Alaska Department of Fish and Game
Division of Wildlife Conservation
Federal Aid in Wildlife Restoration
Research Progress Report

Distribution and Productivity of the Central Arctic Caribou Herd in Relation to Petroleum Development:

Case History Studies with a Nutritional Perspective

by
Raymond D. Cameron
Project W-23-4
Study 3.35
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SUMMARY

Pertinent data on Central Arctic Caribou Herd (CAH) studies have been summarized in 2 interim reports to U.S. Fish and Wildlife Service, which we submit here as appendices. Both Federal Aid objectives are being met:

1. To determine the calving and summer distribution of CAH caribou in relation to oilfield development on the Arctic Coastal Plain (Appendix A).

   In June 1987-90, caribou were counted and classified by helicopter within north-south strip transects extending 35-73 km inland from the coast. At least 4 areas of consistent use during the calving period are apparent. Relatively high densities of caribou were observed both in the uplands southwest of the Kuparuk Development Area (KDA) and between the Kavik and Canning Rivers; lower numbers were found within and immediately west of the KDA and in the general vicinity of Franklin Bluffs.

   Additional June surveys encompassing all of the KDA were flown annually from 1979 through 1990. From 1979 through 1982, caribou were distributed in a single concentration north of the Spine Road. However, after construction of the Milne Point Road in 1982, 2 distinct nodes of use became apparent, one on either side of the road; that separation persisted through 1990. In addition, relatively fewer caribou were observed in transect segments near the expanding CPF-1 and CPF-2 production complexes.

   In June and July 1987-90, systematic surveys were conducted once daily along the Kuparuk Spine Road and Oliktok Road. Caribou ostensibly avoid industrial

development during the calving period, as few caribou and calves were observed along the road system during the first 2 weeks of June. In July, insect-harassed caribou were observed crossing the road transect near Oliktok Point and at the Kuparuk River. Relative numbers of caribou along the road decreased between 1987 and 1990, but higher proportions of caribou and calves were observed closer to the road, suggesting some accommodation to industrial activity. However, large insect-harassed groups still appear to have difficulty reaching coastal insect relief habitat.

2. To determine relationships between body condition and reproductive performance of CAH female caribou (Appendix B).

   In October 1986-90 and July 1988-90, 73 adult female caribou of the Central Arctic and Porcupine Herds were captured (or recaptured), radio-collared, and weighed. Parturition success, calving dates, and early calf survival were determined during June 1987-90, and lactation status was assessed in October 1988-90.

   Radio-collared females producing viable calves within 3 days of the peak of calving were significantly heavier during the previous fall than those that were nonparous, had nonviable calves, and/or calved >3 days after the peak of calving. Furthermore, pregnant/lactating females lost significantly more body weight during winter and spring, and gained significantly less weight during summer and autumn, than reproductively inactive females; females bearing nonviable calves lost more weight over the previous winter than those producing calves that survived. We conclude that female condition in fall is closely related to subsequent reproductive success. Heavier females are more likely to conceive, calve earlier, and bear viable calves. Additionally, the data show that the metabolic burdens of gestation and lactation tend to exacerbate winter weight loss and depress summer weight gain, thereby influencing condition attained in fall and, hence, subsequent fecundity.

Key Words: body condition, caribou, Central Arctic Herd, distribution and movements, oilfield development, population status, reproductive success, summer range

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Appendix A. Caribou Responses to Development Infrastructures and Mitigation Measures Implemented in the Central Arctic Region

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WORK UNIT II Habitat requirements and potential impacts of oil development on caribou

Work Subunit IIb Caribou responses to development infrastructures and mitigation measures implemented in the Central Arctic Region

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INTRODUCTION

The Central Arctic Caribou (*Rangifer tarandus granti*) Herd (CAH) has been exposed to petroleum development in the Prudhoe Bay region for more than a decade. Previous studies have indicated that oilfield complexes directly influence the distribution and movements of CAH caribou (Shideler 1986). Parturient and post-partum females are particularly sensitive to disturbance and tend to avoid areas of human activity, resulting in losses of CAH calving habitat (Whitten and Cameron 1985, Dau and Cameron 1986). In addition, access to portions of summer range has been impaired, either through avoidance of disturbed areas (Smith and Cameron 1983, Whitten and Cameron 1983, Johnson and Lawhead 1988) or because of the impediments to movement posed by roads and pipelines (Smith and Cameron 1985a,b; Curatolo and Murphy 1986). Thus far, habitat losses have included direct losses due to placement of gravel for roads and pads and behavioral losses due to avoidance of nodes of concentrated human activity and access to some areas due to blockage of movement corridors. Habitat losses have been limited to areas occupied by industrial complexes near Prudhoe Bay and within the Kuparuk Development Area (KDA) (Fig. 1). However, concern exists that continued expansion and intensification of oil development within the Central Arctic region could result in large-scale displacement of caribou with the potential for major impacts on herd productivity.

Studies of CAH calving distribution and summer movements in relation to petroleum development were initiated in 1978. Between 1987 and 1990, helicopter strip transects were reinstituted between the Colville and Canning Rivers to assess area-wide calving distribution, and concentrated road and aerial surveys were continued within the KDA. Specific objectives included:

1. To compare the distribution and movements of caribou in the KDA with those of caribou in undeveloped areas.

2. To determine the frequency with which CAH caribou in the KDA encounter development infrastructures.

3. To evaluate the effectiveness of caribou mitigation measures implemented to date within the Prudhoe Bay, Kuparuk, Lisburne, and Endicott production units.

Results herein pertain to Objectives 1 and 2. Objective 3 is to be addressed through a cooperative industry/agency team.

METHODS

Between 10 and 15 June 1987-90, low-level surveys were conducted annually by helicopter (Cameron et al. 1985, Whitten and Cameron 1985) between the Colville and Canning Rivers. Caribou were counted and classified within 24-26 north-south strip transects, each 3.2 km wide and extending 35-73 km inland from the coast (Fig. 2). Additional surveys of the area encompassing the KDA (transects 6-10, Fig. 2) were flown annually from 1979 through 1986. We synthesized the 1987-90 data on calving distribution of the CAH by partitioning each transect into 10.4-km^2 (4-mi^2) segments (or known fractions thereof) and computing the mean percent occurrence of caribou in each.

In June and July 1987-90, systematic surveys (Smith and Cameron 1985a) were conducted once daily along the Kuparuk Spine Road (SR) and Oliktok Road (OR) (Fig. 1), similar to surveys initiated in 1978. Each SR/OR survey began on the east bank of the Kuparuk floodplain (km 0.0), continued through Central Processing Facility-1 (CPF-1) (km 29.3) near the SR/OR junction, and terminated at Oliktok Point (km 56.0).

RESULTS

Aerial Surveys

Sex/age composition of caribou observed during 1987-90 transect surveys between the Colville and Canning Rivers appear in companion reports (Table 4, Fancy et al. 1991; Fig. 4, Cameron et al. 1991). Similar data for coverage within the KDA are summarized in a previous report (Cameron et al. 1988).

At least 4 areas of consistent use during the calving period were noted from the 1987-90 combined data (Fig. 3). Greater than 5 times the expected densities of caribou were observed both in the uplands southwest of the KDA and between the Kavik and Canning Rivers; lower densities (3-5 times) were found within and immediately west of the KDA and in the general vicinity of Franklin Bluffs.

The 1979-90 data on caribou distribution in the KDA were averaged in the same manner for each of 3 intervals: 1979-81, prior to construction of the Oliktok and Milne Point Roads; 1982-86, a period of intermediate development of production facilities; and 1987-90, when the Kuparuk and Milne Point Units approached full production potential (Fig. 1). During the early development period, caribou were clustered north of the Spine Road (Fig. 4). However, after construction of the Milne Point Road in 1982, 2 distinct nodes of use became apparent (Fig. 4). The use of these 2 distinct areas persisted throughout the final period; in addition, relatively fewer caribou were observed in transect segments near the expanding CPF-1 and CPF-2 production complexes. These results graphically demonstrate the effects of road/pipeline construction and facilities development on the distribution of calving caribou.

Road Surveys

The results of 1987-90 road surveillance within the KDA have been incorporated into a 13-year draft report entitled "Distribution and Movements of Caribou in Relation to Roads and Pipelines, Kuparuk Development Area, 1978-90" (W. T. Smith, R. D. Cameron, and D. J. Reed), an Executive Summary of which follows.

1. From 1978 through 1990, the distribution, sex/age composition, and road/pipeline crossing success of Central Arctic Herd caribou in the Kuparuk Development Area (Fig. 1) were determined by systematic road surveys (Smith and Cameron 1985). Observations were subdivided according to the stage of oilfield development:

   Preconstruction (1978-80), prior to any pipeline construction; Initial Construction (1981—84), construction of CPF-1 and the Kuparuk Pipeline; and Advanced Construction (1985-90), placement of production and distribution facilities for CPF-2 and CPF-3.

2. Preconstruction (1978-80)

   a. Midsummer (3 Jul-10 Aug)

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

(2) Overall distribution and movements appeared to be generally 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%.
(4) Except for some avoidance of local construction activity, distribution and composition appeared to be unaffected by development.

3. Initial Construction (1981-84)

a. Precalving (10-25 May)
(1) Numbers of caribou, group size, and calf (short—yearling) percentage increased during the period, suggesting some accommodation to the road system.
(2) Caribou were concentrated in the middle sections of both the OR and SR, and most avoided CPF-1. Sighting rates, group sizes, 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 there was a tendency to avoid CPF-1, caribou were distributed closer to the road than in other seasons. They were attracted to snow-free areas adjacent to the road caused by dust from traffic. However, the majority of these caribou were bulls, barren cows, and short yearlings, and not maternal cows.

b. Calving
(1) Consistently few caribou were observed from the road during the first 2 weeks of June. Even non-maternal females, which appeared less sensitive 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) Observed caribou crossings of roads were infrequent, even though increasing numbers of caribou were present in the Milne Point calving area.

c. Midsummer
(1) Sighting rates, group sizes, and calf percentages were substantially higher during midsummer than during calving. With the appearance of insects, nonparous caribou move into the coastal zone, and resident cow/calf groups become 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 annual 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, suggesting some habituation to local disturbance.

(3) After the construction of the Kuparuk Pipeline, caribou avoided the SR when harassed by insects and circumvented CPF-1 to the west en route 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 turned 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 area remained a node of road crossing activity throughout the period, most of the additional crossings of the road/pipeline observed were along the OR. In 1981 and 1982, after construction of the Kuparuk Pipeline, most large insect-harassed groups were unsuccessful in crossing the SR/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 areas. However, by 1984, 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.

4. Advanced Construction (1985-90)

a. Precalving (10-25 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 decreased substantially.

b. Calving

(1) After 1985, sighting rate, mean group size, and calf percentage 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 less than the regional estimate.

(2) At the end of the period, most caribou were found in stationary groups between CPF-1 and CPF-3.

(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, the numbers of cows and calves seen along the road transect did not increase.

c. Midsummer
(1) During the period, the proportion of caribou seen within 1,000 m increased, but sighting rate and mean group size decreased to levels recorded during Initial Construction.
(2) Under insect conditions, 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 and following termination of heavy construction activity near the Kuparuk River, calf percentage 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 seen 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 suggests some habituation to the road by cows and calves.
(4) Although the number of observed road/pipeline crossing attempts declined after 1988, crossing success increased steadily 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.

5. Road Survey Conclusions: 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, to estimate regional calf percentage by determining the sex/age composition of large aggregations, and to document the movements of insect-harassed groups adjacent to and within the oilfield complex.

CONCLUSIONS

It is evident from aerial surveys of caribou in the KDA that roads, above-ground pipelines, and oil production facilities alter the distribution of caribou during the calving period. Together with previous reports of reduced use of areas adjacent to linear structures near Milne Point (Dau and Cameron 1986), our data suggest that growing oilfields within calving concentration areas will depress the abundance of parturient females in the general vicinity during June. Such a process of gradual withdrawal may explain the paucity of caribou within and adjacent to the Prudhoe Bay oilfield complex (Whitten and Cameron 1985).

Road survey data corroborate the aerial survey findings. Consistently few females with calves have been present along the KDA road system in June, and those observed tended to occupy areas of little development and human activity.

Many of the changes in caribou summer distribution along the SR and OR are also attributable to intensive oilfield development. Reduced use of the CPF-1 area and the road system during calving reflects a partial loss of habitat; and extensive detours around industrial complexes and low road/pipeline crossing success, principally by large groups, indicate that caribou often experience difficulty in their efforts to move between coastal insect relief habitat and inland feeding areas. Given the importance of summer weight gain to subsequent reproductive success (Cameron et al. 1991), interference with foraging and insect avoidance processes could have serious consequences to individual and herd productivity, particularly in years of high insect activity.

MANAGEMENT IMPLICATIONS AND POTENTIAL RESEARCH DIRECTIONS

During the calving period, specifically, parturient females are extremely sensitive to adverse stimuli and withdraw from areas with unfamiliar structures and human activity. Ideally, to ensure that caribou have free access to preferred calving habitats, development within known calving concentration areas should not be authorized. If, however, such development is deemed essential, the infrastructure and the attendant human activity should be reduced to an absolute minimum. On coastal summer range, large dense development complexes should not be constructed in insect relief areas (coastal and inland), nor in areas crossed by caribou during insect-induced movements. Known movement corridors (e.g., in the immediate coastal zone, along drainages) should be preserved to the maximum extent possible through the use of special pipeline crossing structures (preferably buried pipe) and traffic control.

Aerial surveys between the Colville and Canning Rivers should be conducted in alternate years to monitor the overall distribution and sex/age composition of caribou on the CAH calving grounds and, also, to quantify any additional changes in the occurrence of calving caribou in the KDA. Daily surveys along the SR and OR in July should continue as a means of describing the midsummer distribution of caribou in relation to industrial development and to determine their success in crossing various linear structures.

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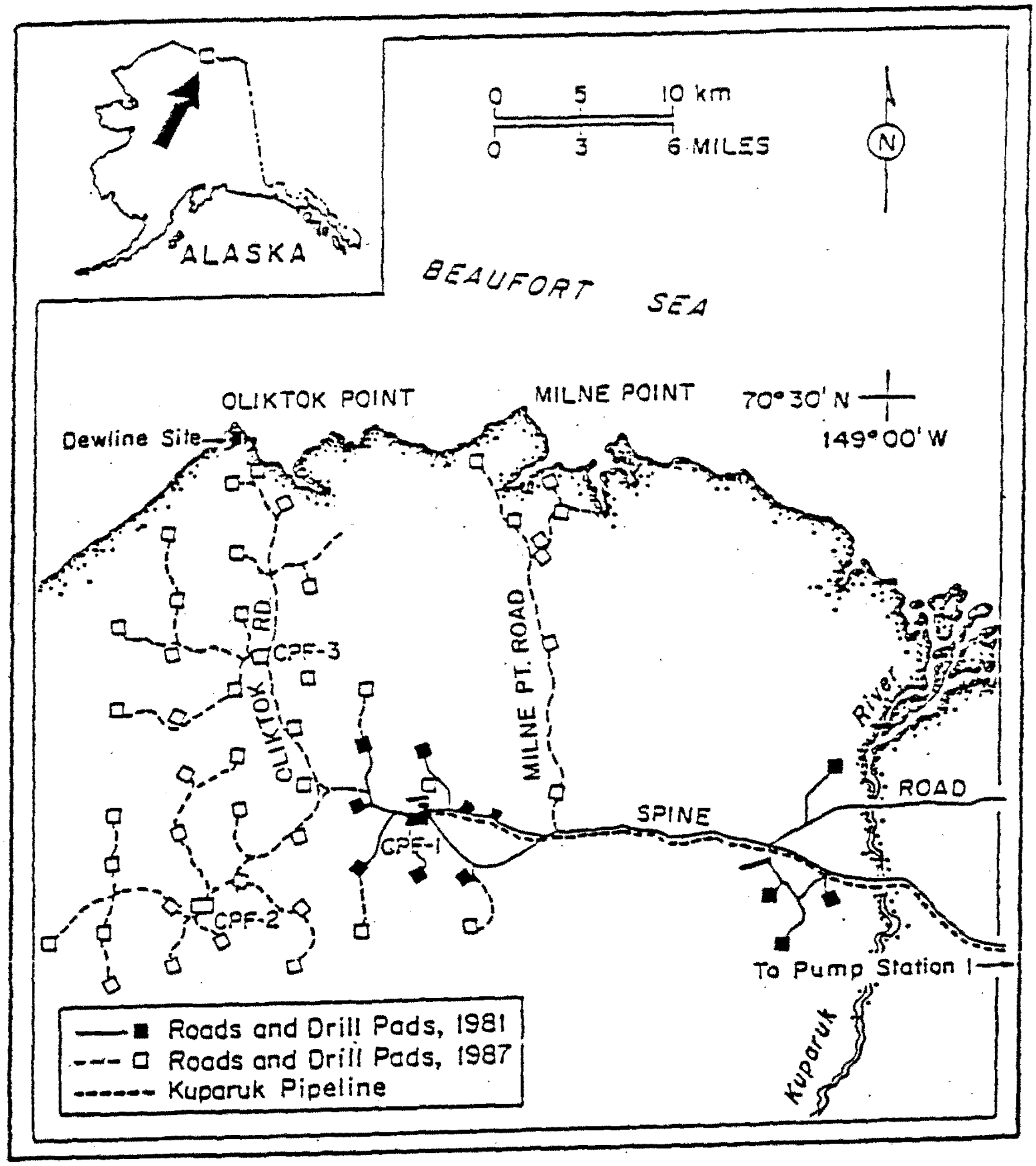

Figure 1. The Kuparuk Development Area, 1981 and 1987.

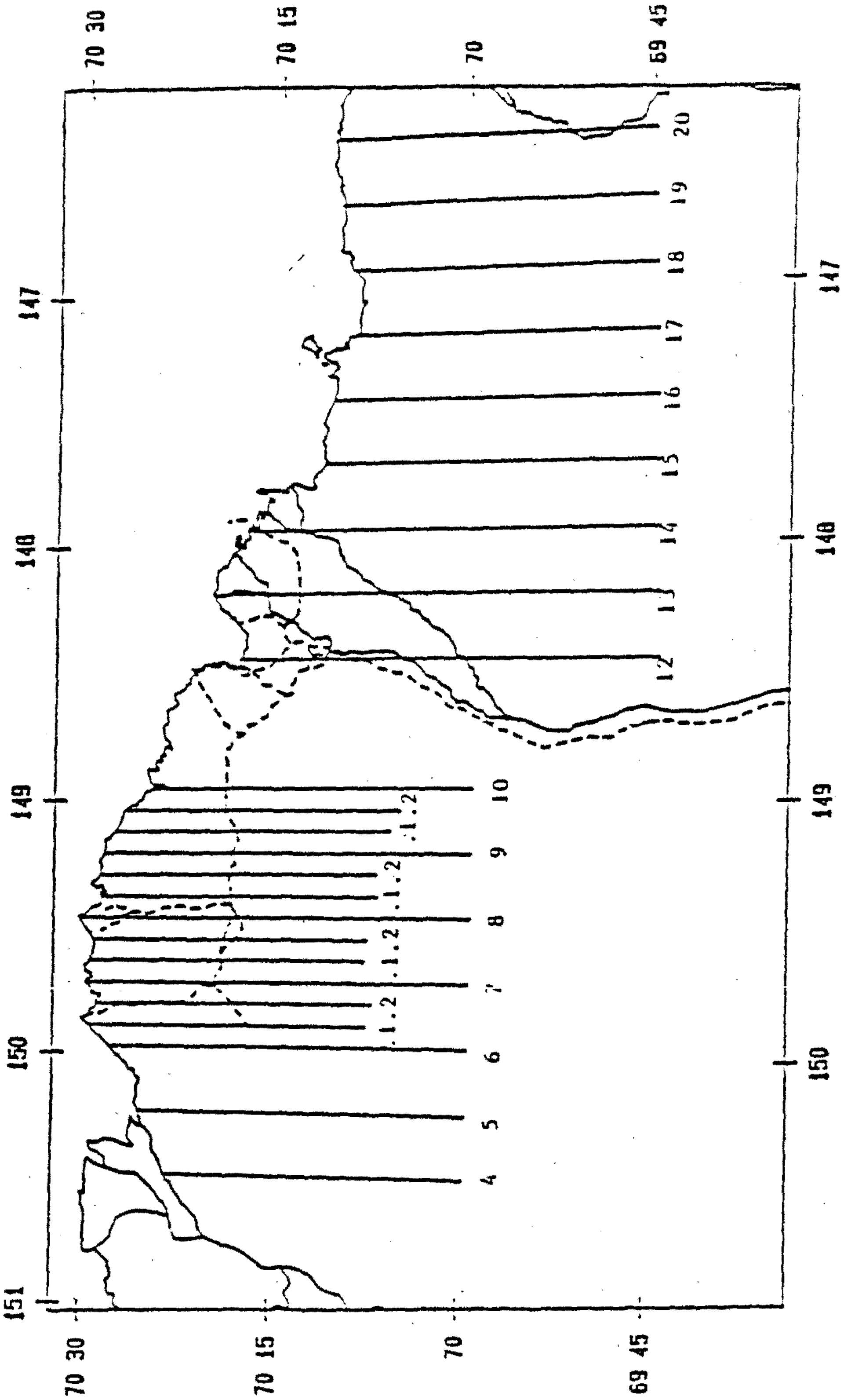

Figure 2. Center lines of transects surveyed by helicopter during calving within range of the Central Arctic Herd. Complete transects 4-20 were used to determine overall calf distribution, and all transects from 6-10 to latitude 70° 15' were used to determine distribution within the KDA.

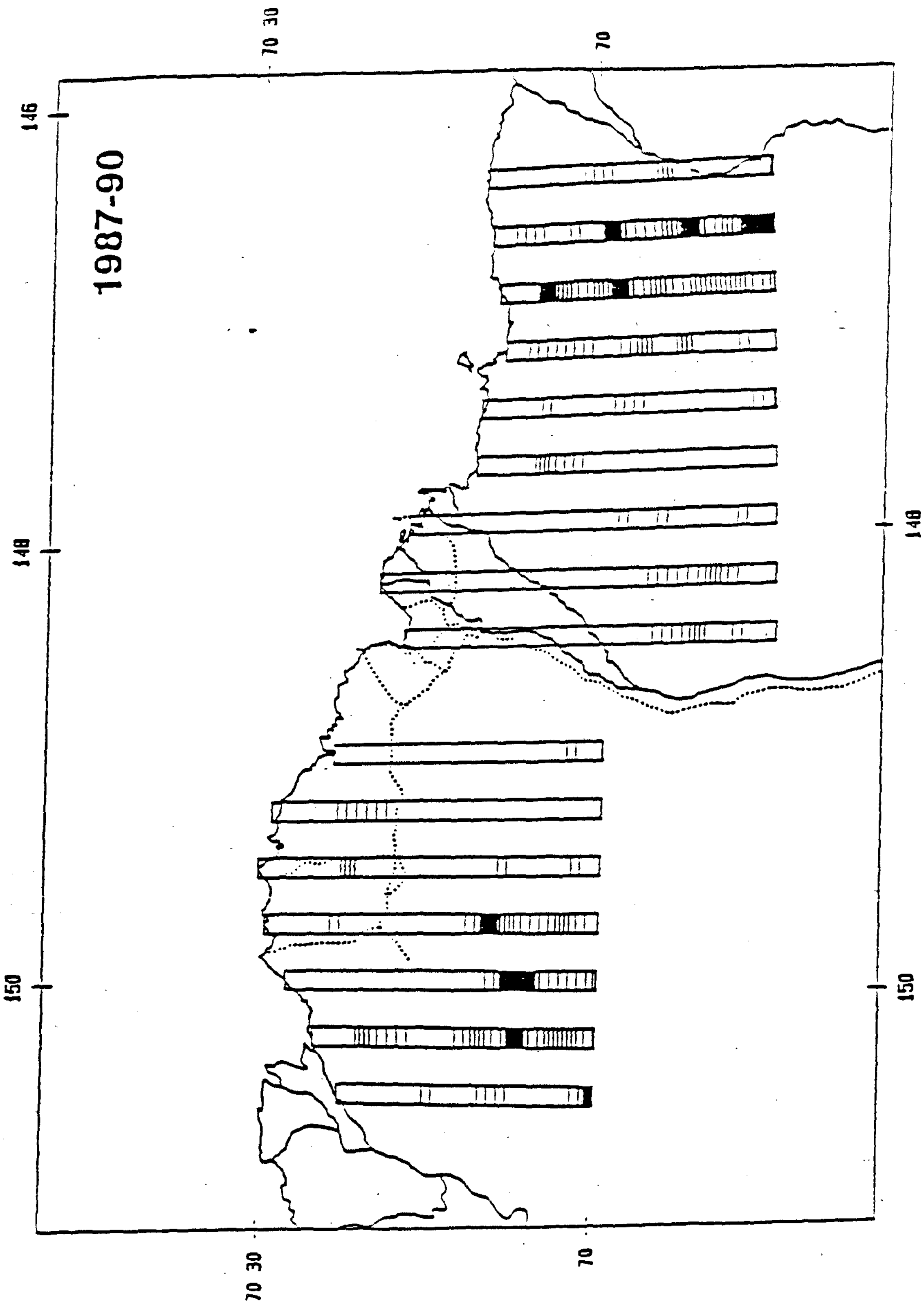

Figure 3. Mean relative distribution of CAH caribou during calving, 1987-90. Shown only are those 10.4 km^2 transect segments in which the occurrence of caribou exceeded the area contribution to total coverage (0.3%). Gradations in line spacing depict multiples of observed use relative to availability: wide, $\leq$3X; narrow, >3X-5X; solid, >5X.

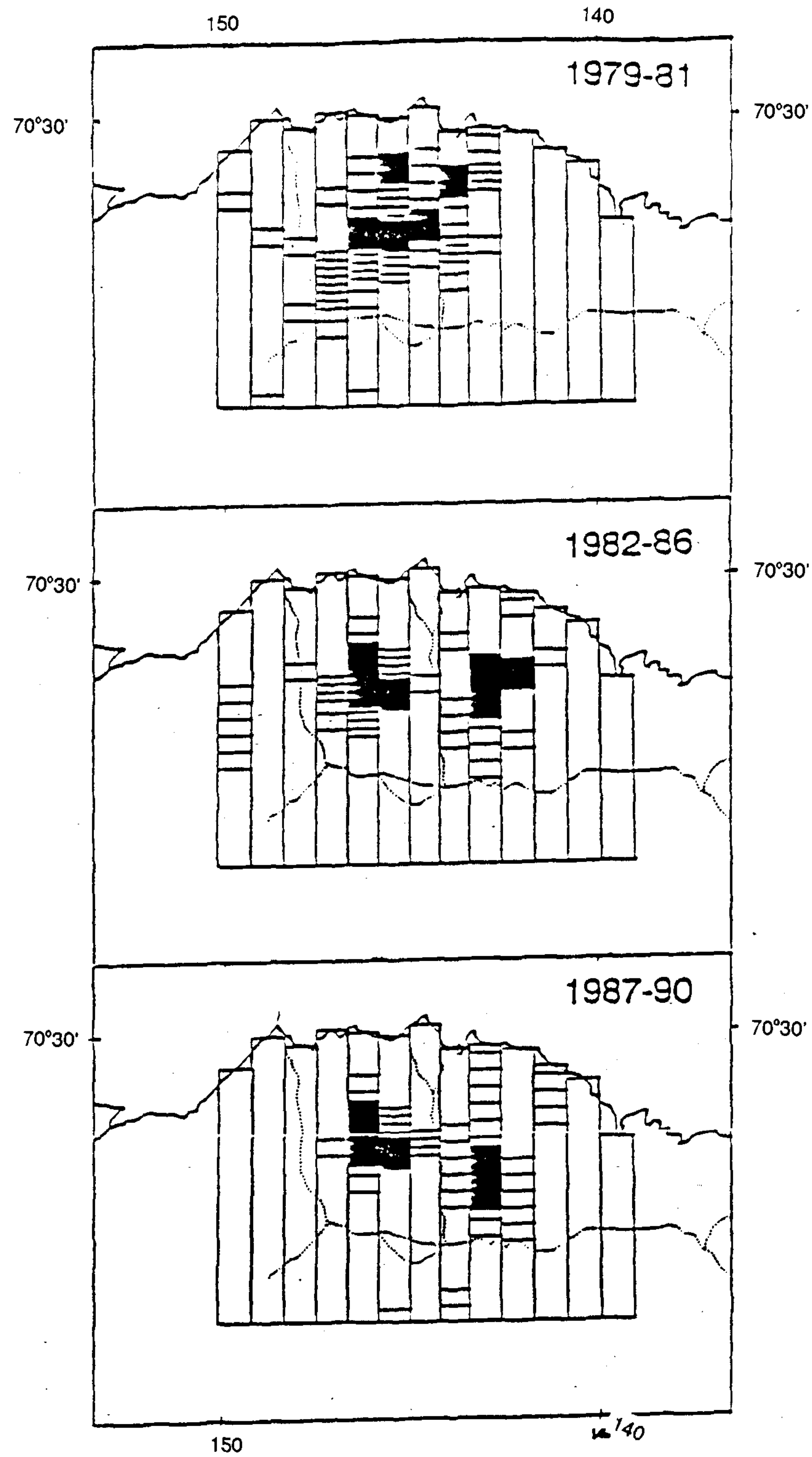

Figure 4. Changes in mean relative distribution of caribou in the Kuparuk Development Area during calving: 1979-81, 1982-86, and 1987-90. Shown only are those 10.4-km^2 transect segments in which the occurrence of caribou exceeded the area contribution to total coverage (0.9%). Gradations in line spacing depict multiples of observed use relative to availability: wide, $\leq$3X; narrow, >3X-5X; solid, >5X.

Appendix B. Habitat Requirements and Potential Impacts of Oil Development on Caribou

by
R. D. Cameron, W. T. Smith, and S. G. Fancy

1991

In T. R. McCabe, D. B. Griffith, N. E. Walsh, and D. D. Young, eds. Terrestrial research: 1002 area - Arctic National Wildlife Refuge, Interim Rep., 1988-90. U.S. Fish and Wildl. Serv., Anchorage, Alaska. In prep.

WORK UNIT II Habitat requirements and potential impacts of oil development on caribou.

Work Subunit IIa Reproductive performance of caribou in relation to habitat availability and quality.

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INTRODUCTION

A reduction in caribou (*Rangifer tarandus granti*) herd size or productivity resulting from habitat loss is the primary basis for concerns regarding oil development on the Arctic Slope of Alaska (Cameron 1983, Elison et al. 1986, Clough et al. 1987). Displacement of maternal females and their calves from preferred areas may adversely affect foraging success and, therefore, growth and fattening, which in turn may reduce subsequent reproductive performance. Previous studies of domestic and wild reindeer (*R. t. tarandus*) in Norway, and of barren-ground (*R. t. groenlandicus*) and Peary caribou (*R. t. pearyi*) in Canada, indicate that condition of adult females at breeding and during winter influence conception/parturition rate, calving date, calf birth weight, and calf survival (Dauphine 1976; Haukioja and Salovaara 1978; Thomas 1982; Reimers 1983a,b; Reimers et al. 1983; Skogland 1983, 1984; Lenvik 1988; Lenvik et al. 1988). However, there is little evidence to support the idea that these specific relationships apply universally to *Rangifer* subspecies (Davis et al. 1990).

This study was designed to clarify the process by which disturbance-induced alterations in habitat use and/or activity patterns of arctic barren-ground caribou might reduce the productivity of the population through a decline in female body condition. The following objectives and hypotheses were the basis for the research effort:

1. To determine relationships between body condition and the reproductive performance of female caribou.

   a. H_o: Conception and parturition rates are independent of fall body condition.

   b. H_o: Calf survival is unrelated to maternal condition prior to parturition.

   c. H_o: Calving date is independent of fall body condition of cows.

2. To compare the body condition and reproductive performance of female caribou of the Central Arctic Herd (CAH) in frequent contact with oil development (i.e., west of the Sagavanirktok River) with the status of those seldom, if ever, contacting development (i.e., east of the Sagavanirktok River).
   a. H_o: Female body condition and reproductive performance vary independent of exposure to oil development.

3. To determine the influence of habitat availability/quality on the body condition of female caribou.

4. To develop and implement procedures for monitoring changes in herd status through body condition trends of hunter-killed caribou and sequential sampling of marked individuals.

Preliminary data pertaining to Objectives 1 and 2 are presented here. Objective 3 will be addressed through simulation modeling when detailed habitat data become available. The results of studies dealing with Objective 4 are presented by Gerhart et al. (1991) and Allaye-Chan and White (1991).

METHODS

The study areas were within the ranges of the Central Arctic Herd (Fig. 1; Cameron and Whitten 1979) and the Porcupine Herd (PCH) (Fig. 1; Fancy et al. 1991).

In late September or October 1986-90 and in early July 1988-90, 73 radio-collared adult ($\geq$3 years old at calving) female caribou from the CAH and PCH were darted (3 mg Carfentanil citrate, or 1.5 mg Carfentanil citrate with 20 mg xylazine; Adams et al. 1988) from a helicopter and weighed 1-5 times each (Table 1). During late May and early June 1987-90, females were relocated on approximately alternate days using standard radio-tracking methods by fixed-wing aircraft. Parturition status was determined by calf presence, antler retention, and/or udder distension, and the calving date for each pregnant female was estimated from successive observations. To ascertain the occurrence of perinatal calf mortality (i.e., <48 hours post-partum), radio-collared females were relocated and observed 1-3 days after parturition. Females were then located at least once in July and again during the following late September or October; lactation status was determined on the basis of calf presence.

Body weights, rates of weight change, parturition rates, and perinatal survival rates were compared using Student's *t*-tests. Relationships between fall body weight and calving date were evaluated by Spearman's rank correlation. Statistical comparisons were evaluated at the 90% confidence level.

RESULTS

The combined results for the CAH and PCH demonstrate that fecundity, neonatal calf viability, and calving time are closely related to fall body weight. Radio-collared females that produced a calf were significantly heavier than those that did not, as were those whose calves survived >48 hours post-partum (Table 2). Furthermore, calving date varied inversely with fall body weight ($\underline{P} < 0.1$) (Fig. 2), which was significantly higher among females that calved within 3 days of the estimated peak of calving (Table 2). Parturition rate, perinatal survival rate, and the incidence of earlier calving all increased with fall body weight (Fig. 3). Thus, females exceeding 94 kg in fall are most likely to conceive and bear viable calves; additionally, calves tend to be born earlier, thereby enhancing summer growth potential and increasing the chances of overwinter survival and recruitment to the herd.

Closely linked to prerut body weight, and hence the probability of reproductive success, is the pattern of weight change over the previous year. Pregnant/lactating females lost significantly more weight during winter and spring, and lactating females gained significantly less weight during summer and autumn than nonlactating females (Table 3). Combined, these daily rates yield a mean annual net loss of 7 kg for pregnant/lactating females, compared with a net gain of 5 kg for nonpregnant/nonlactating females.

Clearly, these additive costs of gestation and lactation can depress pre-rut body weight, thereby reducing the probability of subsequent reproductive success (Fig. 3). On the other hand, periodic failure to produce and rear a calf permits a recovery in condition, allowing reproductive activity to resume--but at the expense of not contributing to at least one cohort.

Excessive overwinter weight loss may also predispose pregnant females to produce nonviable offspring. Those bearing calves that suffered perinatal mortality had lost significantly more weight (= -64 g/day) between the previous October and July ($\underline{P} < 0.05$) than did females whose calves survived (= -36 g/d). Hence, failure to adequately compensate for the metabolic demands of gestation may compromise subsequent reproductive success, both through higher calf mortality and, because of a resultant reduction in postcalving body weight of maternal females, which reduces the chances of a successful pregnancy the following year.

Mean July and October body weights of lactating females to the west of the Sagavanirktok River were not significantly lower than those to the east (Table 4). Likewise, neither oversummer weight gains nor overwinter losses differed significantly (Table 4). However, given that any effects of oilfield-related disturbance are likely to be manifested as a reduction in postcalving body weights and rates of summer weight gain (Smith and Cameron 1991), such differences, if real, may have biologically significant implications. To assess the theoretical consequences, we adjusted individual July body weights of western and eastern females according to the deviation of that year's mean from the 4-year means of 75 and 76 kg, respectively (Table 4). To each of these adjusted body weights, we then applied all observed rates of weight gain comprising each mean (Table 4), generating 2 matrices of projected fall body weights, to which normal curves were fitted (Fig. 4). For each distribution, reproductive success was computed as a "calf yield" [(% parturient x % perinatal survival)/100]. Hypothetically, a mean July body weight that is lower by a nominal 1 kg, together with a mean 41% reduction in the rate of summer weight gain, resulted in a mean 4-kg decrease in fall body weight, depressing calf yield by 19% (i.e., from 42% to 34%); moreover, the projected proportion of females calving within 3 days of the peak of calving decreased from 55% to 50%.

Seemingly minor differences in the rate of weight change may therefore account for the generally lower initial calf production of female caribou exposed to oil development west of the Sagavanirktok River (Fig. 5). Because of lower nutrient retention during the calving and summer periods, western females, overall, may be unable to attain the same level of fall condition as their eastern counterparts, resulting in lower parturition rates because of more frequent breeding pauses and reduced perinatal calf survival among females that continue to breed. In fact, among western females, both the occurrence of successive 2-year parturition events (67%) and the rate of perinatal calf survival (73%) were lower than for eastern females (87% and 84%, respectively), but the differences were not significant ($\underline{P} < 0.2$ and $\underline{P} < 0.4$, respectively).

CONCLUSIONS

The available data indicate that female body weight in fall is closely related to subsequent reproductive performance. Heavier females are characterized by higher rates of parturition and perinatal calf survival, as well as a tendency to calve earlier. We therefore reject the hypotheses that parturition rate, calf survival, and calving date are independent of fall condition.

The metabolic burdens imposed by gestation and lactation can exacerbate overwinter weight loss and reduce summer weight gain, both of which can influence pre-rut body weight. Apparently the cost of fetal development, particularly during the last trimester of pregnancy, cannot be met through compensatory feeding; and maternal females are unable to fully compensate for the cost of milk production by foraging more frequently or intensively.

The correlations between fall body condition and reproductive success, and lactational status and weight gain indicate a certain sensitivity to circumstances that might further reduce nutrient acquisition or retention. For example, snow depth during the calving period, the severity of summer insect harassment, and the level of disturbance associated with industrial development may influence foraging success and energy expenditure in an additive, compensatory, or synergistic fashion.

Despite this extrinsic variability, the results suggest differences in parturition rate, July and October body weight, summer weight gain, repetitive fecundity, and perinatal calf mortality between caribou east and west of the Sagavanirktok River during 1987-90. Lack of statistical significance may be a function of the low power of our tests to detect small differences which might, nonetheless, be biologically meaningful. Trends in the data suggest that female caribou exposed to oil development are in poorer condition and, as a consequence, less productive than those under disturbance-free conditions.

MANAGEMENT IMPLICATIONS AND POTENTIAL RESEARCH DIRECTIONS

There is reason to suspect that the proliferation of oilfields in the Central Arctic is having, and will continue to have, an effect on herd productivity. The possibility of adverse effects on female body condition and reproductive performance should be sufficient justification for a slow, cautious approach to petroleum development on other areas of the Arctic Coastal Plain.

Aspects of this research program addressing west-east differences in herd productivity continue to be hampered by inadequate sample sizes. Specifically, the need to subclassify radio-collared females on the basis of reproductive status (i.e., pregnant/lactating vs. nonpregnant/nonlactating) often diminishes our data sets to the point that statistical analyses are not possible; hence, the present necessity to combine data across years. Accordingly, future efforts should be directed toward augmenting our sample of collared females and intensifying our capture and weighing program.

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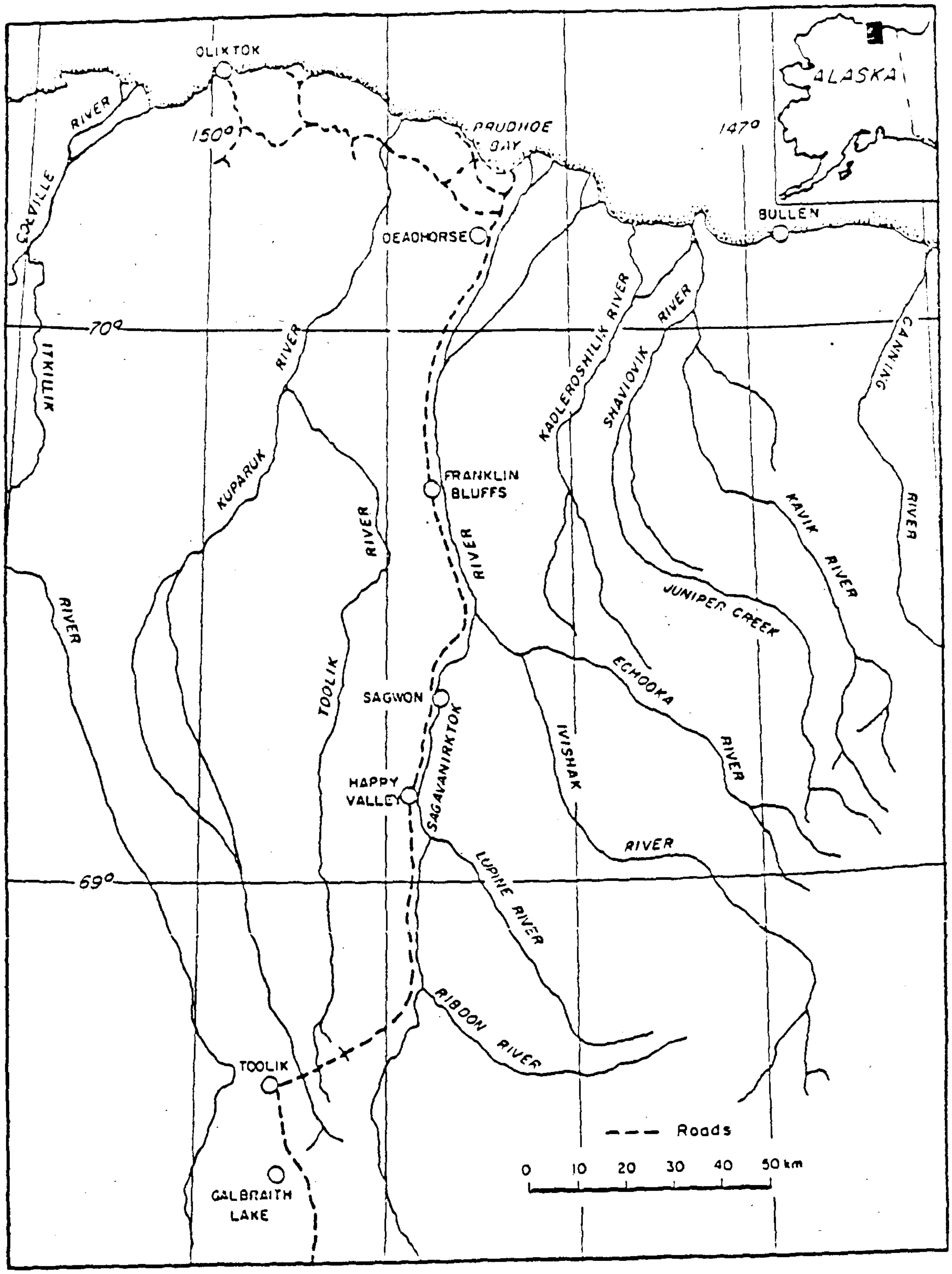

Figure 1. The greater range of the CAH.

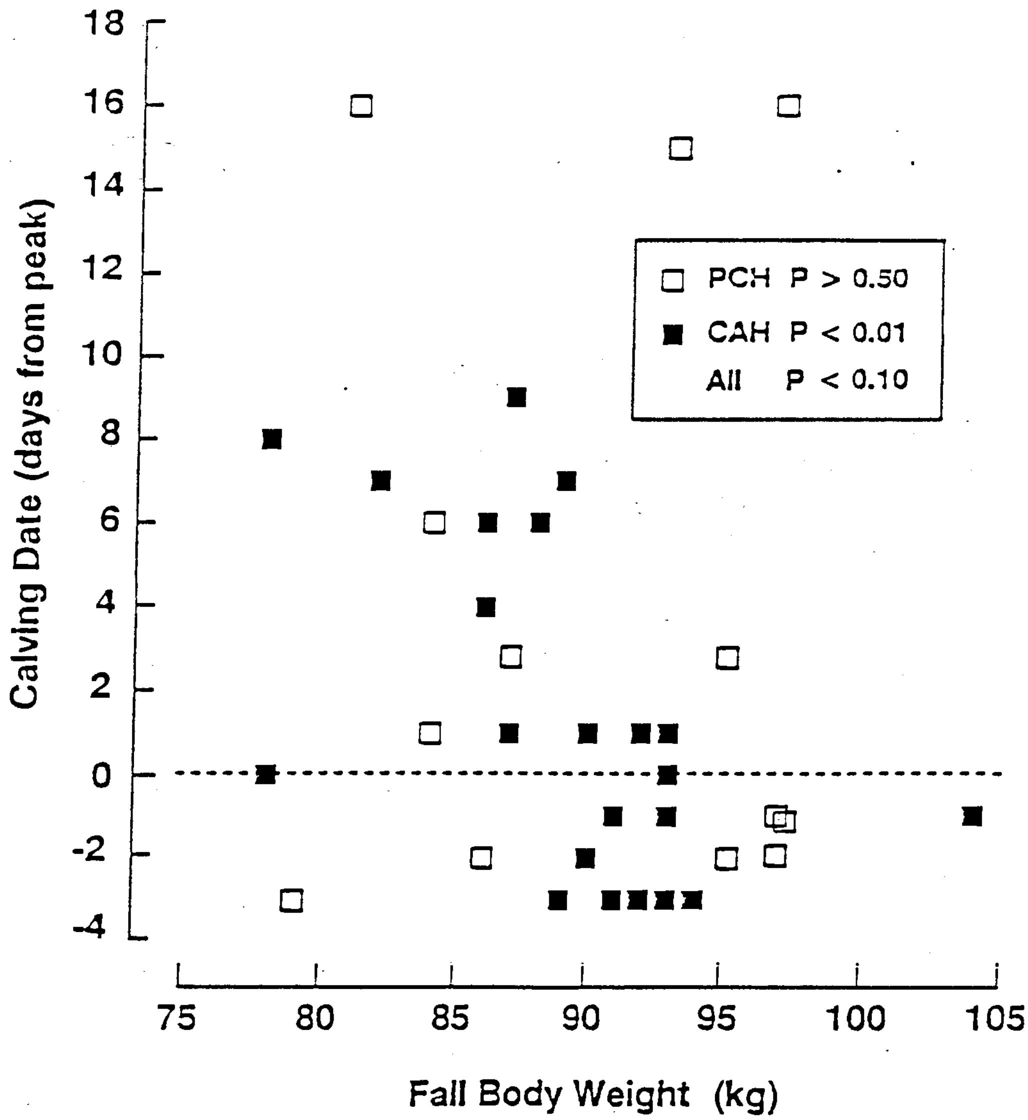

Figure 2. Relationship between 1987-90 calving dates (days from estimated peak of calving) and preceding fall (1986-89) body weights of radio-collared CAH and PCH female caribou.

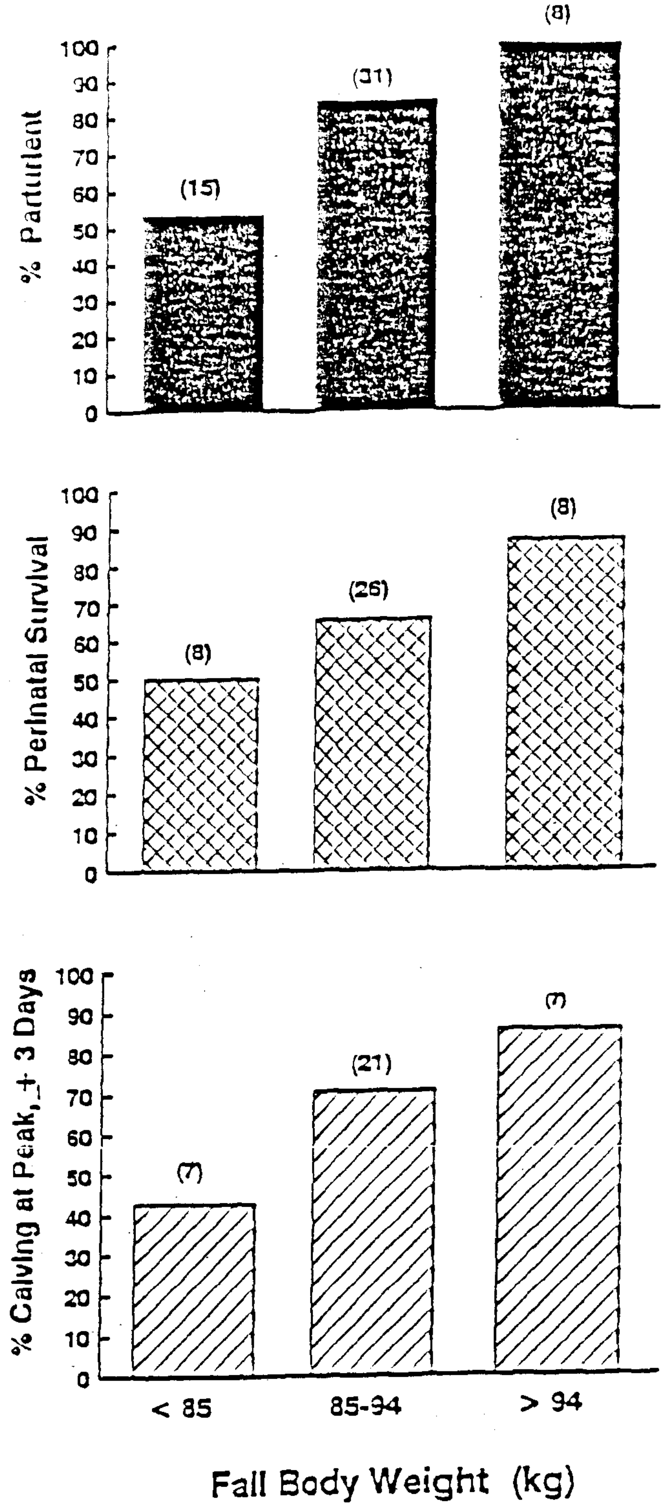

Figure 3. Parturition rate, perinatal calf survival rate, and calving time of fecund female caribou of the CAH and PCH, 1986-90, in relation to fall body weight.

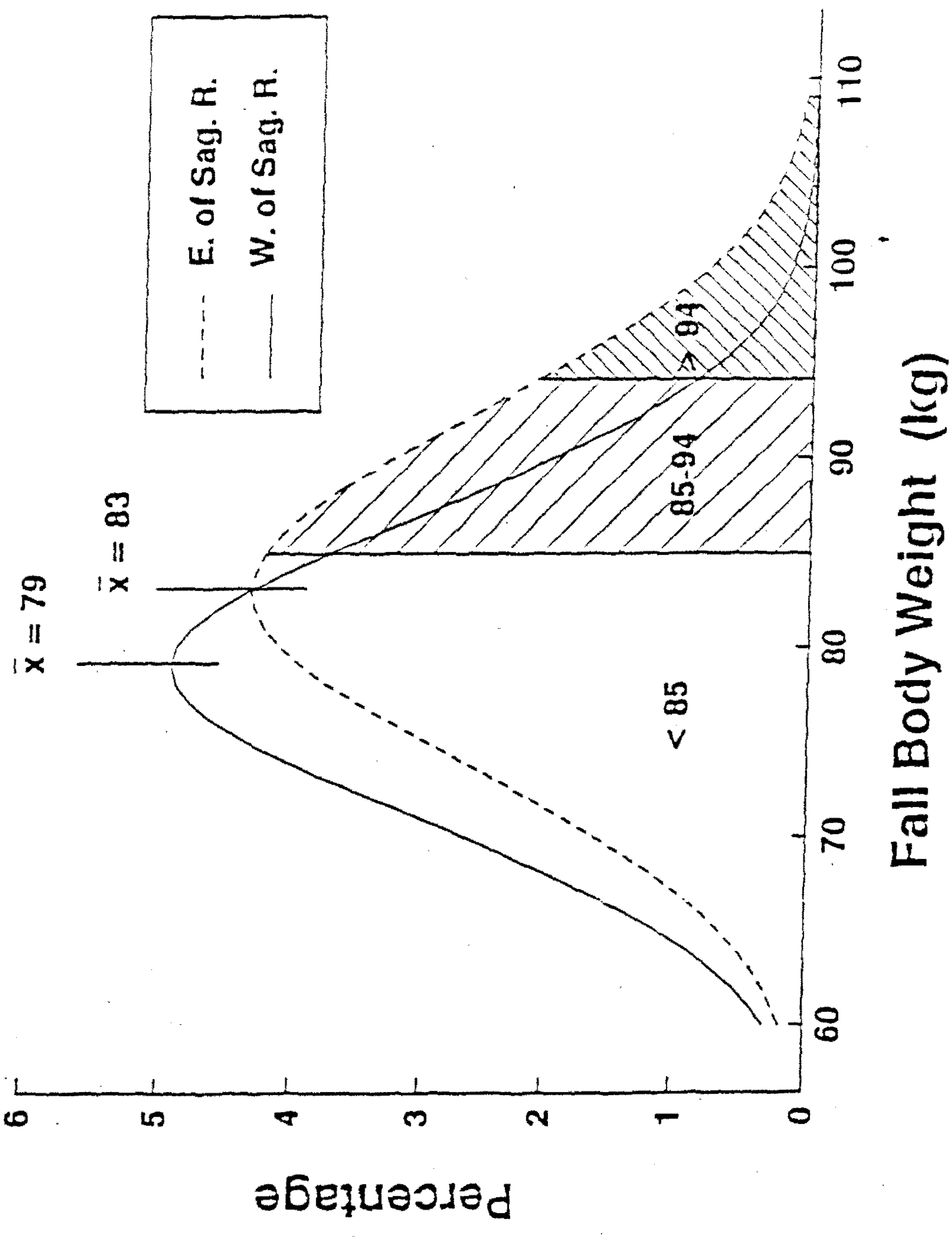

Figure 4. Hypothetical distributions of fall body weights of lactating female caribou of the CAH east and west of the Sagavanirktok River, 1987-90.

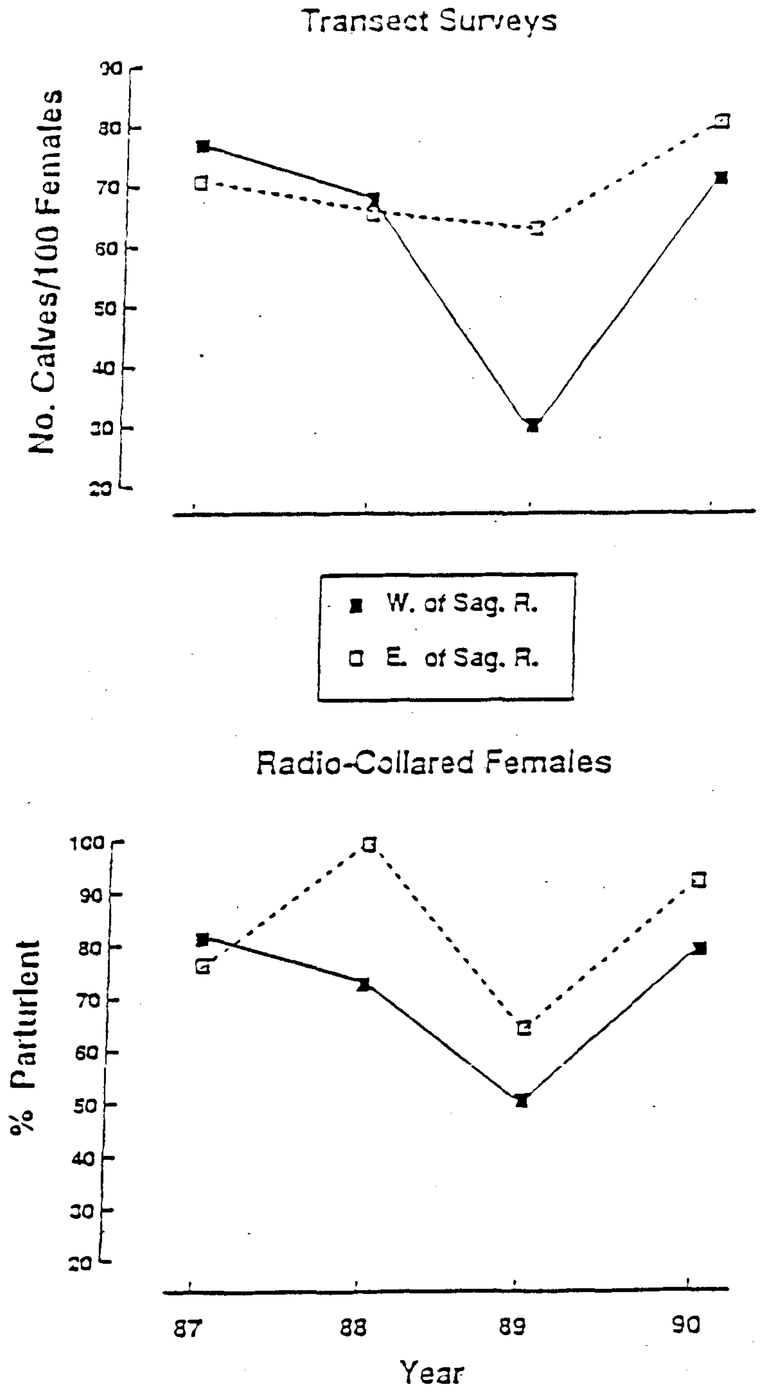

Figure 5. Changes in initial calf production (based on transect survey results) and parturition rate (of radio-collared females) of CAH caribou west and east of the Sagavanirktok River, 1987-90.

Table 1. Numbers of captures (or recaptures) of 73 adult female caribou of the Central Arctic Herd (CAH) and Porcupine Herd (PCH), 1986-90.[a]

	CAH		PCH
Year	Jul	Sep/Oct	Oct
1986	--	3	4
1987	--	15	8
1988	20	18	5
1989	22	17	--
1990	15	21	--

[a] Excludes those females for which reproductive status was unknown or uncertain.

Table 2. Mean $\pm$ SE (n) body weights of fecund[a] female caribou in October relative to subsequent parturition, perinatal calf survival/mortality, and calving time, Central Arctic Herd and Porcupine Herd, 1986-90.

Status[b]	Body weight (kg)	*t*-test
Parturient	90 $\pm$ 1 (42)	$P < 0.001$
Nonparturient	82 $\pm$ 2 (12)	
Perinatal survival[c]	91 $\pm$ 1 (28)	$P < 0.01$
Perinatal mortality[d]	87 $\pm$ 1 (14)	
Calving at peak, $\pm$3 d[e]	91 $\pm$ 1 (24)	$P < 0.05$
Calving >3 d after peak[e]	86 $\pm$ 2 (11)	

[a] Calf at heel when collared, or reproductive activity observed previously.
[b] Based on observations during the June calving period.
[c] Calf alive $\geq$48 post-partum.
[d] Calf confirmed dead or not observed with its dam <48 hours post-partum.
[e] See Fig. 1.

Table 3. Seasonal mean ± SE (n) rates of weight change of pregnant/lactating and nonpregnant/nonlactating female caribou, Central Arctic Herd, 1987-90.

	Mean weight change (g/d)		
Interval	Pregnant/ lactating	[t-test]	Nonpregnant/ nonlactating
Jul-Oct	+62 ± 14 (14)	[P < 0.001]	+138 ± 14 (16)
Oct-Jul	-47 ± 6 (16)	[P < 0.02]	-27 ± 4 (10)

Table 4. Seasonal mean ± SE (n) body weights and rates of weight change of pregnant/lactating female caribou west and east of the Sagavanirktok River, Central Arctic Herd, 1987-90.

Variable	Month(s)	West	[t-test]	East
Body weight (kg)	Jul	75 ± 2 (21)	[P > 0.5]	76 ± 2 (21)
	Oct	82 ± 2 (22)	[P > 0.2]	84 ± 1 (19)
Weight change (g/d)	Jul-Oct	+44 ± 18 (6)	[P > 0.2]	+75 ± 19 (8)
	Oct-Jul	-49 ± 6 (8)	[P > 0.9]	-48 ± 12 (7)

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