves (i.e., neonates). In addition, stratification and ANOVA were used to compare the responses of maternal groups (i.e., $\geq$25% calves) and nonmaternal groups (i.e., <25% calves) to roads. It should be noted that the latter is an *a posteriori* analysis, and the results should not be granted the same level of objectivity as other results presented here.

All statistical operations were performed using a Compaq Deskpro computer system and SPSS/PC statistical software (Norusis, 1984). Alpha levels (P-values) $\leq$0.05 were considered statistically significant.

Results

Fewer caribou were near the present road system after construction than before construction. The median percentage of caribou in the seven road quadrats was significantly different between 1978 - 81 and 1982 - 85 (8.5 vs. 2.0%, T = 26.0, P = 0.03). Before construction, 17% of all caribou observed in the study area (465 of 2806) were within these seven quadrats, compared with only 2% (90 of 5424) after construction.

Differences between periods for calves were not clear. Even though the median percentage of calves in the road quadrats was higher during 1978 - 81 (10.5%) than during 1982 - 85 (0.0%), the difference was not statistically significant (z = -1.69, P = 0.09). However, the disparity between pre- and postconstruction periods in the percentage of all calves observed in the seven quadrats was greater than that for all caribou. Before construction, 17% of all calves observed (190 of 1150) were within these quadrats, compared with <1% (6 of 2339) after road construction.

Linear relationships between caribou density and distance from roads were significantly different between 1978 - 81 and 1982 - 85 for all caribou, and for calves (Table 1). The annual variability in these relationships within each four-year period was not significant for all

caribou, but was nearly significant for calves (P = 0.053). The latter may have resulted from yearly differences in levels of human activity in the study area after 1981. Nevertheless, differences in these relationships were greater between periods than among years within periods (Table 1).

During 1978 - 81, there was no detectable linear relationship between the density of either total number of caribou or number of calves, and distance from roads. In 1982 - 85, however, both density parameters were correlated with distance (Fig. 3). This further suggests that the between-period difference in the relationship between calf density and distance (see above) was real and not attributable to within-period variation.

The similar results obtained for total number of all caribou and number of calves (Fig. 3) indicate that the distribution of maternal caribou was not appreciably different from the distribution of all caribou. This is not surprising considering that most adult (≥2 years) caribou in the study area during June were maternal females (minimum mean = 69%; SD = 15).

The relationships between number of maternal groups per km^2 and distance from roads differed significantly between 1978 - 81 and 1982 - 85, a difference that cannot be attributed to within-period variability (Table 2). No such difference was found for nonmaternal groups, either between or within the pre- and postconstruction periods. Furthermore, there was no linear correlation between the number of maternal or nonmaternal groups per km^2 and distance during 1978 - 81; nor was there any correlation for nonmaternal groups during 1982 - 85. In 1982 - 85, however, the number of maternal groups per

Table 1. Analysis of variance examination of the relationships between numbers of all caribou, and calves, per km^2, and distance from roads, Milne Point, Alaska, June 1978 - 85.

Density parameter	Model[a]	Source of variability	Sums of squares	df	Mean square	F	P	Entering F value	P
All caribou		Total	25.26	47					
	Basic[b]	Regression	3.43	1	3.43	7.23	0.01	7.23	0.01
		Error	21.83	46	0.47				
	Reduced[c]	Regression	8.84	3	2.95	7.89	<0.01	7.24	<0.01
		Error	16.42	44	0.37				
	Full[d]	Regression	15.69	15	1.05	3.50	<0.01	1.91	0.07
		Error	9.56	32	0.30				
	Test[e]	Periods	8.84	3	2.95	5.15	0.02		
		Years/Periods	6.86	12	0.57				
Calves		Total	14.63	47					
	Basic[b]	Regression	2.07	1	2.07	7.58	<0.01	7.58	<0.01
		Error	12.56	46	0.27				
	Reduced[c]	Regression	5.38	3	1.79	8.51	<0.01	7.85	<0.01
		Error	9.26	44	0.21				
	Full[d]	Regression	9.40	15	0.63	3.83	<0.01	2.05	0.05
		Error	5.24	32	0.16				
	Test[e]	Periods	5.38	3	1.79	5.35	0.02		
		Years/Periods	4.02	12	0.34				

[a] Each model tests simple linear relationship(s), where the dependent variable is the square root of caribou density (numbers/km^2) and the independent variable is distance from the road site (km).

[b] Fits a linear model with data pooled across all years; H_0: the eight relationships are not significantly different. The Entering F value tests for the significance of this model beyond the significance of the Basic model.

[c] Fits a separate linear model for each period; H_0: the two relationships are not significantly different. The Entering F value tests for the significance of this model beyond the significance of the Basic model.

[d] Fits a separate linear model for each year within each period; H_0: the four relationships are not significantly different. The Entering F value tests for the significance of this model beyond the significance of the Reduced model.

[e] Tests H_0: the variation in linear models between periods is not significantly greater than the variation in linear models among years within each period.

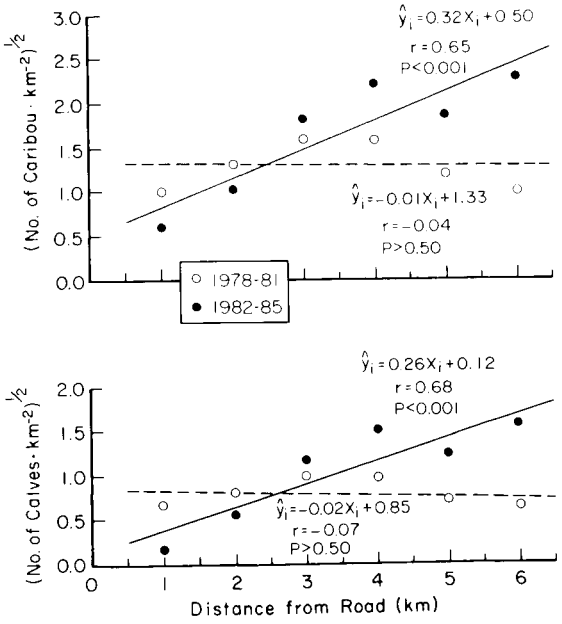

Fig. 3. The relationships between caribou density and distance from roads for all caribou, and calves (i.e., neonates), during June 1978 — 81 and 1982 - 85, Milne Point, Alaska. Data points shown are strata means for each 4-year period; however, linear models were fit using data for individual years.

km² was highly correlated with distance from roads (Fig. 4).

Discussion

Results of the quadrat analysis for calves are probably misleading. The absence of a statistically significant difference between 1978 - 81 and 1982 - 85 in the median percentage of calves in the seven road quadrats may be attributable to the small sample size (n = 8), tied ranks, and the large effect on ranks of the slightly greater percentage of calves observed during 1985 (1%) vs. 1980 (0%).

Linear regression analyses clearly show significant differences between 1978 - 81 and 1982 - 85 in the relationships between caribou density and distance from roads, differences that are not artifacts of annual variability. Apparently, displacement of maternal females from areas near the Milne Point road system account for this change.

Extrapolating these local effects to a regional level requires some speculation. The logical implication is that an extensive, dense network of roads will result in widespread, partial displacement of maternal caribou from calving

Table 2. Analysis of variance examination of the relationships between numbers of maternal and nonmaternal groups per km² and distance from roads, Milne Point, Alaska, June 1978-85.

Density parameter	Model[a]	Source of variability	Sums of squares	df	Mean square	F	P	Entering F value	P
Maternal groups		Total	0.875	47					
	Basic[b]	Regression	0.144	1	0.144	9.09	<0.01	9.09	<0.01
		Error	0.730	46	0.016				
	Reduced[c]	Regression	0.363	3	0.121	10.40	<0.01	9.39	<0.01
		Error	0.512	44	0.012				
	Full[d]	Regression	0.507	15	1.050	2.94	<0.01	1.04	0.44
		Error	0.368	32	0.012				
	Test[e]	Periods	0.363	3	0.121	10.10	<0.01		
		Years/Periods	0.144	12	0.012				
Nonmaternal groups		Total	0.742	47					
	Basic[b]	Regression	0.026	1	0.026	1.66	0.20	1.66	0.20
		Error	0.716	46	0.016				
	Reduced[c]	Regression	0.111	3	0.037	2.58	0.07	2.97	0.06
		Error	0.631	44	0.014				
	Full[d]	Regression	0.273	15	0.018	1.24	0.29	0.92	0.54
		Error	0.469	32	0.015				
	Test[e]	Periods	0.111	3	0.037	2.74	0.10		
		Years/Periods	0.162	12	0.013				

[a-e] See footnotes to Table 1.

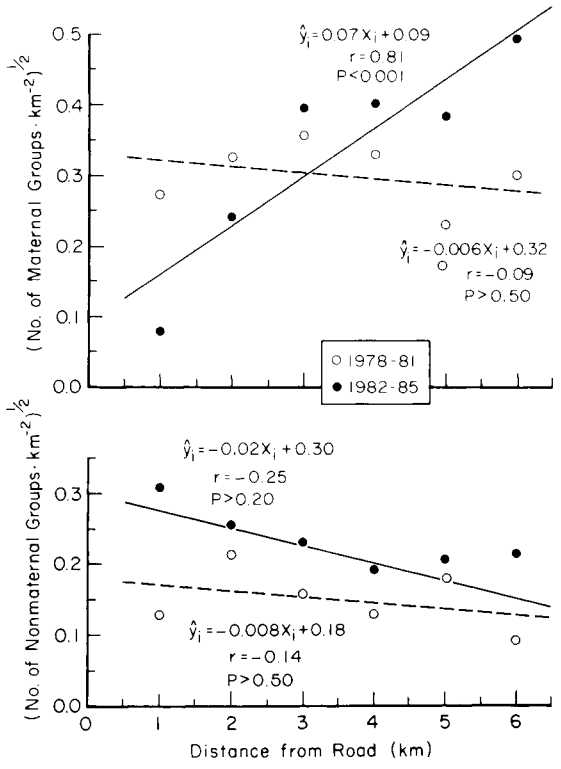

Fig. 4. The relationships between the number of maternal groups (i.e., ≥25% calves) and nonmaternal groups (i.e., <25% calves) per km², and distance from roads during June 1978 - 81 and 1982 - 85, Milne Point, Alaska. Data points shown are strata means for each 4-year period; however, linear models were fit using data for individual years.

grounds unless they begin to tolerate these structures and associated activities (Cowan, 1974). Unfortunately, there is no evidence for habituation by maternal caribou. On the contrary, numbers of CAH females calving within the Prudhoe Bay oil field have remained consistently low (Whitten and Cameron, 1985, unpublished data), despite nearly a decade of exposure to manmade structures.

The fidelity that most caribou herds show to calving grounds suggests that these areas may be more important than other seasonal ranges which are used less predictably (Skoog, 1968). Bergerud (1974) stated: «The basic question is.... why the same areas, limited in extent, are used year after year as calving sites.» Valkenburg et al. (in press) discuss some of the factors that could influence the affinity of caribou to calving areas.

The CAH has continued to grow despite the loss of calving habitat. However, this apparent inconsistency does not preclude the possibility that traditional calving areas confer an advantage to caribou. Thus far, displacement of CAH maternal females has been relatively minor, and the low density of this herd on its calving grounds has allowed use of suitable alternative areas (Whitten and Cameron, 1985).

To our knowledge, this study is the first to systematically and quantitatively address the effects of development within a high-use calving area. If petroleum development continues to expand across the central Arctic Coastal Plain, we should have more opportunities to evaluate the importance of calving areas to the CAH. Other seasonal ranges have been only slightly affected by man, losses to predation are thought to be low, and the annual human harvest is small. The absence of these confounding factors provides a unique opportunity to evaluate the consequences of habitat loss to the productivity of a barren-ground caribou herd.

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