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Distribution and Productivity of the Central Arctic Caribou Herd in Relation to Petroleum Development: Case History Studies with a Nutritional Perspective

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SUMMARY

We provide a brief overview of Central Arctic herd (CAH) status and a summary of progress on research involving caribou (*Rangifer tarandus granti*) body condition and responses to oilfield-related disturbance. Growth rate of the CAH since the early 1980s has been substantially lower than that noted in the late 1970s and early 1980s; the herd now numbers approximately 20,000 head. Aerial survey data obtained during the calving period since 1978 clearly demonstrate that maternal females and their calves were displaced outward after construction of the Milne Point road system. Results to date on radio-collared caribou indicate that the likelihood of producing a calf is directly related to female body weight during the previous autumn, whereas both the incidence of early calving and the probability of calf survival are a function of postpartum weight. Additionally, reproductively active females lost more weight during winter and gained less weight during summer than reproductively inactive females. We submitted two journal manuscripts and one technical report for publication.

Key Words: Alaska, body weight, calving, caribou, Central Arctic herd, disturbance, oilfield.

CONTENTS

BACKGROUND

Reduced local use of calving and summer ranges by Central Arctic herd (CAH) caribou (*Rangifer tarandus granti*) has occurred with progressive oil development on the Arctic Coastal Plain (Cameron et al. 1979; Cameron and Whitten 1980; Smith and Cameron 1983; Whitten and Cameron 1983*a*, 1985; Dau and Cameron 1986). Habitat loss is, in itself, an undesirable consequence of petroleum development, but there is an additional major concern that such proximate impacts, operating cumulatively, will eventually result in reduced size and/or productivity of the herd through one or more possible mechanisms (Cameron 1983). Unfortunately, such concerns, though justified from a theoretical point of view, gain little empirical support from the literature. As industrial development in the Arctic is virtually unprecedented, there is little basis for predicting the extent and duration of habitat loss, much less the secondary short- and long-term effects on the well-being of a particular caribou herd.

These uncertainties form the basis of the present two-component study: (1) assessments of CAH productivity and distribution in relation to oilfield development; and (2) an investigation of the influence of female body condition on reproductive performance. Herein, we summarize selected data obtained since 1987. A Final Report on this research will be submitted in 1993.

OBJECTIVES

To monitor the size, calf production, and recruitment of the CAH,.

To describe changes in the distribution and movements of CAH caribou in relation to oilfield development on the Arctic Coastal Plain.

To determine the relationship between body condition and reproductive performance of female caribou of the CAH, including comparisons of:

- the body condition, reproductive success, and offspring survival of females under disturbance-free conditions (i.e., east of the

Sagavanirktok River) with the status of those exposed to oil-related development (i.e., west of the Sagavanirktok River); and

- the rates of summer weight gain and subsequent reproductive performance of lactating vs. nonlactating female caribou

RESULTS AND DISCUSSION

Status of the Central Arctic Caribou Herd

Fancy et al. (1992) reviewed CAH composition data obtained through annual surveys of the calving grounds from 1978 through 1990. Initial calf production ranged from 48 calves:100 cows in 1989 to 91 calves:100 cows in 1983. A survey in 1992 yielded a ratio of 73:100 (R. Cameron, unpubl. data). Overall, the trend has been downward, but not significantly so (Spearman's rank, $0.2 > \underline{P} > 0.1$). Nonetheless, with high rates of natality in the late 1970s and early 1980s, the herd grew rapidly from an estimated 6,000 in 1978 (Whitten and Cameron 1983*b*) to 13,000 in 1983 (W. Smith, unpubl. data), an average annual increase of 15%. Accompanying the generally lower natality rates in the late 1980s and early 1990s was a correspondingly lower rate of growth. The 1991 estimate was 19,000 (D. Reed, unpubl. data), representing a net annual increase of only 5% after 1983, despite modest harvest levels (Fancy et al. 1992). The CAH was photocensused in July 1992; final results are not yet available, but preliminary indications are that the count probably will not exceed 20,000. Thus, there is little doubt that the CAH is now growing at a far lower rate and may even be stable.

Development-related Changes in Caribou Distribution

Changes in the distribution of calving caribou associated with oilfield development have been quantified using strip-transect surveys flown by helicopter. As a follow-up to an earlier paper by Dau and Cameron (1986), Cameron et al. (in press) (Appendix A) have shown that, following construction of a road system near Milne Point, mean caribou abundance declined by more than two-thirds within 2 km and nearly tripled 4-6 km from the road. Such perturbed distribution reduces the capacity of an area to support females and their calves. Logically, close spacing of roads within an oilfield complex may depress area-wide calving activity. That outward displacement of calving caribou from the Milne Point road system has occurred is corroborated by the regional changes in caribou distribution accompanying construction. Prior to road placement, caribou were found in a single, more-or-less continuous concentration roughly centered on the Milne Point Road; whereas a bimodal distribution, with one concentration each to the east and west of the road, was clearly apparent after construction (Smith and Cameron 1992).

It is also noteworthy that a companion investigation within the oilfield complex west of the Kuparuk River has been completed. For more than a decade, systematic surveys were conducted annually from that road system to monitor the influence of oilfield development on caribou distribution, group size and composition, movements, and road/pipeline crossing success. An overview of that work entitled "Distribution and movements of caribou in relation to roads and pipelines, Kuparuk Development Area, 1978-90" by W. T. Smith, R. D. Cameron, and D. J. Reed has been submitted for publication as a separate technical report. The Executive Summary is given as Appendix B.

Female Caribou Body Condition vs. Reproductive Performance

Our data indicate that body weight of female caribou in autumn is closely related to subsequent calving success (Appendix C). Radio-collared females that produced a calf were significantly heavier than those that did not; and the logistic regression relating parturition rate and autumn body weight was significant as well. In contrast, calving date and early calf survival are more closely correlated with maternal weight shortly after parturition. Females that calved on or before 7 June and/or whose calves survived at least 48 hours postpartum were significantly heavier in early July than those calving after 7 June and/or whose calves died within 48 hours; the corresponding logistic models also were significant. Hence, the likelihood of conceiving is, for the most part, a reflection of body condition during the rut, while parturition date and calf survival may be related to maternal condition during late gestation. One should recognize, however, that body weight alone may not be the most reliable indicator of condition. Variable alimentary fill, changes in chemical composition that are independent of weight, and individual differences in skeletal size are possible complicating factors. Indices incorporating subjective condition scores and morphometric measurements are currently being evaluated.

Comparative data on condition and reproductive success of females exposed to oil development west of the Sagavanirktok River vs. those under disturbance-free conditions to the east are, thus far, inconclusive. However, even though differences were not significant, some interesting consistencies emerged from the various analyses. July and October body weights, oversummer weight gain, the incidence of successive 2-year pregnancies, and perinatal calf survival were all lower for western than for eastern females (Cameron et al. 1992).

Data on sequential body weights of individual females confirm previous reports that the metabolic costs of gestation and lactation are substantial. Pregnant/lactating females lost significantly more weight during winter and spring, and lactating females gained significantly less weight during summer and autumn than nonfecund females. On average, reproductively active females lost 7 kg annually, while reproductively inactive females gained 5 kg (Cameron et al. 1992). Because pre-rut body weight is closely linked to the probability of conception (Appendix C), failure to meet these additional metabolic demands through compensatory feeding will eventually compromise reproductive success.

LITERATURE CITED

Cameron, R. D. 1983. Issue: caribou and petroleum development in Arctic Alaska. Arctic 36:227-231.

_____, S. G. Fancy, and W. T. Smith. 1992. Reproductive performance of caribou in relation to habitat availability and quality. Pages 67-78 *in* T. R. McCabe, B. Griffith, N. E. Walsh, and D. D. Young, eds. Terrestrial research: 1002 area--Arctic National Wildlife Refuge, Interim Rep., 1988-1990. U.S. Fish and Wildl. Serv., Anchorage, AK.

_____, D. J. Reed, J. R. Dau, and W. T. Smith. 1992. Redistribution of calving caribou in response to oilfield development on the Arctic Slope of Alaska. Arctic (in press).

_____, and K. R. Whitten. 1980. Influence of the Trans-Alaska Pipeline corridor on the local distribution of caribou. Pages 475-484 *in* E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proc. Second Int. Reindeer/Caribou Symp., Roros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim.

_____, _____, W. T. Smith, and D. D. Roby. 1979. Caribou distribution and group composition associated with construction of the Trans-Alaska Pipeline. Can. Field-Nat. 93:155-162.

Dau, J. R., and R. D. Cameron. 1986. Effects of a road system on caribou distribution during calving. Rangifer, Spec. Issue No. 1:95-101.

Fancy, S. G., K. R. Whitten, N. E. Walsh, and R. D. Cameron. 1992. Population dynamics and demographics of caribou in developed and undeveloped areas of the arctic coastal plain. Pages 1-20 *in* T. R. McCabe, B. Griffith, N. E. Walsh, and D. D. Young, eds. Terrestrial research: 1002 area--Arctic National Wildlife Refuge, Interim Rep., 1988-1990. U.S. Fish and Wildl. Serv., Anchorage, AK.

Smith, W. T., and R. D.Cameron. 1983. Responses of caribou to industrial development on Alaska's Arctic Slope. Acta Zool. Fenn. 175:43-45.

_____, and _____. 1992. Caribou responses to development infrastructures and mitigation measures implemented in the Central Arctic Region. Pages 79-86 *in* T. R. McCabe, B. Griffith, N. E. Walsh, and D. D. Young, eds. Terrestrial research: 1002 area--Arctic National Wildlife Refuge, Interim Rep., 1988-1990. U.S. Fish and Wildl. Serv., Anchorage, AK.

Whitten, K. R., and R. D. Cameron. 1983*a*. Movements of collared caribou, *Rangifer tarandus*, in relation to petroleum development on the Arctic Slope of Alaska. Can. Field-Nat. 97:143-146.

_____, and _____. 1983*b*. Population dynamics of the Central Arctic Herd, 1975-1981. Acta Zool. Fenn. 175:159-161.

_____, and _____. 1985. Distribution of caribou calving in relation to the Prudhoe Bay oilfield. Pages 35-39 *in* A. Martell and D. Russell, eds. Proc. First North Am. Caribou Workshop, Whitehorse, 1983. Can. Wildl. Serv. Spec. Publ., Ottawa.

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APPENDIX A

REDISTRIBUTION OF CALVING CARIBOU IN RESPONSE TO OILFIELD DEVELOPMENT ON THE ARCTIC SLOPE OF ALASKA

R. D. Cameron, D. J. Reed, J. R. Dau, and W. T. Smith

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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 oilfield 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, oilfield

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 oilfield supported the lowest caribou densities within the calving grounds of the herd (Whitten and Cameron, 1985), suggesting a causal relationship between oilfield 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 4 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 4 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 10 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 6,000 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 flowlines, 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 enlarged the administrative/support facilities at CPF-1; expanded the network of access roads, well pads, and elevated pipelines; commissioned two additional CPF's; 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 flowlines, 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 1 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 10 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 five-fold during the 10 years of study, from 232 in 1980 to 1,259 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).

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 unable to maintain an acceptable distance from adverse stimuli, triggering a general withdrawal. In retrospect, this may have occurred within the Prudhoe Bay oilfield 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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REFERENCES

BERGERUD, A. T. 1971. The Role of the Environment in the Aggregation, Movement, and Disturbance Behaviour of Caribou. In: Geist, V., and Walther, F., eds. Vol. 2, The Behaviour of Ungulates and Its Relation to Management. IUCN New Series No. 234, Morges, Switzerland. 552-584.

BISHOP, S. C., and CAMERON, R. D. 1990. Habitat Use by Post-parturient Female Caribou of the Central Arctic Herd. Paper presented at the Annual Meeting of The Wildlife Society, Alaska Chapter, Juneau, Alaska, 4-6 April 1990. Book of Abstracts. p. 9.

CAMERON, R. D., and WHITTEN, K. R. 1979. Seasonal Movements and Sexual Segregation of Caribou Determined by Aerial Survey. Journal of Wildlife Management 43:626-633.

CAMERON, R. D., WHITTEN, K. R., and SMITH, W. T. 1986. Summer Range Fidelity of Radio-collared Caribou in Alaska's Central Arctic Herd. Rangifer, Special Issue No. 1:51-55.

CAMERON, R. D., WHITTEN, K. R., SMITH, W. T., and REED, D. J. 1985. Sampling Errors Associated with Aerial Transect Surveys of Caribou. Proceedings of the Second North American Caribou Workshop, Val Morin, Quebec. McGill Subarctic Research Paper No. 40:273-283.

CHAPIN, F. S. III, VAN CLEVE, K., and CHAPIN, M. C. 1979. Soil Temperature and Nutrient Cycling in the Tussock Growth Form of Eriophorum vaginatum. Journal of Ecology 67:169-189.

CHRISTIANSEN, J. S., RAYNOLDS, M. K., and BISHOP, S. C. 1990. Snow Melt, Plant Phenology, and Seasonal Availability of Forage Nutrients and Biomass in Concentrated and Peripheral Calving Areas of Caribou on the Arctic Coastal Plain. In: McCabe, T. R., ed. Terrestrial Research: 1002 Area--Arctic National Wildlife Refuge, Annual Progress Report, 1989. U.S. Fish and Wildlife Service, Anchorage, Alaska. 66-79.

CLOUGH, N. K., PATTON, P. C., and CHRISTIANSEN, A. C., eds. 1987. Arctic National Wildlife Refuge, Alaska, Coastal Plain Resource Assessment. U.S. Department of the Interior, Washington, D.C. 208 p.

DAU, J. R., and CAMERON, R. D. 1986. Effects of a Road System on Caribou Distribution During Calving. Rangifer, Special Issue No. 1:95-101.

deVOS, A. 1960. Behavior of Barren-ground Caribou on Their Calving Grounds. Journal of Wildlife Management 24:250-258.

EASTLAND, W. G., BOWYER, R. T., and FANCY, S. G. 1989. Effects of Snow Cover on Selection of Calving Sites by Caribou. Journal of Mammalogy 70:824-828.

FANCY, S. G., and WHITTEN, K. R. 1991. Selection of Calving Sites by Porcupine Herd Caribou. Canadian Journal of Zoology 69:1736-1743.

FANCY, S. G., PANK, L. F., WHITTEN, K. R., and REGELIN, W. L. 1989. Seasonal Movements of Caribou in Arctic Alaska as Determined by Satellite. Canadian Journal of Zoology 67:644-650.

HEMMING, J. E. 1971. The Distribution and Movement Patterns of Caribou in Alaska. Alaska Department of Fish and Game Wildlife Technical Bulletin 1. Juneau. 60 p.

KUROPAT, P., and BRYANT, J. P. 1980. Foraging Behavior of Cow Caribou on the Utukok Calving Grounds in Northwestern Alaska. In: Reimers, E., Gaare, E., and Skjenneberg, S., eds. Proceedings of the Second International Reindeer/Caribou Symposium, Roros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim, Norway. 64-70.

LENT, P. C. 1966. Calving and Related Social Behavior in the Barren-ground Caribou. Zeitschrift fur Tierpsychologie 23:701-756.

LENT, P. C. 1980. Synoptic Snowmelt Patterns in Arctic Alaska in Relation to Caribou Habitat Use. In: Reimers, E., Gaare, E., and Skjenneberg, S., eds. Proceedings of the Second International Reindeer/Caribou Symposium, Roros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim, Norway. 71-77.

LEVINS, R. 1968. Evolution in Changing Environments. Princeton University Press, Princeton, New Jersey. 120 p.

OFTEDAL, O. T. 1985. Pregnancy and Lactation. In: Hudson, R. J., and White, R. G., eds. Bioenergetics of Wild Herbivores. CRC Press, Boca Raton, Florida. 215-238.

REYNOLDS, H. V. 1979. Population Biology, Movements, Distribution, and Habitat Utilization of a Grizzly Bear Population in NPR-A. In: Lent, P. C., ed. Vol. 1, Studies of Selected Wildlife and Fish and Their Use of Habitats On and Adjacent To NPR-A, 1977-1978. U.S. Department of the Interior, Anchorage, Alaska. 129-182.

ROBBINS, C. T., and MOEN, A. N. 1975. Uterine Composition and Growth in White-tailed Deer. Journal of Wildlife Management 39:684-691.

ROBY, D. D. 1978. Behavioral Patterns of Barren-ground Caribou of the Central Arctic Herd Adjacent to the Trans-Alaska Oil Pipeline. M.S. dissertation. University of Alaska, Fairbanks, Alaska. 200 p.

RUGGIERO, L. F., HOLTHAUSEN, R. S., MARCOT, B. G., AUBRY, K. B., THOMAS, J. W., and MESLOW, E. C. 1988. Ecological Dependency: the Concept and Its Implications for Research and Management. Transactions of the North American Wildlife and Natural Resources Conference 53:115-125.

SATTERTHWAITE, F. E. 1946. An Approximate Distribution of Estimates of Variance Components. Biometrics 2:110-114.

SHIDELER, R. T. 1986. Impacts of Oil and Gas Development on the Central Arctic Herd. Vol. II, Impacts of Human Developments and Land Use on

Caribou: A Literature Review. Alaska Department of Fish and Game Technical Report 86-3. Juneau, Alaska. 128 p.

SKOOG, R. O. 1968. Ecology of caribou (Rangifer tarandus granti) in Alaska. Ph.D. dissertation. University of California, Berkeley, California. 669 p.

SPETZMAN, L. A. 1959. Vegetation of the Arctic Slope of Alaska. U.S. Geological Survey Professional Paper 302-B. 58 p.

STEPHENSON, R. O. 1979. Abundance, Movements, and Food Habits of Wolves In and Adjacent To NPR-A. In: Lent, P. C., ed. Vol. 1, Studies of Selected Wildlife and Fish and Their Use of Habitats On and Adjacent To NPR-A, 1977-1978. U.S. Department of the Interior, Anchorage, Alaska. 53-87.

WAHRHAFTIG, C. 1965. Physiographic Divisions of Alaska. U.S. Geological Survey Professional Paper 482. 52 p.

WALKER, D. A., and ACEVEDO, W. 1987. Vegetation and a Landsat-derived Land Cover Map of the Beechey Point Quadrangle, Arctic Coastal Plain, Alaska. U.S. Army Corps of Engineers CRREL Report 87-5.

WALKER, D. A., WEBBER, P. J., BINNIAN, E. F., EVERETT, K. R., LEDERER, N. D., NORDSTRAND, E. A., and WALKER, M. D. 1987. Cumulative Impacts of Oil Fields on Northern Alaskan Landscapes. Science 238:757-761.

WHITE, R. G., FELIX, N. A., and MILNE, J. 1989. Regional Variation in the Digestibility of Caribou Forage in the Calving Ranges of the Porcupine and Central Arctic Herds. In: McCabe, T. R., ed. Terrestrial Research: 1002 Area--Arctic National Wildlife Refuge, Annual Progress Report, 1988. U.S. Fish and Wildlife Service, Anchorage, Alaska. 151-168.

WHITTEN, K. R., and CAMERON, R. D. 1980. Nutrient Dynamics of Caribou Forage on Alaska's Arctic Slope. In: Reimers, E., Gaare, E., and Skjenneberg, S., eds. Proceedings of the Second International Reindeer/Caribou Symposium, Roros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim, Norway. 159-166.

WHITTEN, K. R., and CAMERON, R. D. 1983. Population Dynamics of the Central Arctic Herd 1975-1981. Acta Zoologica Fennica 175:159-161.

WHITTEN, K. R., and CAMERON, R. D. 1985. Distribution of Caribou Calving in Relation to the Prudhoe Bay Oilfield. In: Martell, A. M., and Russell, D. E., eds. Proceedings of the First North American Caribou Workshop, Whitehorse, Yukon. Canadian Wildlife Service, Ottawa, Ontario. 35-39.

YOUNG, D. D., GARNER, G. W., AMBROSE, R. E., REYNOLDS, H. V., and McCABE, T. R. 1990. Differential Impacts of Predators (Brown Bears, Wolves, Golden Eagles) on Caribou Calving in the 1002 Area and Potential Displacement Areas: An Assessment of Predation Risks. In: McCabe, T. R., ed. Terrestrial Research: 1002 Area--Arctic National Wildlife Refuge, Annual Progress Report, 1989. U.S. Fish and Wildlife Service, Anchorage, Alaska. 20-32.

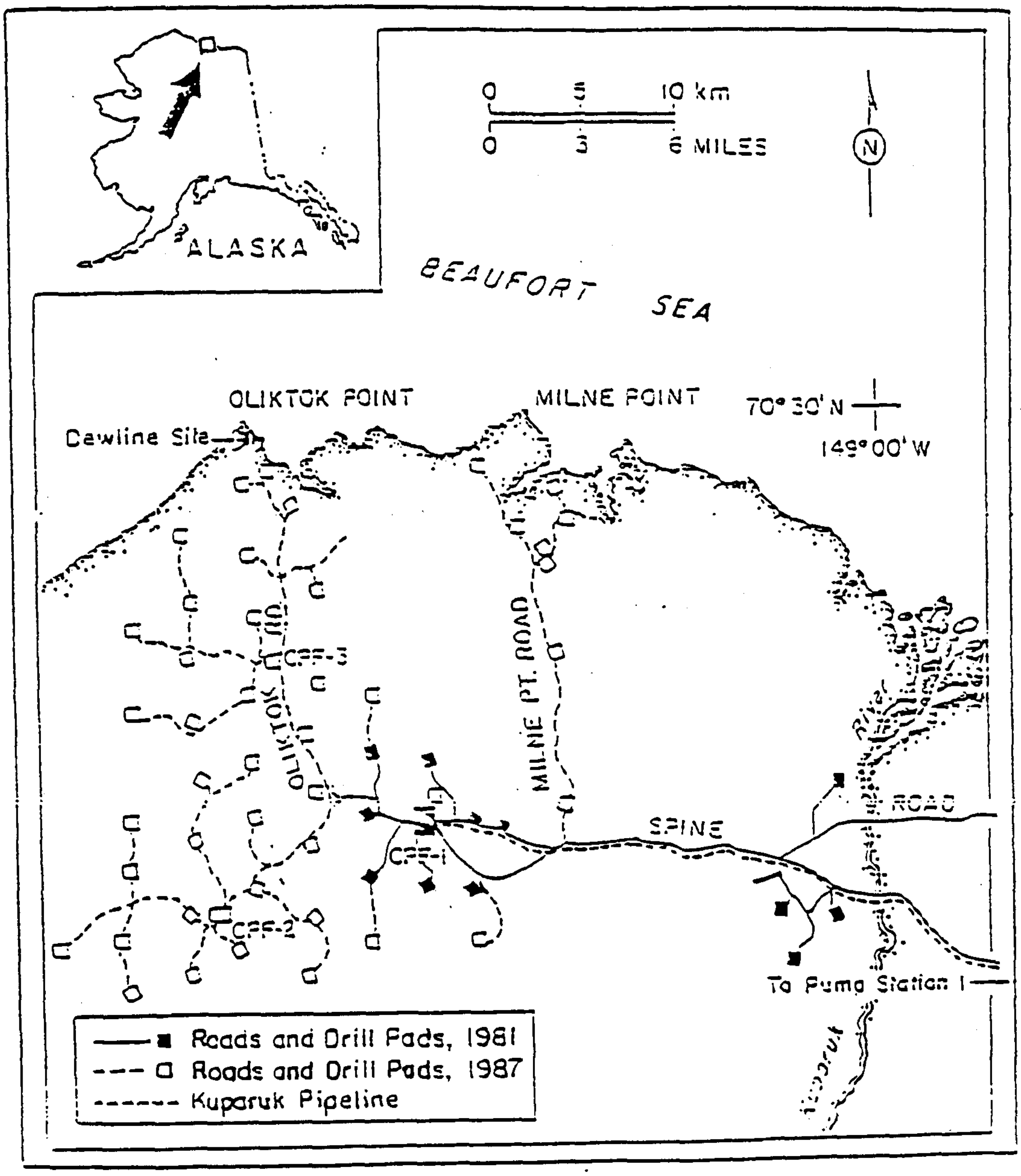


Figure 1. The Kuparuk Development Area as of 1981 and 1987.

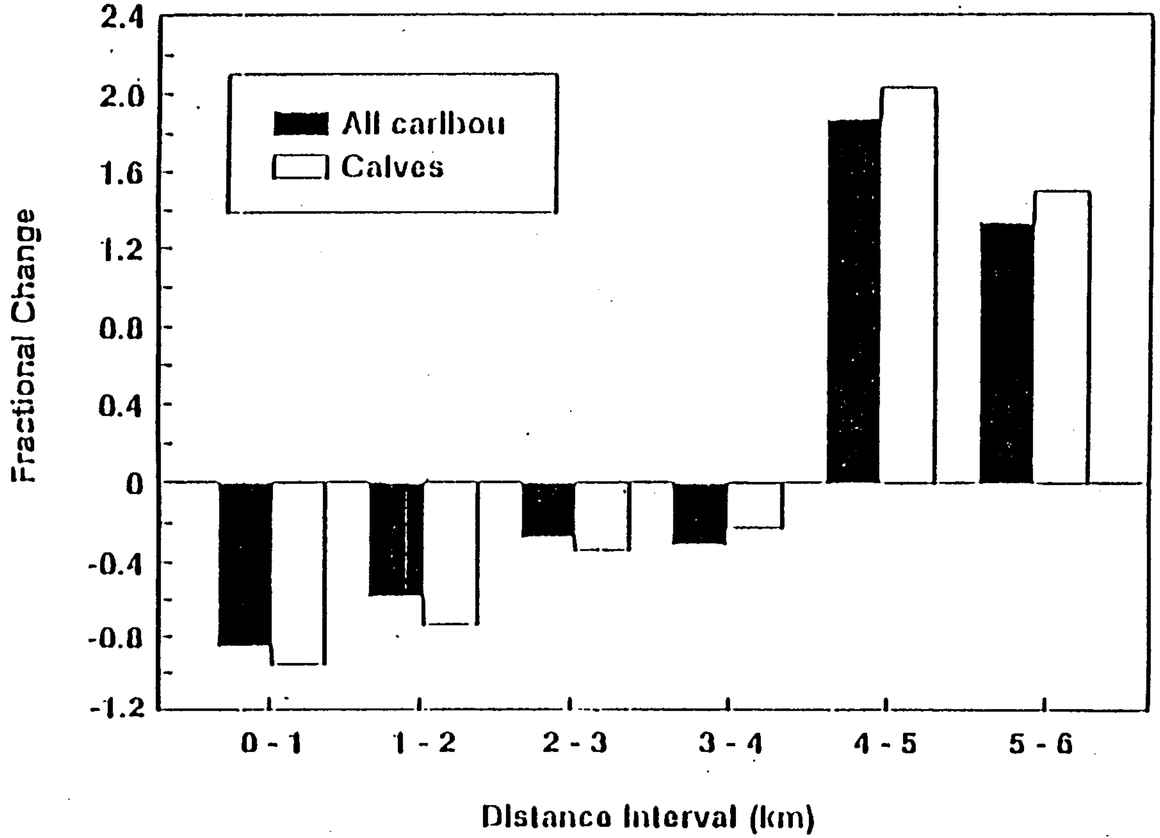
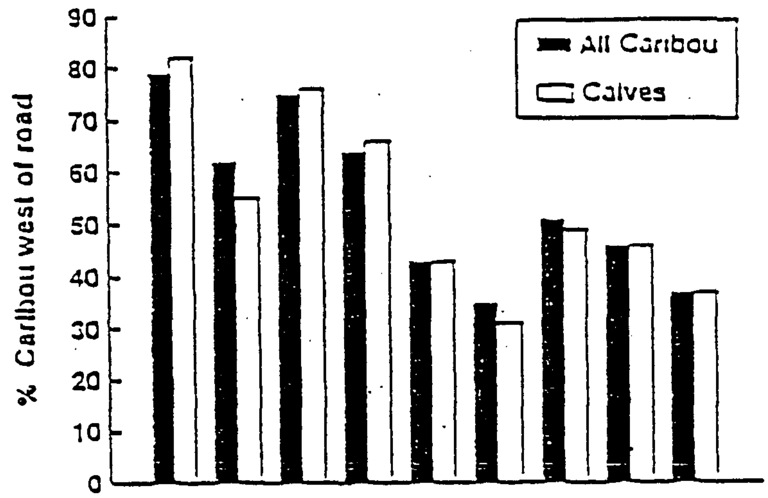


Figure 2. Mean fractional changes in relative caribou density for 1-km distance intervals from the Milne Point Road system, 1982-87 vs. 1978-81.



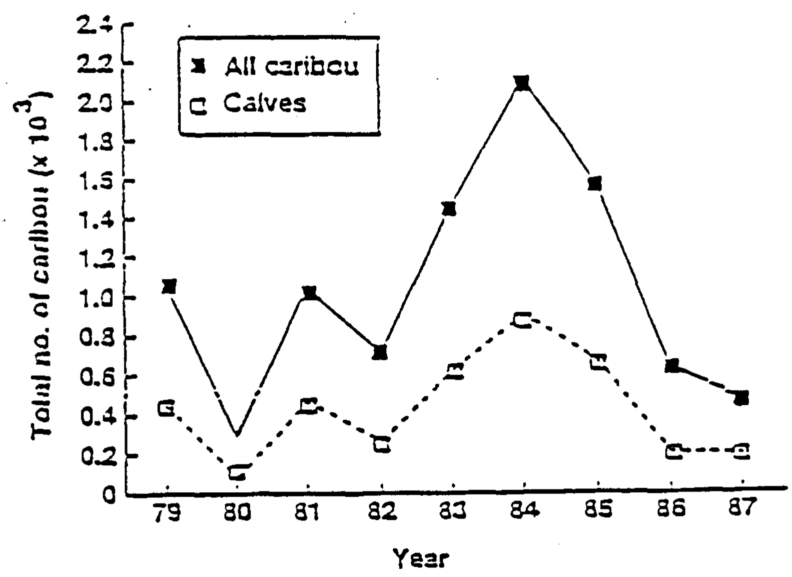


Figure 3. Decline in percent abundance of caribou west of the Milne Point Road (Spearman's Rank, $\underline{P} < 0.02$), and changes in total numbers of caribou observed north of the Spine Road (see Fig. 1), 1979-87. Note: In 1978, one transect in the vicinity of the Oliktok Road was not flown.

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

Years	No. observed		Snowmelt[a]
	All caribou	Calves	
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	1,259	559	E
1985	532	224	L
1986	455	160	L
1987	266	115	L

[a] 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, preconstruction (1978-81) vs. postconstruction (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:[a]	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:[a]	0.04	0.19	0.68	0.85	0.13	0.04

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

APPENDIX B

DISTRIBUTION AND MOVEMENTS OF CARIBOU IN RELATION TO ROADS AND PIPELINES, KUPARUK DEVELOPMENT AREA, 1978-90

Executive Summary

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Alaska Department of Fish and Game

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I. From 1978 through 1990, the distribution, sex/age composition, and road/pipeline crossing success of Central Arctic herd (CAH) caribou (*Rangifer tarandus granti*) in the Kuparuk Development Area (KDA) were determined by systematic road surveys along the Spine Road (SR) and, later, the Oliktok Road (OR). Observations were subdivided according to the stage of oilfield development: Preconstruction (1978-80), prior to any pipeline construction; Initial Construction (1981-84), construction of the first Central Processing Facility (CPF-1) and the Kuparuk Pipeline; and Advanced Construction (1985-90), placement of production and distribution facilities for CPF-2 and CPF-3.

II. Preconstruction (1978-80)

A. Midsummer (3 Jul-10 Aug)

1. Although relative abundance of caribou observed along the SR increased during the period, mean calf representation declined from 25% to 19%. However, these calf percentages were similar to regional estimates obtained by aerial surveys.

2. Overall distribution and movements appeared to be related to the occurrence of riparian areas, but caribou tended to avoid areas of local construction activity, especially within the Kuparuk floodplain.

3. Most crossings of the SR were observed when caribou were harassed by insects, and crossing sites appeared to be associated with areas where drainages transected the SR. Crossing success of both individuals and groups was generally >90% and away from sites of local construction.

4. Except for some avoidance of local construction activity, distribution and composition appeared to be unaffected by development.

III. Initial Construction (1981-84)

A. Precalving (10-25 May)

1. Numbers of caribou, group size, and calf (short-yearling) percentage increased annually, suggesting some habituation to the road system.

2. Caribou were concentrated in the middle sections of both the SR and OR, and most avoided CPF-1. Sighting rates, group size, and calf percentages were higher along the OR than the SR. This may have been a response to heavier traffic along the SR and/or the presence of the Kuparuk Pipeline.

3. Even though caribou avoided CPF-1, caribou were distributed closer to the road than in other seasons. They were attracted to adjacent snow-free areas caused by dust from traffic. However, the majority of these caribou were bulls, barren cows, and short yearlings--not maternal cows.

B. Calving (2-30 Jun)

1. Few adult caribou or calves were observed from the road during the first 2 weeks of June. Even nonmaternal caribou, which appeared habituated to the road in May, moved away during the calving period.

2. Caribou were concentrated in the middle sections of both the OR and SR, avoiding the CPF-1 area, as well as other sections of the road system with more traffic and local construction.

3. Few caribou were observed crossing roads, even though increasing numbers of caribou were present in the Milne Point calving area.

C. Midsummer (1 Jul-7 Aug)

1. Sighting rates, group sizes, and calf percentages were substantially higher during midsummer than during calving. With the appearance of parasitic insects, cow/calf groups became less sensitive to human activity.

2. Numbers of caribou observed increased each year; however, both calf percentage and mean group size were highly variable because of differences in initial calf production of the herd and dissimilar patterns of insect harassment. The relative abundance of caribou and calves within 1,000 m of the road also increased, indicating some habituation to local disturbance.

3. After construction of the Kuparuk Pipeline, caribou avoided the SR when harassed by insects and circumvented CPF-1 to the west enroute to coastal insect relief habitat. In 1982 and 1983, caribou moving south after cessation of insect harassment approached to within a few kilometers of the SR, paralleled the Kuparuk pipeline until west of CPF-1, and then moved south to foraging areas. In 1984, however, sighting rate, group size, and calf percentage along the SR increased because a number of groups crossed the Kuparuk Pipeline directly instead of detouring to the west.

4. Although the Kuparuk River remained a node of road crossing activity throughout the period, most additional crossings of the road/pipeline observed were along the OR. In 1981 and 1982, after the construction of the Kuparuk Pipeline, most large insect-harassed groups were unsuccessful in crossing the road/pipeline complex, depressing individual crossing success. By the end of the period, only about half of both individual caribou and groups crossed successfully. Crossing groups continued to be dominated by maternal cows, except within the Kuparuk floodplain.

5. In general, caribou avoided the SR/Kuparuk Pipeline when moving to and from insect relief. By 1984, however, some habituation was evident; caribou moving inland were observed closer to the road and were more successful in their attempts to cross the Kuparuk Pipeline.

IV. Advanced Construction (1985-90)

A. Precalving (11-24 May)

1. In 1986, after construction of pipelines along the OR, sighting rate, group size, and calf percentage decreased to the lowest values recorded. Caribou were concentrated between CPF-1 and CPF-3 within the dust shadow caused by heavy traffic.

2. With the increasing complexity of the oilfield and heavy traffic, caribou occupancy along the road system in 1986 was reduced to low numbers of highly habituated caribou.

B. Calving (1-20 Jun)

1. After 1985, sighting rates, mean group sizes, and calf percentages declined and remained low until 1990, when sighting rate increased. However, after 15 June 1990, the percentage of calves in groups observed from the road was considerably lower than the regional estimate.

2. At the end of the period, most caribou were found in stationary groups between CPF-1 and CPF-2.

3. Few caribou crossed the road/pipeline, and the largest groups continued to be least successful in crossing.

4. Avoidance of the road system by maternal groups observed during Initial Construction continued during Advanced Construction. Even in 1990, when caribou were unusually abundant in the Kuparuk region, numbers of cows and calves seen along the road transect did not increase.

C. Midsummer (1 Jul-6 Aug)

1. During the period, the proportion of caribou seen within 1,000 m of the road increased, but sighting rates and mean group sizes decreased to levels recorded during Initial Construction.

2. Under insect harassment, increasing numbers of caribou were observed at the extremes of the road transect. Caribou crossed the road northbound at the Kuparuk River and eastbound near Oliktok Point. When insects were not active caribou were more evenly distributed along the road system. After closure of Service City camp and following termination of heavy construction activity near the Kuparuk River, calf percentages within the Kuparuk floodplain returned to values similar to regional estimates.

3. For observations under insect and non-insect conditions combined, statistical comparisons of sighting rate, group size, and calf percentage indicate that more caribou and calves were closer to the road, but that group size was generally smaller. In contrast, during Initial Construction, maternal groups tended to be farther from the road when insects were inactive. This change indicates some habituation to the road by cows and calves.

4. Although the number of observed road or pipeline crossing attempts declined after 1988, crossing success increased steadily following the decline noted immediately after construction of the Kuparuk Pipeline in 1981. In 1990, group and individual crossing success was the highest for the decade. Crossings involving separate roads and pipelines were less successful after 1988, however, when crossing groups were thwarted by heavy vehicular traffic.

V. Recommendations

We recommend that precalving and calving surveys be suspended. Maternal group avoidance of the road noted at the onset of pipeline construction has persisted. Annual transect data from helicopter surveys of Kuparuk calving areas should suffice as "snapshots" of regional calving distribution. However, annual road surveys during summer should continue as a means of monitoring changes in caribou abundance and composition along the road system, estimating regional sex and age composition, and documenting the movements of large insect-harassed groups of caribou within and adjacent to the oilfield complex.

APPENDIX C

CALVING SUCCESS OF FEMALE CARIBOU IN RELATION TO BODY WEIGHT

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In late September and October 1987-90 and early July 1988-91, 68 radio-collared female caribou (*Rangifer tarandus granti*) of the Central Arctic Herd were captured and weighed 121 times. Caribou were relocated repeatedly during early June 1988-91; parturition status, calving date, and perinatal calf survival were determined. Mean autumn body weights of subsequently parturient (89.4 kg) and nonparturient (82.4 kg) females differed significantly ($\underline{P} < 0.01$). Mean summer weights approximately 1 month after parturition were significantly higher for females that had calved on or before 7 June (82.2 kg), rather than after 7 June (72.1 kg, $\underline{P} < 0.01$); and for females whose calves survived at least 2 days postpartum (80.2 kg) vs. those whose calves died within 2 days (70.3 kg, $\underline{P} < 0.01$). Significant logistic models were generated for relationships between parturition rate and autumn weight ($\underline{P} < 0.01$), between the occurrence of early calving and summer weight ($\underline{P} < 0.05$), and between calf survival rate and summer weight ($\underline{P} < 0.02$). Body weight appears to be a reasonable index of body condition which, in turn, is related to reproductive performance. The probability of a successful pregnancy is largely predetermined at breeding based on fall condition, whereas calving date and early calf survival appear to be influenced by maternal condition during late pregnancy.

INTRODUCTION

The body condition of female reindeer and caribou (*Rangifer tarandus* spp.) at breeding appears to have a strong influence on subsequent reproductive success. Dauphine (1976) determined that body weight and fat content in autumn were higher among pregnant, than among nonpregnant Canadian barren-ground caribou (*R. t. groenlandicus*), and Reimers (1983*a*) reported a positive relationship between pregnancy rate of wild reindeer (*R. t. tarandus*) and autumn dressed weight. Thus, females in good condition are more likely to conceive than those in poor condition.

The timing of parturition may be a function of either autumn or overwinter condition. Large mature female caribou tend to calve earlier than small young females (Bergerud 1975), but the underlying mechanism is unclear. Reimers (1983*b*) reported that calving date of wild reindeer populations varied inversely with autumn dressed weight of adult females, suggesting that breeding may be initiated earlier if body reserves are sufficient for fetal development. Skogland (1983, 1984), however, related late calving to low food availability in winter. Differences in calving date may be attributable to a nutritional effect on breeding date, gestation length, or both.

Perinatal calf survival has been linked to maternal condition during the previous winter. Skogland (1984) observed high rates of early calf mortality among wild reindeer following winter undernutrition; depressed fetal growth and low birth weights were associated with reduced viability of near-term fetuses or neonates. Offspring losses at or near parturition ostensibly reflect a relative intolerance for nutritional stress during late gestation.

Thus far, investigations of the role of condition in the reproductive performance of free-ranging *Rangifer* have been based on carcass analysis, uterine/ovarian examination, or population-level estimates of calf production. Such methods preclude a determination of the calving success of individual females after assessment of body condition. We report here on the reproductive performance of radio-collared Alaskan barren-ground caribou (*R. t. granti*) observed in June relative to their live weights during the previous September or October, and also during the following July. We show that parturition rate is closely related to fall body weight, whereas both calving date and perinatal calf survival are best explained by summer weight.

METHODS

In late September and October 1987-90, 29 adult female caribou from the Central Arctic Herd (Cameron and Whitten 1979) were darted (3-4 mg Carfentanil citrate/100 kg, or 1-2 mg Carfentanil citrate with 19-42 mg Xylazine hydrochloride/100 kg) from a helicopter (Hughes 500D or Bell 206B), equipped with VHF transmitter collars (where appropriate), and weighed (Table 1) to the nearest kg using a net and tripod-mounted spring scale. Drug antagonists were then administered (150 mg Naloxone/mg Carfentanil citrate, intramuscular; 20 mg Yohimbine, intravenous, as necessary, to enhance recovery from Xylazine hydrochloride), and the animal was released.

During late May and June 1988-91, each radio-collared female was relocated every 1-3 days by PA-18 Super Cub using standard telemetry techniques. Parturition status was ascertained by calf presence, or inferred from the timing of antler shedding and/or udder distension (Whitten 1991*a*; Whitten *et al.* 1991). The calving date for each pregnant female was estimated from successive observations. Most maternal females were also relocated 1-3 times within 3-4 days after calving to identify any perinatal calf mortality, which was judged to have occurred if a calf was either observed dead or not seen with its dam during the 2-day period postpartum (Whitten *et al.* 1991). Following calving, in early July 1988-91, 62 females of known parturition status were darted (2-5 mg Carfentanil citrate/100 kg, or 2-3 mg Carfentanil citrate with 21-53 Xylazine hydrochloride/100 kg), radio-collared, and weighed (Table 1), as described above.

Body weight in late September or October served as estimators of condition at breeding. Weights in early July were used as indices of condition during late gestation; in so doing, we assumed that maternal weight change during the period from approximately 2 months prepartum to 1 month postpartum was reasonably constant across years.

Analyses were restricted to females observed with a calf at heel when collared or, in instances of recapture, those known to have calved previously. Mean body weights for the categories of parturition status, calving date, and perinatal calf survival were compared using modified t-tests. Not all observations were independent, as some females were weighed more than once (Table 1). Therefore, the mean for each individual was computed as a ratio of the sum of the weights to the number of observations in a category, and a two-sample comparison was made (Cochran 1977:181). Functional relationships between reproductive variables and weight were described by univariate logistic regression (Gauss, Version 2.1 Applications programs) of the form

$$\pi(x) = \frac{e^{\beta_0 + \beta_1 x}}{1 + e^{\beta_0 + \beta_1 x}} \times 100, \qquad (1)$$

where π is the percent probability of each response variable occurring at body weight x; logistic models were checked for goodness-of-fit (Lemeshow and Hosmer 1982). Collinearity between autumn and summer body weight was evaluated with Pearson's correlation coefficient. In all cases, P-values <0.05 were considered statistically significant.

RESULTS

Autumn body weights of radio-collared caribou differed with respect to parturition status (Table 2). Females that produced calves were, on average, 7 kg heavier than those that did not. Weight differences in summer, however, were associated with both calving time and offspring viability. Mean weight of females that had calved during the first week of June was 10 kg higher than for those calving later in the month, and females with calves that had survived at least 48 hour postpartum averaged 10 kg heavier than those whose calves had died.

Mathematical models relating parturition rate, the incidence of early calving, and perinatal survival to body weight (Fig. 1, Table 3) were consistent with the above pattern of mean weights. A significant logistic regression for parturition rate was generated only when fall body weight was used as the explanatory variable, despite strong collinearity between paired autumn and summer weights (n = 30, r = 0.47, P = 0.008). In contrast, significant models for both early calving and perinatal survival were based on summer body weight; paired weights were weakly collinear (n = 17 and 19, r = 0.43 and 0.44, P = 0.076 and 0.065, respectively).

DISCUSSION

Parturition

Parturition rate may be closely tied to autumn body weight, in general agreement with previous reports of direct relationships between pregnancy or parturition rate and live or dressed weight of female barren-ground caribou (Dauphine 1976), wild reindeer (Reimers 1983a), and domestic reindeer (Eloranta and Nieminen 1986) in autumn. Similarly, pregnancy rate based on winter collections has been shown to vary directly with both intact weight of Peary caribou (*R. t. pearyi*) (Thomas 1982) and dressed weight of domestic reindeer (Lenvik *et al.* 1988). Thus, as an index of condition, the body weight of a female reindeer or caribou at or within a few months after breeding is an important determinant of the likelihood of conceiving and carrying a fetus to term. Body fat or body protein content, rather than body weight itself, appears to influence breeding success (Thomas 1982; Adamczewski *et al.*

1987; Allaye-Chan 1991; Crete *et al.* 1991) through an effect on ovulation (Leader-Williams and Rosser 1983). Although the metabolic mechanism is largely unknown (Ryg 1986), a possible nutritional signal or modulator to the endocrine system is an increased supply of branched-chain amino acids (Downing *et al.* 1990).

Rates of *in utero* mortality were apparently low. Summer weight did not differ with parturition status (Table 2), nor did parturition rate vary over the observed range of summer body weights (Fig. 1), suggesting that fetal development proceeded irrespective of female condition during late gestation. Likewise, both Dauphine (1976) and Reimers (1983*a*) reported negligible fetal losses, and D. E. Russell (Canadian Wildlife Service, pers. comm.) noted that all 16 radio-collared females of the Porcupine Herd, determined to be pregnant in November 1990, calved in June 1991. Skogland (1984) suspected higher *in utero* mortality among wild female reindeer in a high-density population, but acknowledged difficulties in distinguishing between losses of near-term fetuses and neonatal calves. In contrast, Gates *et al.* (1986) reported probable abortions among some barren-ground caribou on Coats Island following winter starvation. Hence, prenatal mortality may occur under severe circumstances, but it appears that conception and parturition rates are effectively equivalent. For the most part, if conception is achieved, fetal development assumes a high metabolic priority. While the possibility of abortion or premature births resulting from chronic undernutrition cannot be ruled out, the incidence of such mortality is ostensibly uncommon, at least for mainland *Rangifer* populations under conditions similar to those in our study.

Finally, the relationship between parturition rate and autumn body weight, although highly significant, does not entirely preclude age-dependent effects. By restricting the analysis to fecund females (see Methods), any condition-unrelated complications associated with the age of first reproduction were eliminated. Nonetheless, it is conceivable that younger age classes were overrepresented in our sample of nonparturient females. Reimers (1983*a*) suspected that the pregnancy rate of yearling reindeer was lower than expected on the basis of autumn dressed weight, but reported that all females ≥ 3 years of age at breeding conformed with mathematical predictions of pregnancy rate based on weight alone. Likewise, Dauphine (1976) detected no among-age differences in pregnancy rate of females ≥ 3 years old. Whitten (1991*b*), however, observed lower parturition rates among both 3- and 4-year-old female caribou than among those older than 4 years. Age may therefore be implicated in the reproductive success of sexually mature females, but probably only to a minor extent.

Calving date

A direct relationship between the incidence of early calving and female body condition during the following July (Fig. 1) implies that maternal undernutrition late in gestation might delay parturition, a view supported by other work. In experiments on penned reindeer, Espmark (1980) noted that underfed females calved several days later than well-nourished controls. Similarly, Skogland (1983) reported later calving by wild reindeer following winters of deep, persistent snow when females were in poor condition, and suggested that parturition is postponed until the fetus attains a certain critical size. Bergerud (1975) concluded that breeding dates of caribou vary little between years and that variable calving dates may result from nutritionally related differences in gestation length. Such a mechanism is consistent with findings for other cervids (Bowyer 1991).

Alternatively, body condition at or near breeding may alter calving date via an effect on conception time. Baskin (1970) noted that "poorly fattened" domestic reindeer ovulate later than those in the best condition, and Reimers (1983*b*) reported a significant inverse relationship between mean autumn dressed weight of females and median calving date in eight populations of wild reindeer. Based on data from reindeer slaughtered approximately 4 months post-rut, Lenvik (1988) obtained inverse correlations between conception date (estimated from fetal age; Roine *et al.* 1982) and female dressed weight. However, Dauphine and McClure (1974), employing a similar approach for barren-ground caribou collected in autumn, found no relationship between conception date and either body weight or fat content.

The mechanism by which the timing of parturition varies is therefore uncertain. Despite the absence of a significant relationship between calving time and autumn body weight (Table 3), our data do not negate the possibility of delayed ovulation among barren-ground caribou. Logically, female condition during either summer *or* late winter could be implicated, depending upon the timing of food limitation (Skogland 1984). For example, a late spring followed by a particularly severe insect season might depress condition and delay ovulation, but whether the effect would be manifested as a subsequent reduction in parturition rate or as later calving remains conjectural.

The genetic makeup and movement characteristics of *Rangifer* populations may also influence the timing of parturition, independent of nutritional status. Norwegian wild reindeer originating from domestic stock generally calve earlier than their truly wild counterparts; and, within a genetic line, calving tends to be earlier for migratory than for resident reindeer (Skogland 1983).

The consequences of delayed parturition are potentially serious. Late-born calves have less opportunity for growth and development before the onset of winter (Baskin 1970; Bergerud 1975; Skogland 1983, 1985) and are therefore more likely to suffer mortality due to predation and undernutrition (Dauphine and McClure 1974; Bergerud 1975; Couturier *et al.* 1990). Moreover, females calving late might be unable to complete lactation in time to replenish their own body reserves by autumn, thereby reducing their chances of conceiving that year (Skogland 1985).

Calf survival

Among the caribou sampled, perinatal calf survival varied directly with the weight of females shortly after calving. This relationship is consistent with other reports that maternal weight or food intake of *Rangifer* during late pregnancy is positively correlated with calf birth weight (Varo and Varo 1971; Bergerud 1975; Espmark 1980; Rognmo *et al.* 1983; Skogland 1984; Eloranta and Nieminen 1986; Adamczewski *et al.* 1987) and early survival (Rognmo *et al.* 1983; Skogland 1984; Eloranta and Nieminen 1986; Adamczewski *et al.* 1987). Evidently, if maternal reserves and food intake are insufficient to accommodate the increasing requirements of fetal growth (McEwan 1970; McEwan and Whitehead 1972; Robbins and Moen 1975; Oftedal 1985), a smaller, less viable neonate will be produced. Body protein content, in particular, appears to influence fetal and newborn weights of caribou (Allaye-Chan 1991; Allaye-Chan and White 1991).

The effect of calf birth weight on survival apparently extends beyond the perinatal stage. Domestic reindeer calves that survive the entire calving period (2-3 weeks) are heavier at birth than those that die (Eloranta and Nieminen 1986). Low weight at birth, and an associated low survival rate, may (Espmark 1980) or may not

(Rognmo *et al.* 1983) be sustained through summer--depending upon both milk production, as influenced by maternal nutrition (White and Luick 1984; White 1991), and the degree of compensatory feeding possible on a given summer range (Rognmo et al. 1983; White 1991). Even surviving calves that remain small up to 6 weeks postpartum may be subject to higher mortality through autumn (Haukioja and Salovaara 1978).

<u>Body weight as a condition index</u>

Though statistically meaningful as an explanatory variable for caribou reproductive success, unadjusted body weight is not necessarily an accurate representation of body condition. Protein and fat content may vary independent of live weight (Allaye-Chan 1991; Allaye-Chan and White 1991), as can the contribution of alimentary fill (Cameron *et al.* 1975; Staaland *et al.* 1979; Adamczewski *et al.* 1987; White *et al.* 1987; Huot 1989), obscuring the interpretation of weight changes or differences. Variations in skeletal size introduce additional errors when body weight is used as the sole estimator of condition. It may be appropriate, therefore, to incorporate numerical condition scores with body weight determinations (Gerhart *et al.* 1992) or to scale body weight according to one or more morphometric measurements (Huot 1988).

Inaccuracies notwithstanding, the highly significant relationship between parturition rate and fall body weight, in particular, is potentially of practical value in caribou management. Specifically, if it can be demonstrated that the logistic regression applies also to subadult (i.e., nonfecund) females, and if the fall weight distribution of females in a population can be determined, an overall parturition rate can be predicted with some confidence.

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ADAMCZEWSKI, J. Z., GATES, C. C., HUDSON, R. J., and PRICE, M. A. 1987. Seasonal changes in body composition of mature female caribou and calves (*Rangifer tarandus groenlandicus*) on an arctic island with limited winter resources. Can. J. Zool. **65**: 1149-1157.

ALLAYE-CHAN, A. C. 1991. Physiological and ecological determinants of nutrient partitioning in caribou and reindeer. Ph.D. thesis, University of Alaska Fairbanks, Fairbanks, Alaska.

_____, and WHITE, R. G. 1991. Body condition variations among adult females of the Porcupine Caribou Herd. *In* Proceedings of the Fourth North American Caribou Workshop, 31 Oct-3 Nov 1989, St. John's, Newfoundland. *Edited by*

C. E. Butler and S. P. Mahoney. Newfoundland and Labrador Wildl. Div., St. John's, Newfoundland. pp. 103-108.

BASKIN, L. M. 1970. Reindeer ecology and behavior [in Russian]. Nauka AS USSR, Moscow.

BERGERUD, A. T. 1975. The reproductive season of Newfoundland caribou. Can. J. Zool. **53**: 1213:1221.

BOWYER, R. T. 1991. Timing of parturition and lactation in southern mule deer. J. Mammal. **72**: 138-145.

CAMERON, R. D., WHITE, R. G., and LUICK, J. R. 1975. The accumulation of water in reindeer during winter. *In* Proceedings of the First International Reindeer/Caribou Symposium, Aug. 9-11, 1972, University of Alaska, Fairbanks. *Edited by* J. R. Luick, P. C. Lent, D. R. Klein, and R. G. White. Biol. Pap., University of Alaska, Spec. Rep. No. 1. pp. 374-378.

_____, and WHITTEN, K. R. 1979. Seasonal movements and sexual segregation of caribou determined by aerial survey. J. Wildl. Manage. **43**: 626-633.

COCHRAN, W. G. 1977. Sampling techniques. John Wiley and Sons, New York.

COUTURIER, S., BRUNELLE, J., VANDAL, D., and ST-MARTIN, G. 1990. Changes in the population dynamics of the George River caribou herd, 1976-87. Arctic **43**: 9-20.

CRETE, M., HUOT, J., NAULT, R., and PATENAUDE, P. 1992. Reproduction, growth, and body composition of Riviere George caribou taken into captivity. *Abstract*. Rangifer. In press.

DAUPHINE, T. C., JR. 1976. Biology of the Kaminuriak population of barren-ground caribou. Part 4. Growth, reproduction, and energy reserves. Can. Wildl. Serv. Rep. Ser. No. 38.

_____, and McCLURE, R. L. 1974. Synchronous mating in Canadian barren-ground caribou. J. Wildl. Manage. **38**: 54-66.

DOWNING, J. A., SCARAMUZZI, R. J., and JOSS, J. 1990. Infusion of branched chain amino acids will increase ovulation rate in the ewe. Proceedings of the Austr. Soc. Animal Prod. **18**: 472.

ELORANTA, E., and NIEMINEN, M. 1986. Calving of the experimental reindeer herd in Kaamanen during 1970-85. Rangifer, Spec. Issue No. 1: 115-121.

ESPMARK, Y. 1980. Effects of maternal pre-partum undernutrition on early mother-calf relationships. *In* Proceedings of the Second Reindeer/Caribou Symposium, Sep. 17-21, 1979, Roros, Norway. *Edited by* E. Reimers, E. Gaare, and S. Skjenneberg. Direktoratet for vilt og ferskvannsfisk, Trondheim. pp. 485-496.

GATES, C. C., ADAMCZEWSKI, J., and MULDERS, R. 1986. Population dynamics, winter ecology and social organization of Coats Island caribou. Arctic **39**: 216-222.

GERHART, K. L., WHITE, R. G., and CAMERON, R. D. 1992. Field estimation of body composition in caribou and reindeer using bioelectrical impedence analysis and body condition scores. *Abstract*. Rangifer. In press.

HAUKIOJA, E., and SALOVAARA, R. 1978. Summer weight of reindeer (*Rangifer tarandus*) calves and its importance for their future survival. Rep. Kevo Subarctic Res. Sta. **14**: 1-4.

HUOT, J. 1989. Body composition of the George River caribou (*Rangifer tarandus caribou*) in fall and late winter. Can. J. Zool. **67**: 103-107.

_____. 1988. Review of methods for evaluating the physical condition of wild ungulates in northern environments. Centre d'etudes nordiques, University of Laval, Collection Nordicana No. 50.

LEADER-WILLIAMS, N., and ROSSER, A. M. 1983. Ovarian characteristics and reproductive performance of reindeer, *Rangifer tarandus*. J. Reprod. Fert. **67**: 247-256.

LEMESHOW, S., and HOSMER, D. W. 1982. The use of goodness-of-fit statistics in the development of logistic regression models. Am. J. Epidemiol. **115**: 92-106.

LENVIK, D. 1988. Selection strategy in domestic reindeer. 6. Oestrus peak and oestrus synchronization in domestic reindeer in Trondelag County, Norway. Norsk landbruksforskning **2**: 163-174.

_____, GRANEFJELL, O., and TAMNES, J. 1988. Selection strategy in domestic reindeer. 5. Pregnancy in domestic reindeer in Trondelag County, Norway. Norsk landbruksforskning **2**: 151-161.

McEWAN, E. H. 1970. Energy metabolism of barren-ground caribou (*Rangifer tarandus*). Can. J. Zool. **48**: 391-392.

_____, and WHITEHEAD, P. E. 1972. Reproduction in female reindeer and caribou. Can. J. Zool. **50**: 43-46.

OFTEDAL, O. T. 1985. Pregnancy and lactation. *In* Bioenergetics of Wild Herbivores. *Edited by* R. J. Hudson and R. G. White. CRC Press, Boca Raton, FL. pp. 215-238.

REIMERS, E. 1983*a*. Reproduction in wild reindeer in Norway. Can. J. Zool. **61**: 211-217.

_____. 1983*b*. Growth rate and body size differences in *Rangifer*, a study of causes and effects. Rangifer **3**: 3-15.

ROBBINS, C. T., and MOEN, A. N. 1975. Uterine composition and growth in white-tailed deer. J. Wildl. Manage. **39**: 684-691.

ROGNMO, A., MARKUSSEN, K. A., JACOBSEN, E., GRAV, H. J., and BLIX, A. S. 1983. Effects of improved nutrition in pregnant reindeer on milk quality, calf birth weight, growth, and mortality. Rangifer **3**: 10-18.

ROINE, K., NIEMINEN, M., and TIMISJARVI, J. 1982. Foetal growth in the reindeer. Acta Vet. Scand. **23**: 107-117.

RYG, M. 1986. Physiological control of growth, reproduction and lactation in deer. Rangifer, Spec. Issue No. 1: 261-266.

SKOGLAND, T. 1983. The effects of density-dependent resource limitation on size of wild reindeer. Oecologia **60**: 156-168.

_____. 1984. The effects of food and maternal conditions on fetal growth and size in wild reindeer. Rangifer **4**: 39-46.

_____. 1985. The effects of density-dependent resource limitations on the demography of wild reindeer. J. Anim. Ecol. **54**: 359-374.

STAALAND, H., JACOBSEN, E., and WHITE, R. G. 1979. Comparison of the digestive tract in Svalbard and Norwegian reindeer. Arctic and Alpine Res. **11**: 457-466.

THOMAS, D. C. 1982. The relationship between fertility and fat reserves of Peary caribou. Can. J. Zool. **60**: 597-602.

VARO, M., and VARO, H. 1971. The milk production of reindeer cows and the share of milk in the growth in reindeer calves. J. Sci. Agr. Soc. Finl. **43**: 1-8.

WHITE, R. G. 1991. Nutrition in relation to season, lactation and growth of north temperate deer. *In* The Biology of Deer. *Edited by* R. D. Brown. Springer-Verlag, New York. pp. 407-417.

_____, R. G., HOLLEMAN, D. F., HUBBERT, M. E., and STAALAND, H. 1987. Herbivores in cold climates. *In* The Nutrition of Herbivores. *Edited by* J. B. Thacker and J. H. Tennouth. Academic Press. Sydney, Olando. pp. 465-486.

_____, and LUICK, J. R. 1984. Plasticity and constraints in the lactational strategy of reindeer and caribou. *In* Physiological Strategies in Lactation. *Edited by* M. Peaker, R. G. Vernon, and C. H. Knight. Symp. Zool. Soc. London No. 51, Academic Press. pp. 215-232.

WHITTEN, K. R. 1991*a*. Antler retention and udder distension as indicators of parturition in free-ranging caribou. *In* Proceedings of the Fourth North American Caribou Workshop, 31 Oct-3 Nov 1989, St. John's, Newfoundland. *Edited by* C. E. Butler and S. P. Mahoney. Newfoundland and Labrador Wildl. Div., St. John's, Newfoundland. pp. 170-173.

_____. 1991*b*. Reproductive rates of radio-collared females in the Porcupine Caribou Herd. *In* Proceedings of the Fourth North American Caribou Workshop, 31 Oct-3 Nov 1989, St. John's, Newfoundland. *Edited by* C. E. Butler and S. P. Mahoney. Newfoundland and Labrador Wildl. Div., St. John's, Newfoundland. pp. 174-177.

_____, GARNER, G. W., MAUER, F. J., and HARRIS, R. B. 1992. Productivity and early calf survival in the Porcupine caribou herd. J. Wildl. Manage. In press.

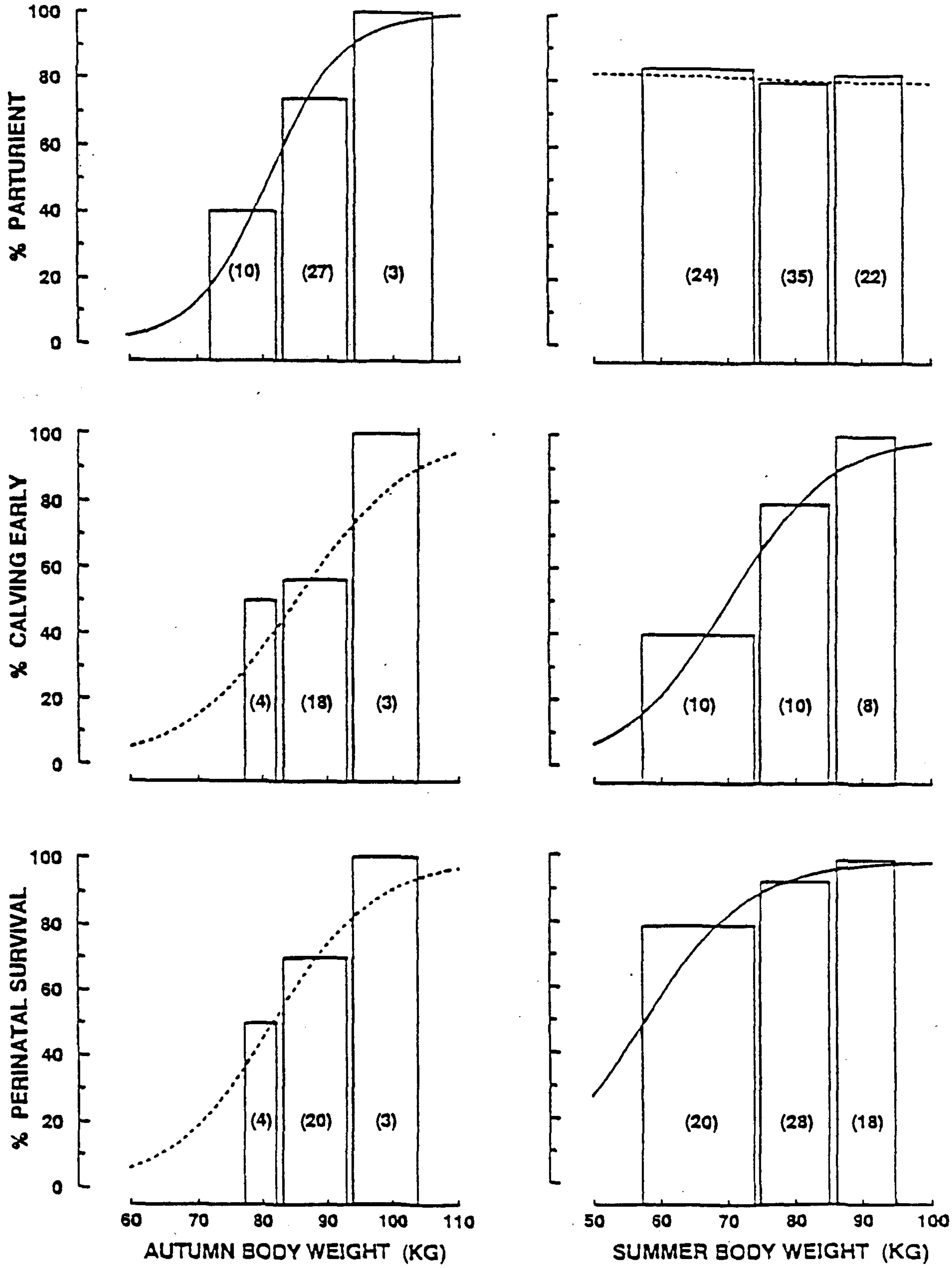


Fig. 1. Parturition rate, incidence of early calving (i.e., on or before 7 June), and perinatal calf survival (i.e., 2 days postpartum) relative to fall and summer body weights of female caribou, Central Arctic herd, 1987-91. Numbers of weight observations are in parentheses. The fitted logistic regressions are also shown (solid lines, significant at $\underline{P} < 0.05$; Table 3).

Table 1. Numbers of adult female caribou captured and weighed, Central Arctic herd, 1987-91.

Year	Autumn		Summer	
	Inclusive dates	No. captured (recaptured[a])	Inclusive dates	No. captured (recaptured[a])
1987-88	8-28 Oct	13	2-4 Jul	20
1988-89	23 Sep-3 Oct	9(5)	1-6 Jul	22(7)
1989-90	26 Sep-6 Oct	10(4)	2-15 Jul	15(6)
1990-91	4-7 Oct	8(2)	9-13 Jul	24(6)
Totals		40(11)		81(19)

[a] Previously captured once or more within a season.

Table 2. Body weights of radio-collared female caribou[a] in fall and summer relative to parturition status, calving time, and perinatal calf survival/mortality, Central Arctic herd, 1987-91.

	Fall				Summer			
		Body weight, kg				Body weight, kg		
Status[b]	n[c]	Range	Mean ± SE	t-test	n[c]	Range	Mean ± SE	t-test
Parturient[d]	27 (21)	77-106	89.4 ± 1.2		66 (57)	57-95	79.3 ± 1.1	
Nonparturient[e]	13 (12)	72-93	82.4 ± 1.9	$P < 0.01$	15 (14)	63-96	79.5 ± 2.7	$P > 0.9$
Early calving[f]	15 (14)	77-104	91.1 ± 2.0		20 (19)	63-95	82.2 ± 2.0	
Late calving[g]	10 (10)	78-93	86.9 ± 1.4	$P < 0.1$	8 (8)	57-84	72.1 ± 3.0	$P < 0.01$
Perinatal survival[h]	18 (15)	77-104	89.9 ± 1.3		60 (55)	62-95	80.2 ± 1.1	
Perinatal mortality[i]	8 (7)	78-91	86.4 ± 2.0	$P < 0.2$	6 (5)	57-79	70.3 ± 3.8	$P < 0.01$

[a] All fecund: calf at heel when collared, or reproductive activity observed previously.

[b] Based on observations during the June calving period.

[c] No. of weight observations (no. of caribou).

[d] Calf at heel, or distended udder observed.

[e] No calf at heel, no distended udder, and/or antlers shed before 1 June.

[f] Calved on or before 7 June.

[g] Calved after 7 June.

[h] Calf alive ≥48 h post-partum.

[i] Calf confirmed dead or not observed with its dam <48 h post-partum.

Table 3. Parameter estimates of logistic models describing relationships between reproductive variables and body weight (Fig. 1).

	Fall				Summer			
		Parameter estimate[b]				Parameter estimate[b]		
Response variable[a]	n	β_0	β_1	P[c,d]	n	β_0	β_1	P[c,d]
Parturient	40	-14.215	0.174	<0.01	81	1.686	-0.003	>0.9
Early calving	39	-9.710	0.114	<0.2	28	-9.115	0.130	<0.05
Perinatal survival	26	-10.199	0.125	<0.2	66	-7.282	0.127	<0.02

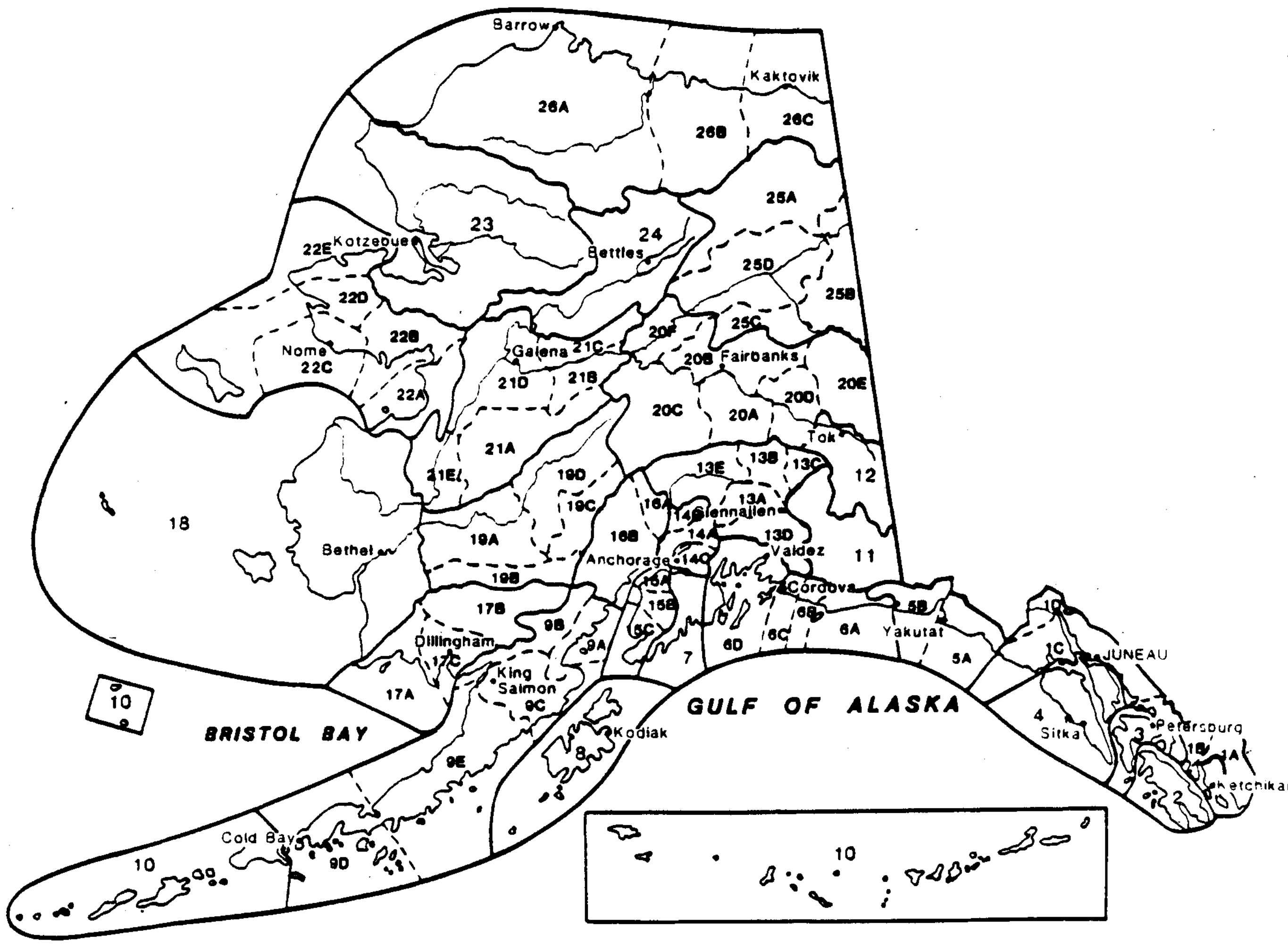
[a] See footnotes, Table 2.

[b] See equation (1).

[c] Probability that $\beta_1 = 0$.

[d] No evidence for lack-of-fit.

Alaska's Game Management Units



WILDLIFE RESTORATION

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