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Redistribution of Calving Caribou in Response to Oil Field Development on the Arctic Slope of Alaska

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ABSTRACT. Aerial surveys were conducted annually in June 1978-87 near Prudhoe Bay, Alaska, to determine changes in the distribution of calving caribou (*Rangifer tarandus granti*) that accompanied petroleum-related development. With construction of an oil field access road through a calving concentration area, mean caribou density (no./km^2) decreased from 1.41 to 0.31 ($P = 0.05$) within 1 km and increased from 1.41 to 4.53 ($P = 0.04$) 5-6 km from the road. Concurrently, relative caribou use of the adjacent area declined ($P < 0.02$), apparently in response to increasing surface development. We suggest that perturbed distribution associated with roads reduced the capacity of the nearby area to sustain parturient females and that insufficient spacing of roads may have depressed overall calving activity. Use of traditional calving grounds and of certain areas therein appears to favor calf survival, principally through lower predation risk and improved foraging conditions. Given the possible loss of those habitats through displacement and the crucial importance of the reproductive process, a cautious approach to petroleum development on the Arctic Slope is warranted.

Key words: Alaska, calving, caribou, disturbance, oil field

RÉSUMÉ. Des photographies aériennes ont été prises au mois de juin chaque année de 1978 à 1987 près de la baie Prudhoe en Alaska, en vue de déterminer les changements dans la distribution des caribous (*Rangifer tarandus granti*) qui mettaient bas, changements accompagnant les projets de mise en valeur reliés au pétrole. Avec la construction d'une route d'accès à un champ pétrolifère à travers une zone importante de mise bas, la densité moyenne du caribou (nombre d'individus/km^2) diminuait de 1,41 à 0,31 ($P = 0{,}05$) à moins d'1 km de la route et augmentait de 1,41 à 4,53 ($P = 0{,}04$) à une distance de 5 à 6 km de la route. En même temps, l'utilisation relative de la zone adjacente par le caribou diminuait ($P < 0{,}02$), apparemment en réponse à l'augmentation de la mise en valeur de surface. On suggère que la perturbation de la distribution associée à la construction de routes diminuait la capacité de la zone environnante à supporter des femelles parturientes et qu'un espacement insuffisant des routes aurait pu faire chuter l'activité générale de mise bas. L'utilisation de terrains traditionnels de mise bas ainsi que de certaines zones à l'intérieur de ces terrains semble favoriser la survie des veaux, en particulier grâce à une baisse de la prédation et à de meilleures conditions de pâturage. Étant donné que le caribou pourrait être évincé de cet habitat et vu l'importance cruciale du processus de reproduction, on recommande une approche prudente à l'exploitation du pétrole sur le versant arctique.

Mots clés: Alaska, mise bas, caribou, perturbation, champ pétrolifère

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INTRODUCTION

For more than 20 years, barren-ground caribou (*Rangifer tarandus granti*) of the Central Arctic Herd (CAH) have been exposed to petroleum-related activity on a portion of their calving grounds. Aerial surveys from 1978 through 1984 revealed that the area encompassing the Prudhoe Bay oil field supported the lowest caribou densities within the calving grounds of the herd (Whitten and Cameron, 1985), suggesting a causal relationship between oil field presence and low caribou abundance; however, comparable pre-development observations were lacking, and the data remained equivocal.

With expansion of surface development west of the Kuparuk River in the late 1970s came an opportunity to monitor changes in the distribution of calving caribou that accompanied placement of roads (and later, above-ground pipelines). Aerial strip-transect observations by Dau and Cameron (1986) during the four years before road construction near Milne Point (i.e., control period) indicated that mean caribou density was unrelated to distance within 6 km of future roads, whereas during the four years following construction (i.e., treatment period) density increased significantly with distance within 6 km of roads. However, neither the actual pre- and post-construction caribou densities nor the associated changes in local distribution were reported. Here we test for significant differences in caribou density at 1 km distance intervals based on ten years' data, estimate the relative magnitude of alterations in habitat use, and discuss the implications of future petroleum development on the Arctic Slope.

STUDY AREA

The CAH inhabits that portion of the Arctic Slope between approximately the Colville River on the west and the Canning River on the east. Seasonal movements are oriented north-south between winter range in the northern foothills of the Brooks Range and calving grounds/summer range near the coast of the Beaufort Sea (Cameron and Whitten, 1979). From 1978 through 1983, the herd increased from approximately 6000 to 13 000 caribou (Whitten and Cameron, 1983; W. Smith, unpubl. data) and in 1991 was estimated at 19 000 caribou (D. Reed, unpubl. data).

Approximately 45 km west of Prudhoe Bay is the Kuparuk Development Area (KDA) (Fig. 1), which lies within one of five calving concentration areas of the CAH (Whitten and Cameron, 1985; W. Smith and R. Cameron, unpubl. data). Terrain relief and vegetation communities are typical of the Arctic Coastal Plain Province (Spetzman, 1959; Wahrhaftig, 1965).

In winter 1977-78, the Spine Road was extended across the Kuparuk River (Fig. 1). By 1981, a construction camp, office/living quarters, rudimentary production facilities, and an airstrip were in place at ARCO's first central processing facility (CPF-1) pad. As well, the Kuparuk Pipeline had been constructed between CPF-1, with its small network of production wells and above-ground flow lines, and the origin station of the Trans-Alaska Pipeline, 40 km east. During winter 1981-82, Conoco built the Milne Point Road from the Spine Road north to the future site of a central facilities pad, and ARCO extended road access to Oliktok Point. Between 1982 and 1987, ARCO

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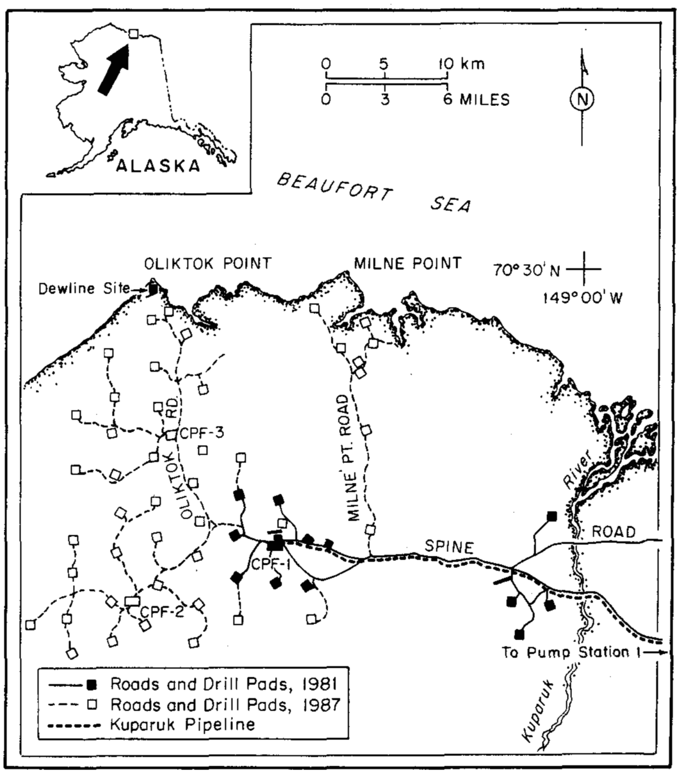

FIG. 1. The Kuparuk development area as of 1981 and 1987.

enlarged the administrative/support facilities at CPF-1; expanded the network of access roads, well pads, and elevated pipelines; commissioned two additional CPFs; constructed dock facilities at Oliktok Point; and installed a system of seawater pipelines for tertiary recovery of crude oil. Conoco built a central camp and processing facility, several drill pads, a modest system of production flow lines, and a main transport pipeline southward, along the Milne Point Road, to the Spine Road where it joins the Kuparuk Pipeline.

Each year, during breakup in late May or early June, the Spine Road was breached at the Kuparuk River, and access to the KDA was possible only by air until after mid-June. Consequently, road traffic was greatly reduced during the period in which our surveys occurred (see below). Mean traffic levels estimated during ground surveys along the Milne Point Road in June 1982-87 were generally < 200 vehicles/day and more commonly < 100 vehicles/day (Dau and Cameron, 1986; J. Dau and W. Smith, unpubl. data).

METHODS

On 10-14 June 1978-87, approximately one week after the peak of calving, we conducted low-level aerial surveys of the study area by helicopter (Cameron *et al.*, 1985; Whitten and Cameron, 1985; Dau and Cameron, 1986). In brief, a pilot and three observers in a Bell 206B or Hughes 500D searched within 11 contiguous north-south strip transects (10 transects in 1978), each 3.2 km wide. For each group of caribou, we recorded total number, sex/age composition, and map location (USGS 1:63 360) where first observed.

The zone within 6 km of the present Milne Point road system was apportioned into 1 km distance strata, and numbers of caribou within each stratum (excluding groups closer to the Spine Road) were totaled for each of the ten surveys. Mean caribou densities for each stratum were compared between pre- and post-construction periods (1978-81 and 1982-87 respectively) using Student's t-tests; degrees of freedom were adjusted for unequal population variances (Satterthwaite, 1946). To assess shifts in caribou distribution within the overall study area, we evaluated changes in the occurrence of caribou between the Oliktok and Milne Point roads (expressed as a percentage of all caribou north of the Spine Road) by Spearman's rank correlation. In all cases, P values < 0.10 were considered statistically significant.

RESULTS

Numbers of caribou observed within 6 km of the Milne Point road system varied more than fivefold during the ten years of study, from 232 in 1980 to 1259 in 1984 (Table 1). Despite this wide range in total counts, densities of caribou within the six distance strata differed between pre- and post-construction periods. After construction, caribou were significantly less numerous within 1 km of roads and significantly more numerous 5-6 km from roads (Table 2). Differences in caribou density for other strata, although statistically insignificant, were intermediate in degree, indicative of the functional relationships reported previously by Dau and Cameron (1986). Data for all caribou and calves were similar, reflecting a predominance of cow-calf pairs.

These changes become clearer when caribou densities are expressed in relative terms and the means for control and treatment periods compared. Following construction, relative abundance (i.e., percent distribution among strata, adjusted for differences in area) declined proportionally by 0.86, 0.59, 0.27, and 0.30 within the first four distance strata respectively, but increased by 1.88 and 1.34 within the last two strata respectively (calves: declined by 0.95, 0.73, 0.33, and 0.21, increased by 2.10 and 1.50 respectively) (Fig. 2).

Associated with the locally perturbed distribution of caribou was a decline in relative use of a portion of the study area. From 1979 through 1987, caribou numbers between the present Oliktok and Milne Point roads, expressed as a percentage of total observations north of the Spine Road (Fig. 1), decreased significantly, independent of total counts (Fig. 3).

TABLE 1. Numbers of caribou observed within 6 km of the Milne Point road system during aerial strip-transect surveys, and snow-melt status in the study area (Fig. 1), 1978-87

Years	No. observed: All caribou	No. observed: Calves	Snow melt*
1978	485	187	L
1979	648	281	E
1980	232	72	L
1981	720	325	E
1982	305	112	L
1983	771	328	E
1984	1259	559	E
1985	532	224	L
1986	455	160	L
1987	266	115	L

*Relative timing: L = late (moderate to complete snow cover or extensive flooding); E = early (little or no snow cover or standing water).

TABLE 2. Mean (SE) caribou density (no./km^2) observed within each of 6 intervals of distance from the Milne Point road system, pre-construction (1978-81) vs. post-construction (1982-87)

		Distance interval (km)					
Sample unit	Years	0-1	1-2	2-3	3-4	4-5	5-6
All caribou	1978-81	1.41(0.35)	1.93(0.49)	3.08(1.26)	3.82(1.11)	1.39(0.82)	1.41(0.40)
	1982-87	0.31(0.13)	1.10(0.40)	2.48(0.73)	3.34(1.11)	5.49(2.12)	4.53(1.17)
	P:*	0.05	0.24	0.70	0.77	0.12	0.04
Calves	1978-81	0.60(0.16)	0.76(0.23)	1.31(0.61)	1.60(0.60)	0.57(0.38)	0.56(0.20)
	1982-87	0.04(0.02)	0.34(0.18)	1.01(0.35)	1.45(0.53)	2.49(1.04)	2.03(0.54)
	P:*	0.04	0.19	0.68	0.85	0.13	0.04

*t-test, degrees of freedom adjusted for unequal variances (Satterthwaite, 1946).

DISCUSSION

Annual variation in the numbers of caribou observed near Milne Point (Table 1) is primarily an effect of spring snow conditions. In years of early snowmelt and runoff, calving caribou occupy the immediate coastal zone in abundance, whereas if snowmelt is late or flooding widespread, distribution tends to be skewed inland (Whitten and Cameron, 1985). The stage of snow ablation also influences caribou sightability and, therefore, the total count. Survey conditions are best when snow is either absent or continuous, as caribou are easily discernible against consistently light or dark backgrounds; however, sightability decreases if snow cover is discontinuous. An additional complication was herd size, which continued to increase during the tenure of this study. Thus, for a given year, the number of caribou observed may have been influenced by measurement error, as well as population variability, but the relative distribution of caribou among distance strata was unaffected.

The data strongly suggest that calving caribou were displaced outward after construction of the Milne Point road system. Relative abundance within 2 km decreased by more than two-thirds, while that beyond 4 km nearly tripled (Fig. 2). Though opposite in direction, these dual effects are additive or synergistic from the perspective of habitat use. Underutilization adjacent to roads and resultant overutilization elsewhere effectively diminish the capacity of the area to support caribou, particularly in years of early snowmelt when absolute densities are high (Table 1).

Another implication is that overall caribou use could be greatly reduced if roads are routed too closely. Owing to a sensitivity to disturbance (deVos, 1960; Lent, 1966; Skoog, 1968; Bergerud, 1971), most females with calves might then be

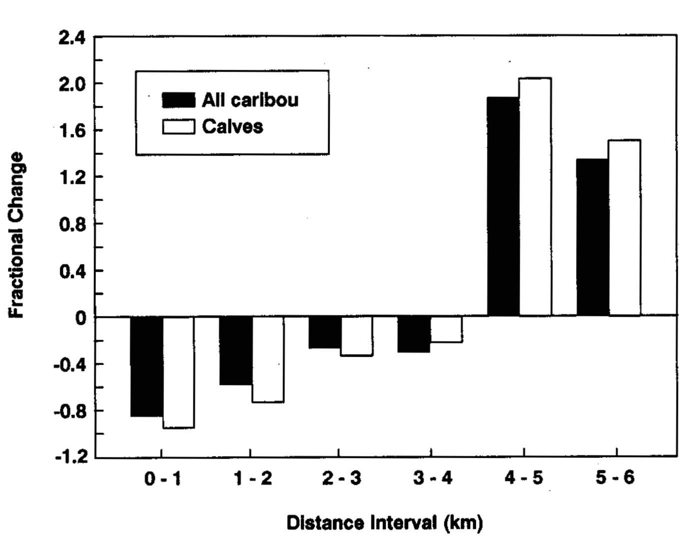

FIG. 2. Mean fractional changes in relative caribou abundance (i.e., percent distribution among strata, adjusted for differences in area) for 1 km distance intervals from the Milne Point road system, 1982-87 vs. 1978-81.

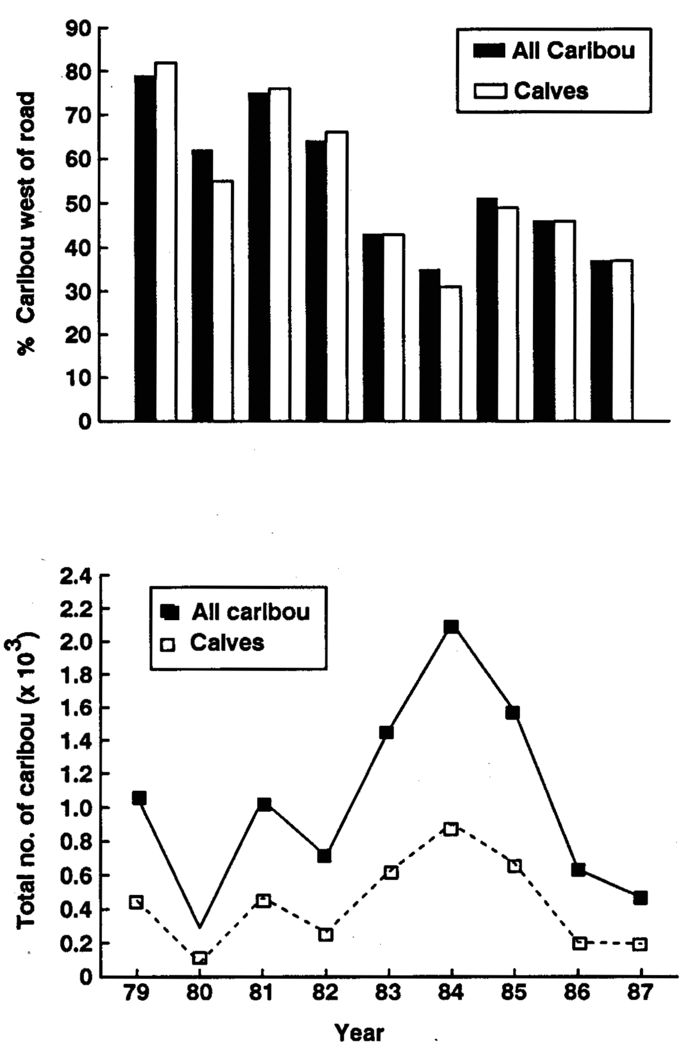

FIG. 3. Decline in percent abundance of caribou west of the Milne Point Road (Spearman's Rank, $P < 0.02$), and changes in total numbers of caribou observed north of the Spine Road (see Fig. 1), 1979-87. Note: In 1978, one transect in the vicinity of the Oliktok Road was not flown.

unable to maintain an acceptable distance from adverse stimuli, triggering a general withdrawal. In retrospect, this may have occurred within the Prudhoe Bay oil field complex (Whitten and Cameron, 1985) as it grew from a remote exploration outpost to a hub of development activity, with numerous support facilities, roads, and pipelines (Shideler, 1986).

Likewise, displacement of calving caribou from the KDA may occur as overlapping and contiguous oil reserves are exploited. Indeed, those changes appear to be in progress, judging from the declining percentage of caribou within the heavily developed area north of the Spine Road (Fig. 3). Construction of the Oliktok Road and its associated pipelines and pads, expansion of processing facilities, and increasing Milne Point development ostensibly have contributed to a gradual redistribution of calving activity. Either some caribou shifted into areas east of the Milne Point Road, or relatively fewer entered the western portion of the study area from the south. That such a change occurred independent of total caribou abundance constitutes circumstantial evidence that it was disturbance-induced and not simply a response to stochastic weather variables.

Repeated use of calving grounds by the CAH (Whitten and Cameron, 1985; Cameron *et al.*, 1986) appears to reflect an ecological compromise whereby net benefits are maximized. Rather than remain on inland winter range (Cameron and Whitten, 1979), where newly emergent forage is abundant during the calving period, parturient females, unlike most bulls and nonparous females, precede the northward progression of plant phenology (Whitten and Cameron, 1980), moving to coastal regions, which generally have fewer wolves (*Canis lupus*) (Stephenson, 1979) and grizzly bears (*Ursus arctos*) (Reynolds, 1979; Young *et al.*, 1990; D. Young, pers. comm. 1991) and where mosquito emergence occurs later (Roby, 1978). By doing so, however, they forego nutritional compensation for the additional metabolic demands of late gestation and early lactation (Robbins and Moen, 1975; Oftedal, 1985). Hence, females that consistently calve near the arctic coast reduce predation risk to their newborn calves, but at the expense of access to high-quality forage.

In contrast, recurrent area-specific calving concentrations (Whitten and Cameron, 1985) are related to the occurrence of dry tundra (Bishop and Cameron, 1990) with abundant *Eriophorum vaginatum* (Walker and Acevedo, 1987), a nutrient-rich forage species (Kuropat and Bryant, 1980) that flowers immediately after snow ablation (Chapin *et al.*, 1979). Also, the better-drained habitats comprising these plant communities are probably superior as birth sites, especially in years of persistent snow cover.

To summarize, it appears that fidelity of the CAH to its calving grounds involves predator and insect avoidance, whereas calving concentrations *within* that broad region correspond to areas characterized by the best habitats. The relative occurrence of caribou among those areas for a given year is influenced primarily by snow conditions and, therefore, forage availability. In essence, then, nutritional factors define calving distribution, but within the spatial constraints imposed by predators and insects.

Preference for a calving environment, be it a broad landscape class or specific vegetation type, implies long-term dependence on those resources to the extent that sustained access is *required* for persistence of the population (Ruggiero *et al.*, 1988). Moreover, particularly adverse conditions (e.g., in weather, predator abundance, insect activity) might periodically render unpreferred — and, presumably, suboptimal — areas totally unfavorable, underscoring the importance of those occupied selectively. Patterns of habitat use, like metabolic adaptations, may play a role in minimizing the consequences of extremes (Levins, 1968) that might otherwise be detrimental to individuals and, ultimately, to the population. If, on the other hand, caribou are not subjected to adverse conditions that approach the limits of their adaptive capability, the constraints inherent in heterogeneous habitats will not become apparent, and the options available will seem more numerous than is actually the case. As a result, the loss of preferred areas might be erroneously viewed as inconsequential.

In view of the probable importance of calving grounds to the long-term reproductive performance of caribou, our data on the CAH indicate a need for discretion in developing petroleum resources elsewhere on the Arctic Slope. The much larger Porcupine Herd (Fancy *et al.*, 1989) is similar to the CAH in terms of fidelity to coastal calving grounds (Skoog, 1968; Hemming, 1971; Clough *et al.*, 1987) that favors calf survival (Fancy and Whitten, 1991); and calving concentration areas (Clough *et al.*, 1987; Fancy and Whitten, 1991) are characterized by beneficial snow conditions (Lent, 1980; Eastland *et al.*, 1989) and a greater abundance of highly digestible *Eriophorum* (White *et al.*, 1989; Christiansen *et al.*, 1990). U.S. legislation is now pending to open a portion of the Arctic National Wildlife Refuge (ANWR) coastal plain to oil exploration. If ANWR leasing is authorized and production follows, extreme care must be exercised to ensure that individual actions adversely affecting calving caribou on a local level do not cumulatively result in major impacts on a regional or population level.

Beyond direct changes in the geobotanical environment (Walker *et al.*, 1987), progressive expansion and intensification of surface development will, at some stage, reduce the totality, diversity, and quality of calving habitats on the Arctic Slope. Our short-term frame of reference and relative inexperience should give rise to caution when we contemplate the exploitation of these ecosystems.

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