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DISTRIBUTION AND MOVEMENTS OF CARIBOU
IN RELATION TO THE KUPARUK DEVELOPMENT AREA

By

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Final Report
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Job 3.30R

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SUMMARY

Between 1981 and 1985, road surveys were conducted along the West Sak (WSR) and Oliktok Roads (OR), within the Kuparuk Development Area (KDA), during precalving (10-26 May), calving (1-14 June), postcalving (15-30 June), and the insect season (1 July-6 August). Fewest total caribou, and calves, were observed during calving, a result attributed to avoidance of the road system and central facilities by cow/calf groups. Caribou were most abundant during the insect season when they crossed the road system between coastal insect relief habitat and inland feeding areas. There were net increases in the total numbers of caribou observed and the mean group size for all survey periods between 1981 and 1985, but distribution and group characteristics within a given year were greatly affected by factors such as snow cover, patterns of insect harassment, and the occurrence and intensity of construction activity. Calf percentages were highly variable by both year and season.

A comparison of data obtained during the insect season in 1981-85, after construction of the Kuparuk pipeline, with corresponding preconstruction data collected in 1978-81,

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² Report preparation only.

indicates that a number of changes in caribou distribution, calf percentage, and road/pipeline crossing patterns have occurred with progressive development. It appears that movements to and from insect relief habitat have been altered in response to the distribution of construction activity, structures, and vehicular traffic.

Key words: Calving, caribou, central arctic coast, construction activity, disturbance, insect harassment, pipelines.

CONTENTS

Summary	i
Background	1
Objectives	3
Methods	4
Results	4
Discussion	9
Overview13
Acknowledgments14
Literature Cited15
Figures18
Tables28
Appendix A. Effects of a road system on caribou distribution during calving.37
Appendix B. Numbers and sex/age composition of caribou observed during aerial surveys of the calving grounds within the Kuparuk Development Area, June 1981-85.47

BACKGROUND

We began studies of the Central Arctic Caribou Herd (CAH) (Rangifer tarandus granti) in 1974, when construction of the Haul Road (now known as the Dalton Highway) and the Trans-Alaska Pipeline (TAP) was begun through the middle of the CAH range (Fig. 1). Early survey results showed that the majority of CAH caribou winter in the northern foothills of the Brooks Range (Cameron and Whitten 1979a). Most parturient cows move onto the coastal plain in April or May and calve within 25 km of the coast during the 1st 2 weeks of June. However, in years when the coastal region is snow-covered or extensively flooded, many cows calve inland (Whitten and Cameron 1985). In late June and early July, bulls, barren cows, and juveniles move north and join cow/calf bands in the coastal zone.

Mosquitoes (Aedes spp.) usually emerge in late June, and oestrid flies (Cephenomyia sp. and Oedemagena sp.) appear during the last half of July. CAH caribou respond differently to these insect pests. Until mid-July, mosquitoes, when active, are the dominant influence on caribou distribution and movements. Mosquito-harassed caribou form large groups and move into the prevailing northeasterly winds toward coastal insect relief habitat. After reaching the coast, these aggregations generally continue moving into the wind, often stopping at sparsely vegetated river deltas. When mosquito harassment abates with the onset of high winds and/or low temperatures, caribou move inland and disperse. This cycle may be repeated several times during midsummer.

The largest aggregations form in mid- to late July, when both oestrid flies and mosquitoes are active. As mosquitoes die off at the end of July, oestrid flies dominate caribou behavior. Under oestrid fly harassment, caribou break up into small groups, movements become more random, and there is a tendency to leave the immediate coastal area. In late August, caribou drift inland toward wintering areas and disperse along the foothills.

Our initial studies along the TAP Corridor and within the Prudhoe Bay Complex indicated that cows with calves avoid petroleum-related structures and human activity during summer (Cameron et al. 1979, Cameron and Whitten 1980a, Smith and Cameron 1983). Unfortunately, few useful preconstruction data were available on seasonal distribution and movements, and many of our conclusions regarding the effects of development on caribou were drawn by inference. However, a unique opportunity for further study presented itself in 1977-78 when ARCO constructed the 32-km West Sak Road (WSR) west from the Kuparuk River into the Kuparuk Development Area (KDA), a new oil development area immediately west of the Prudhoe Bay production unit (Fig. 2). Only construction of the central processing facilities (CPF-1), road maintenance, and a few localized construction sites were planned during summer between 1978 and 1980. This provided an excellent opportunity to collect prepipeline data on caribou distribution and movements as a basis for evaluating the effects of the Kuparuk Pipeline, which was to be constructed during winter 1980-81.

Results of aerial surveys during calving indicated there were 2 calving areas of relatively high density between the Colville and Canning Rivers, one in the vicinity of the Staines River, and the other north of the WSR, between the Kuparuk River and Oliktok Point (Whitten and Cameron 1985). Elsewhere on the coastal plain, calving caribou were less dense, particularly within the Prudhoe Bay Complex. Total numbers of parturient cows and calves within the high-density calving areas in the KDA varied during the 3 years of survey, but the locations of the concentrations were similar (Fig. 3). Most calves were seen within 16 km of the coast. We also noted that virtually no calves were seen within 4 km of the WSR. Initial calf production was consistently high, ranging from 68 to 85 calves:100 cows.

Between 1978 and 1980, numbers of caribou observed among specific 4-km segments of the WSR during summer (i.e., 0-4.0 km, 4.1-8.0 km, etc.) were highly variable (Cameron and Whitten 1979b, 1980b; Cameron et al. 1981) (Fig. 4). Only within the Kuparuk River floodplain (segment 0-4.0 km) were caribou relatively abundant in all 3 preconstruction years. Elsewhere along the road, areas of highest use, as well as

most road crossing sites, were associated with riparian systems. The relative occurrence of caribou among these riparian areas appeared to be influenced by the distribution and intensity of local construction activity. The relative numbers of caribou seen north or south of each 4-km segment were also variable (Fig. 4) and highly dependent upon prevailing insect conditions at the time of survey.

Between 1978 and 1980, the mean calf percentage among caribou observed from the WSR during summer was representative of caribou in the general region. The percentage of calves among caribou seen within specific 4-km segments showed no trends among the 3 years (Fig. 4), except at the initial and terminal segments of the WSR. Although total numbers of caribou within the Kuparuk floodplain remained high, the calf percentage declined to less than half of the corresponding regional estimate by 1980. In contrast, the relative number of calves in groups seen west of the terminal road segment increased, suggesting that cow/calf bands were skirting the complex (Cameron et al. 1981).

In summary, development in the KDA through 1980 did not result in any major changes in calving distribution west of the Kuparuk River, and variations in the numbers of caribou seen from the WSR during summer were largely attributable to differences in insect harassment patterns. Although overall calf percentages remained comparable to regional estimates, it appeared that cows with calves were beginning to avoid some areas of heavy construction activity.

After gathering 3 years of baseline data, we began a 5-year study of the changes in caribou distribution and movements that accompanied construction of the Kuparuk Pipeline and further development of the oil field. The project consisted of 2 phases: an annual survey of calving distribution within the KDA and an annual assessment of caribou distribution along the WSR and, later, the Oliktok Road (OR). Results of the latter phase of study are the subject of this report.

OBJECTIVES

This study was designed to accomplish 4 objectives. Material addressing objectives 1 and 4 has been reported elsewhere; the appropriate citations appear in parentheses.

1. To describe annual variations in the distribution of CAH caribou on their calving grounds (Whitten and Cameron 1985), with special reference to calving activity in the vicinity of the KDA (Cameron et al. 1985; Appendix A: Dau and Cameron, in press; Appendix B).

2. To determine between-year differences in the distribution, movements, and sex/age composition of caribou within or near the KDA during precalving, calving, postcalving, and insect periods.

3. To determine the locations of caribou crossings of the road(s) and/or pipeline(s).

4. To characterize the responses of caribou to local structures and disturbance (Smith and Cameron 1985a, b).

METHODS

The WSR was surveyed systematically by light truck (Smith and Cameron 1985a) during 4 phases of the caribou annual cycle: precalving (10-26 May), calving (1-14 Jun), postcalving (15-30 Jun), and the summer insect season (1 Jul-7 Aug). Beginning in 1982, these surveys included the OR, from CPF-1 to Oliktok Point (Fig. 2).

For midsummer surveys, the level of insect harassment was estimated subjectively by direct observation as none, light, moderate, or severe. In addition, mean 4-hr insect levels were calculated using hourly weather reports from Deadhorse airport (obtained from the Arctic Environmental Information and Data Center, University of Alaska, Anchorage) and the weather/insect activity relationship of White et al. (1975). Caribou survey data obtained along the WSR and OR (including location, observation distance, group composition, direction of movement, road/pipeline crossings, and insect levels) were recorded on data sheets or entered on an Epson HX-20 field data recorder, and then transferred to a Honeywell Model 20 (University of Alaska, Fairbanks), IBM PC XT, or Compaq Deskpro.

Groups interacting with roads and/or pipelines were observed until the termination of the initial crossing episode; that is, until groups crossed, moved away from the road, bedded down, began a feeding bout, or otherwise indicated they were not soon likely to attempt another crossing.

RESULTS

I. Precalving

A. Population characteristics (Table 1)

1. Mean group size, sighting rate, and calf (short yearling) percentage for the combined WSR and OR surveys increased through 1985.

2. Trends in caribou mean group size and sighting rate along the WSR and OR were similar to combined values, except for the low sighting rate along the OR in 1983.
 3. Caribou were relatively more abundant and in larger groups along the OR than along the WSR.
 4. Calves were relatively more abundant along the OR in 1982-83, and more abundant along the WSR in 1984-85.
 5. Numbers of caribou/km seen within 1,000 m and 2,000 m of roads increased through 1984 and then decreased in 1985; the percentage of calves among caribou within both distance intervals was similar to the overall calf percentage for all years.
- B. Distribution of caribou among 4-km road segments (Fig. 5)
1. Cumulatively, fewest caribou were seen near the Kuparuk floodplain (0.0-8.0 km) and near CPF-1 (24.1-28.0 km); most caribou were seen north of the WSR and south of the high-density calving area near Milne Point, and along the OR, midway between CPF-1 (28.0 km) and Oliktok Point (56.0 km).
 2. With few exceptions, calves appeared to be evenly distributed along the WSR and OR.

II. Calving

A. Population characteristics (Table 2)

1. Fewer caribou and calves were seen from the road system during the calving period than during any of the 3 other periods (Tables 1-4).
2. Total sighting rate increased each year until 1985. The lowest sighting rate was recorded in 1982 when the KDA was still covered with snow.
3. Calf percentage based on total caribou observed increased each year, but remained substantially lower than that for caribou groups in the entire area (Appendix B). Most calves were seen during the last few days of calving; e.g., 35 of the 60 (60%) calves observed during the 1985 calving period were seen on 14 June.

4. Mean group size increased each year except in 1984.
 5. Although the caribou sighting rate along the OR increased after 1982, relatively more calves were observed from the WSR.
 6. The number of caribou seen within 1,000 m and 2,000 m of the WSR and OR increased each year, except for those within 2,000 m in 1985.
- B. Distribution of caribou among 4-km segments (Fig. 6)
1. Most caribou were seen north of the WSR and south of the Milne Point calving area, and along northern portions of the OR.
 2. Most calves were observed north of the WSR near the Milne Point calving area, with a smaller peak midway along the OR. (The peak at road km 26 is attributable to a single group of 12 caribou.)

III. Postcalving

- A. Population characteristics (Table 3)
1. More caribou and calves were seen during postcalving than during the calving period (Tables 2, 3). Group size was also higher, reflecting the formation of maternal post-calving groups.
 2. Mean group size, sighting rate, and calf percentage were variable among years. Fewest caribou and calves were seen in 1982 when the study area was still partially snow covered, and the most were observed in 1985.
 3. Annual comparisons of mean group size, sighting rate, and calf percentage of caribou observed along the WSR and OR showed no clear trends among years. The highest mean group size, sighting rate, and percentage for any year was recorded in 1985 along the OR.
 4. The number of caribou/km within 1,000 m and 2,000 m of the roads increased each year after 1982; calf percentage of groups within these

distance intervals varied considerably, but was highest in 1985. Between 1981 and 1985, the relative percentage of total caribou seen within both 1,000 m and 2,000 m tended to increase.

B. Distribution of caribou among 4-km segments (Fig. 7)

1. During 1981 and 1982, most caribou were seen along the WSR south of the Milne Point calving area and west of CPF-1. Beginning in 1983, most caribou were seen along the WSR south of the Milne Point calving area and in the middle portion of the OR. Caribou tended to avoid CPF-1.
2. Peaks in cumulative calf percentage were similar to those for the calving period; most calves were observed south of the Milne Point calving area and in the middle portion of the OR. In 1985, both the number of caribou observed and calf percentage of groups along the OR increased substantially.

IV. Insect season

A. Population characteristics (Table 4)

1. Mean group size and sighting rate were highest during the insect period (Tables 1-4).
2. Mean group size and sighting rate increased each year except for 1982; the calf percentage varied considerably, but was highest in 1984.
3. Sighting rates along the WSR were highly variable; highest values were in 1984. Along the OR, the sighting rate increased each year between 1983 and 1985.
4. Between 1983 and 1985, relatively more caribou and calves were seen along the OR than along the WSR.
5. Except for 1982, numbers of caribou within 1,000 m and 2,000 m increased each year; the calf percentage of groups within these intervals was similar to the calf percentage of all groups.

B. Distribution of caribou among 4-km segments (Fig. 8)

1. Most caribou were seen at the initial and terminal segments of the survey route, i.e., at the Kuparuk River and west of CPF-1 in 1981 and 1982, and at the Kuparuk River and near Oliktok Point between 1983 and 1985. In 1985, 60% of all caribou were seen within the 1st segment (0-4.0 km) and within the last 2 segments (48.1-56.0 km).
2. The cumulative calf percentage of groups observed was similar among 4-km segments, except for that segment within the Kuparuk floodplain (0.0-4.0 km).

V. Attempted crossings of roads and/or pipelines by caribou

A. Seasonal and annual distribution of attempted crossings (Table 5).

1. Few caribou were observed crossing roads and/or pipelines in May and June. The only significant annual increase was during postcalving in 1985, when a number of cows and calves attempted to cross to the west along the OR.
2. More caribou attempted to cross roads and/or pipelines during the insect season than during other periods. The large increase in crossing attempts in 1983 was primarily due to the inclusion of the OR in the survey route. Similarly, the increase in 1984 resulted from numerous crossing attempts along the OR (e.g., a group of 5,500 on 8 July) and the eastern portion of the WSR. Extremely low mosquito activity in 1985 resulted in fewer sightings that year.
3. The increase in attempted road/pipeline crossings in 1985 is a consequence of the addition of a pipeline along OR.

B. Locations of attempted crossings of the WSR and OR (Fig. 9)

1. Most caribou attempted to cross roads and/or pipelines within the Kuparuk floodplain (0-4.0 km) and along the northern portion of the OR (44.1-56.0 km).

2. In 1981 and 1982, most caribou attempted to cross the WSR in the vicinity of the Kuparuk floodplain, and at 2 locations east of CPF-1 (28.0 km); the latter responses of insect-induced aggregations are described in Smith and Cameron 1985b.
3. Most caribou attempted to cross within the Kuparuk floodplain and immediately west of CPF-1 (32.1-38.0 km) in 1983.
4. In 1984, most attempted crossings were made by mosquito-harassed aggregations along the middle portion of the OR (44.1-48.0 km) and, while moving southward to inland feeding areas, along the eastern portion of the WSR (0-12.0 km).
5. After construction of a pipeline along the OR in 1984-85, several large mosquito-harassed groups attempted to cross eastbound near Oliktok Point (48.1-56.0 km). Shortly thereafter, many of these caribou were observed crossing westbound, just north of the CPF-1 complex.

DISCUSSION

Parturient cows and short yearlings are observed along the road system when we begin surveys in May. In most years, they are attracted to snow-free areas within the dust shadow of the road, and repeated sightings of groups indicate they are relatively stationary during the precalving period. Some short yearlings have separated from their dams and form small bands, and bull groups are commonly seen near Oliktok Point.

Caribou avoid the CPF-1 area during precalving, and may also be responding to differences in traffic on the WSR and OR. Except for 1982 when there was frequent gravel hauling on the OR, daytime traffic has been moderate to heavy (30-40 vehicles/hr) along the WSR and light (0-10) along the OR. This may account for the higher caribou sighting rates along the OR than along the WSR. Calves (short yearlings) are evenly distributed along the roads and appear relatively tolerant of construction activity and traffic.

Few maternal females and new calves are seen along the road system during the 1st 2 weeks of June. This is consistent with road and aerial survey data collected near Milne Point that indicate an avoidance of the road system by cow/calf groups for distances of up to 4 km (Dau and Cameron 1986; Dau

and Cameron, in press). In 1982, cows and calves were more numerous along the newly constructed OR than along the lightly traveled WSR (the Kuparuk River crossing was out during breakup), suggesting that even light traffic evoked an avoidance response. With an increase in traffic on the OR after 1982, fewer total caribou, but more calves, were seen along the WSR. Thus, it appears that the relative occurrence of cow/calf pairs near the 2 road transects shifted toward the area with least local disturbance.

Most of the calves observed during the calving period are seen within the last few days of the survey series when postcalving groups are forming; however, those seen still represent but a small proportion of all calves in the area (Table 2, Appendix B). Higher caribou sighting rates, more frequent road crossings, and data on movements of collared caribou together indicate that in 1982 most caribou moved into the Milne Point calving area across the OR (Cameron et al. 1983).

Distribution of caribou within 4-km segments during calving indicate that most caribou are seen along the WSR south of the Milne Point calving area and along the middle portion of the OR (Fig. 6). Few caribou or calves are seen near the flooded Kuparuk River, CPF-1, or Oliktok Point. A few bull bands remain near Oliktok Point and small groups of yearlings are seen along much of the road system.

The occurrence of larger groups and more numerous cows and calves toward the end of the calving period also characterizes the postcalving period. As the dust shadow disappears and areas away from the road green up, nonmaternal groups move from the immediate vicinity of the road system. Most caribou are seen along the WSR south of the Milne Point calving area and along the northern portion of the OR. As for movements into the Milne Point calving area, it appears that most of the early postcalving movements are across the OR rather than the WSR. In 1985, the newly constructed pipeline along the OR appeared to delay these movements. Sighting rates and calf percentage increased markedly, and nearly three-quarters of the caribou were seen on the east side of the OR, suggesting they delayed moving to the west.

Insect activity dominates caribou distribution and movements during summer. During summers 1978 through 1980, caribou moved north, across the WSR, to coastal insect relief habitat when harassed by mosquitoes and returned directly south when harassment ceased, generally along north/south-oriented riparian systems (Cameron et al. 1981). Beginning in 1981, a different pattern of insect-related movements was apparent (Fig. 9). Insect-harassed caribou generally moved toward the coast from areas west of CPF-1, as well as from the Kuparuk

floodplain. When insect harassment ceased, caribou moved inland to within a few kilometers north of the WSR, paralleled the WSR until west of CPF-1, and then turned south; except for the road segment within the Kuparuk floodplain, there were few southbound crossings of the WSR. It should also be noted that, in 1984, we observed a number of large southbound groups successfully crossing the WSR between the Kuparuk River and CPF-1. However, these crossings occurred in the evening when low traffic levels favored increased crossing success.

There was only 1 brief period of mosquito harassment in 1985. On 1 July, a group of 2,500 caribou crossed the OR westbound near Oliktok Point, but fragmented with the onset of strong winds. Except for the subsequent formation of a few small aggregations with localized movements, no other mosquito-induced movements were observed that year.

Local calf representation within the KDA changed after the construction of the Kuparuk pipeline (Table 4). During our 1st 3 years of midsummer surveys (1978-80), the proportion of calves observed along the WSR was similar to regional values (Cameron et al. 1981). However, in 1981 and 1982, local calf percentages were substantially lower than regional estimates (Smith et al. 1984). In midsummer 1983, the calf proportion was 18.1%, again lower than the regional estimate of 21.3% obtained from counts of postcalving aggregations on 23 July 1983 (unpubl. data). In 1984, the midsummer proportion of calves along the road system increased to 23.2%, similar to our estimate for the CAH. Furthermore, there was little difference in the proportion of calves seen near the WSR/Kuparuk pipeline complex (22.3%) vs. the OR (24.4%). In 1985, however, the overall calf percentage declined to 20.8%, attributable to a low percentage along the WSR, specifically near the Kuparuk River.

In summer 1978, not only was the overall calf percentage similar to regional values, but there were no differences in calf percentage among 4-km segments of the WSR (Fig. 4). However, construction activity increased within the Kuparuk floodplain and the calf percentage for that road segment decreased; by 1985, it had declined to about one-fourth of the estimated regional value. This decrease in calf representation is consistent with our observations during summer (along the TAP Corridor and within the Prudhoe Bay Complex) that cow/calf groups avoid areas of heavy construction activity and traffic (Cameron et al. 1979; Cameron and Whitten 1980; Smith and Cameron 1983). Carruthers et al. (1984) and Curatolo and Reges (1986) have suggested that such avoidance can be attributed to a preference of bulls for riparian areas and cow/calf preference for upland (nonriparian) areas. Their findings do

not support this conclusion, however. An examination of the data of Carruthers et al. (1984) reveals that bull percentages are high and calf percentages low only within riparian zones associated with the TAP Corridor (Whitten and Cameron, in press). Curatolo and Reges (1986) classified 5,097 caribou in upland habitats along the OR and reported a bull:cow ratio of 83:100, similar to the estimated ratio for the CAH (Whitten and Cameron 1985) and higher than documented for most Alaskan herds (Skoog 1968). Because calves were normally represented in the Kuparuk River before intensive construction activity began in the area, and as bulls appear to be normally represented in upland areas, we conclude that low calf percentages in the Kuparuk floodplain are due to avoidance by cow/calf groups.

Instances of cow/calf avoidance notwithstanding, there is some evidence that caribou are accommodating to the structures and human activity within the KDA during midsummer. In 1984, local calf percentage increased to a level comparable to the estimate for the regional population, and numerous insect-induced movements into the Milne Point area transected the OR where traffic was lower than on the WSR. Also, a number of groups moved south across the WSR, rather than circumventing CPF-1 to the west as they had done on several occasions between 1981 and 1983; as a result there was seemingly little delay of southbound movements toward inland feeding areas. Finally, caribou movements across the WSR, Kuparuk pipeline, and SOHIO's flowline (a few kilometers north of the WSR) have persisted, despite increasing development and activity in the immediate area. Perhaps wide separation of the 3 linear structures facilitates caribou movements along the drainage.

Much of the data obtained in 1985 is less encouraging. The cumulative calf percentage of 16.8% along the WSR again decreased to below regional estimates of 24%, derived from counts of large insect-induced aggregations. In addition, there was little movement of caribou across the WSR in 1985, and only 1 large movement across the OR was observed. As noted above, however, mosquito activity in 1985 was unusually low, and comparisons with previous years of "normal" insect patterns are difficult, if not impossible. Perhaps caribou were generally more sensitive to human-related disturbance in 1985 because of the relative scarcity of insects; that is, a tendency to be more responsive to local disturbance in the relative absence of a competing negative stimulus.

One final optimistic note. There has been a general increase in the numbers of caribou within 1,000 m and 2,000 m of roads. Although this trend may be primarily a function of continued herd growth, it suggests, at the very least, that avoidance of developed areas has not intensified in recent years.

Sustained tolerance of development activities at or near present levels, together with a concerted effort to facilitate caribou movements across roads and pipelines, will hopefully preclude further losses of habitat in the region.

OVERVIEW

This study was begun in 1978, in response to a need for baseline data on caribou distribution in the Kuparuk/Colville region, the intent being to provide the basis for mitigation as development of the Kuparuk River Oil Field proceeded. Much of the initial funding for this work was provided by the Unit owners. By 1982 supplemental funding was terminated, and all project support was assumed by ADF&G through Federal Aid sources. Thus, despite a change in sponsorship, the surveillance program has continued intact for 8 years, addressing essentially the same broad objectives and employing nearly identical sampling procedures.

Our early surveys yielded considerable data on the spring and summer distribution of CAH caribou west of the Kuparuk River. An area of concentrated calving activity north of the WSR was identified, and insect-induced movements of caribou within the coastal zone were described. Ground survey observations along the WSR indicated that areas of highest caribou use were associated with riparian systems. Based on our preliminary findings and the relevant literature on caribou disturbance behavior, several recommendations were made, notably those relating to the placement of structures, the distribution and scheduling of construction activity, and the intensity of vehicular traffic.

Regional development increased rapidly after construction of the Kuparuk Pipeline in 1980-81. Production and camp facilities at ARCO CPF-1 were greatly expanded, CPF-2 came on line, a road was constructed to a new dock at Oliktok Point, and the Waterflood pipelines and main CPF-3 production lines were built; in 1981-82, Conoco constructed a road, and later a parallel pipeline, from the WSR north to what is now the Milne Point Production Unit.

ADF&G aerial and road surveys continued through this period of rapid growth. In addition, Alaska Biological Research (ABR) was contracted by ARCO to conduct a series of site-specific investigations of the reactions of caribou to roads and pipelines, including assessment of the use by caribou of several pipeline crossing structures and road/pipeline separations that had been incorporated into the pipeline network of the Kuparuk Oil Field. This work was a useful complement to our areawide surveillance program. ABR's findings contributed

considerably to our understanding of the comparative responses of caribou to roads and pipelines, and resulted in a number of recommendations being made to promote passage of caribou. Several of the recommended actions were implemented by ARCO with consultant follow-up assessment of the effectiveness of the mitigation.

It is now generally acknowledged that the combination of a road with heavy traffic and an adjacent elevated pipeline greatly reduces the crossing success of caribou during mid-summer. Hence, the degree of negative reaction by caribou can be reduced and crossing success enhanced by separating these linear structures--that is, isolating the 2 stimuli. However, general agreement is lacking on the optimal separation distance and whether or not the separation technique can be used routinely as a substitute for pipeline crossing ramps. Nor is there substantial agreement on the best ramp design in terms of width, height, and grade. Hopefully, these uncertainties can be largely eliminated as additional behavioral data are obtained in conjunction with our standard surveys, and also by further site-specific evaluations by consultants, under industry sponsorship.

As noted above, the principal intent of our work in the KDA during the 1st 3 years was to collect preconstruction data on caribou distribution as the basis for future mitigation. However, the results of this early work also serve as a baseline data set, against which future observations of caribou distribution and group composition can be compared. With the recent decline in construction activity and the options for mitigation fewer, more attention has been focused on the changes that have occurred with progressive development. We now have computer capabilities for rapid and efficient entry and retrieval of road survey data. In addition, we will soon be digitizing the entire set of caribou locations from all aerial surveys of the KDA portion of the CAH calving ground; this will allow a graphic illustration of trends in distribution. We propose to continue a routine annual inventory of the caribou population west of the Kuparuk River using established sampling and analytical techniques. Considering the greater emphasis on a monitoring function related to a long-term case history analysis, and less emphasis on questions related to mitigation, we believe it appropriate to reinstate this project as a "Survey and Inventory" task.

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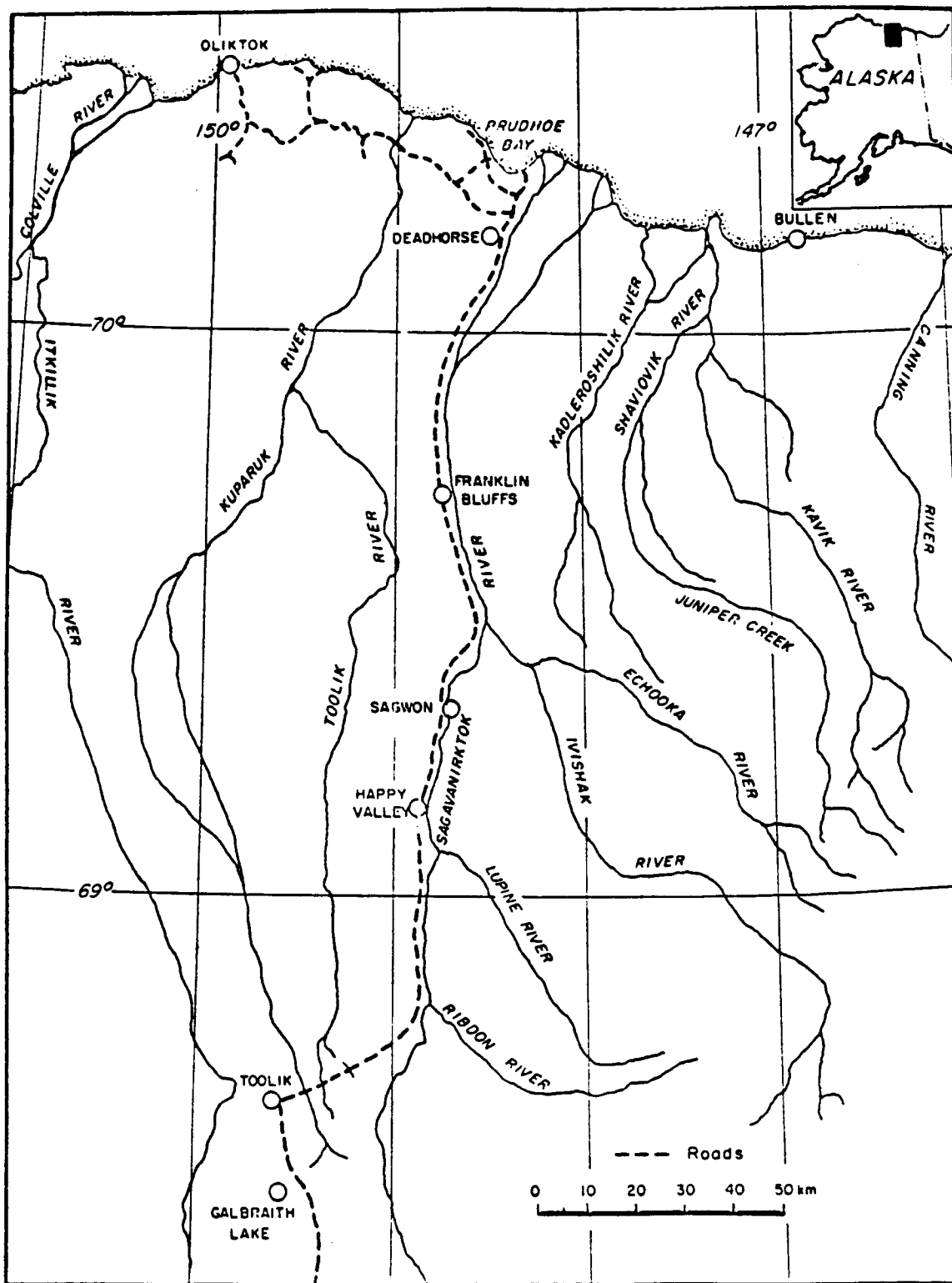


Fig. 1. The central Arctic Slope of Alaska. From Cameron et al., in press.

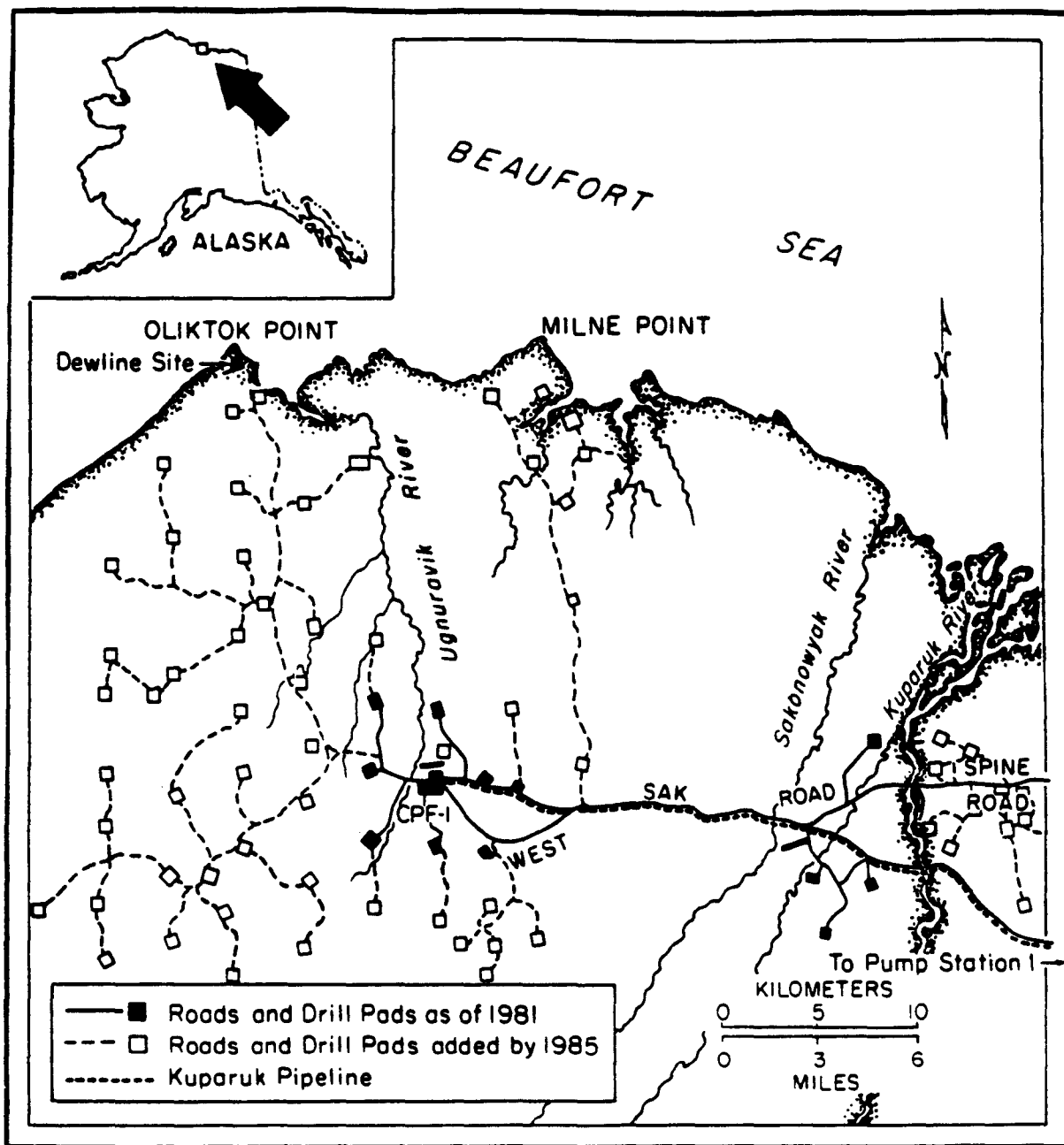


Fig. 2. The Kuparuk Development Area, Alaska. From Dau and Cameron, in press.

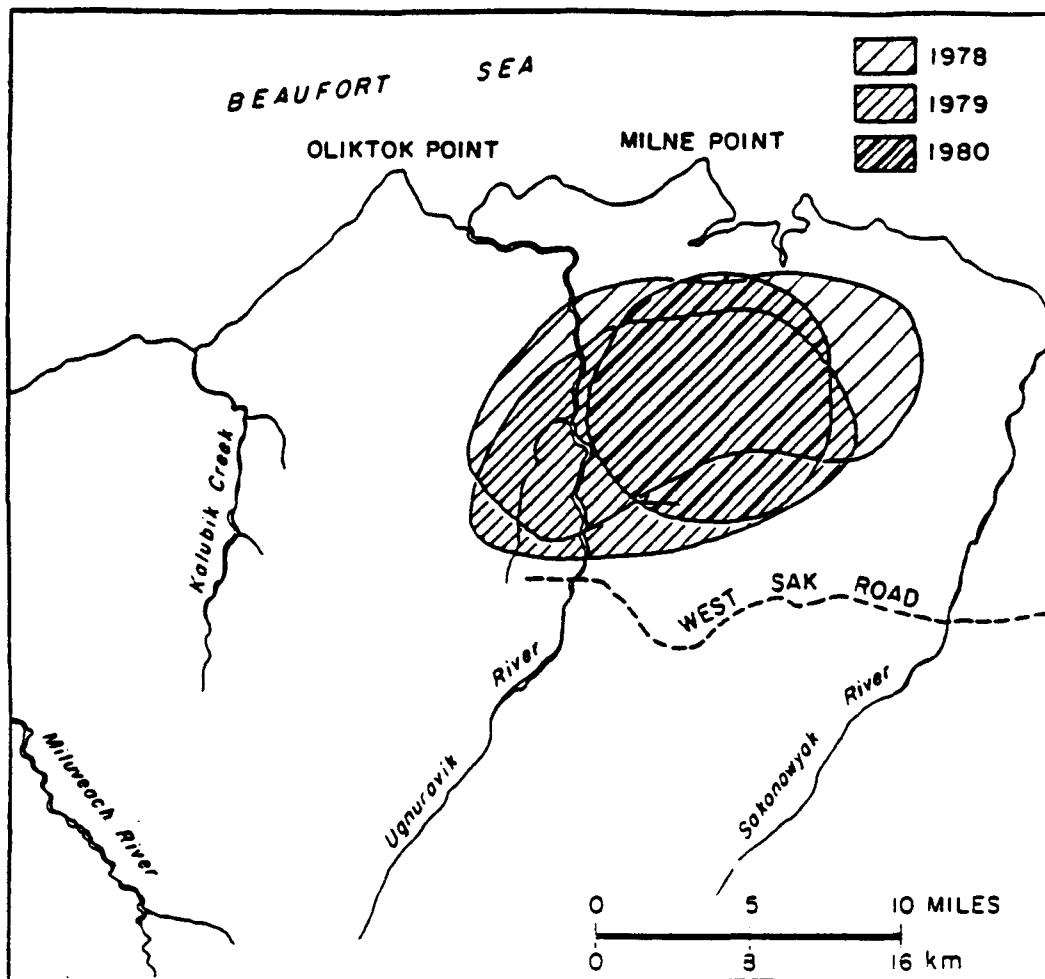


Fig. 3. Calving concentrations within the Kuparuk Development Area, June 1978-80. From Cameron et al. 1981.

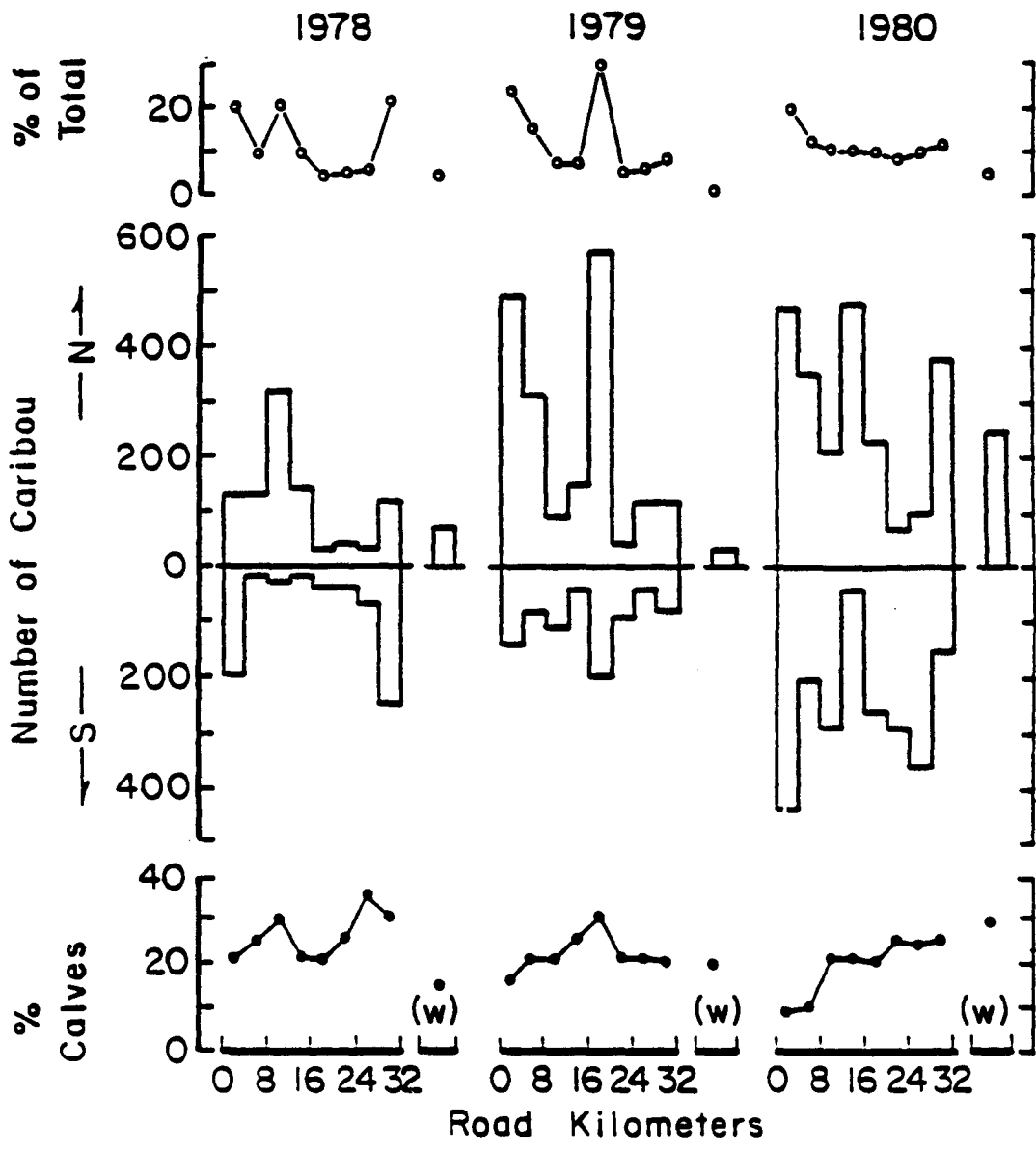


Fig. 4. Distribution of caribou among 4-km segments of the West Sak Road, and calf percentages for each segment, summer 1978-80. From Cameron et al. 1981.

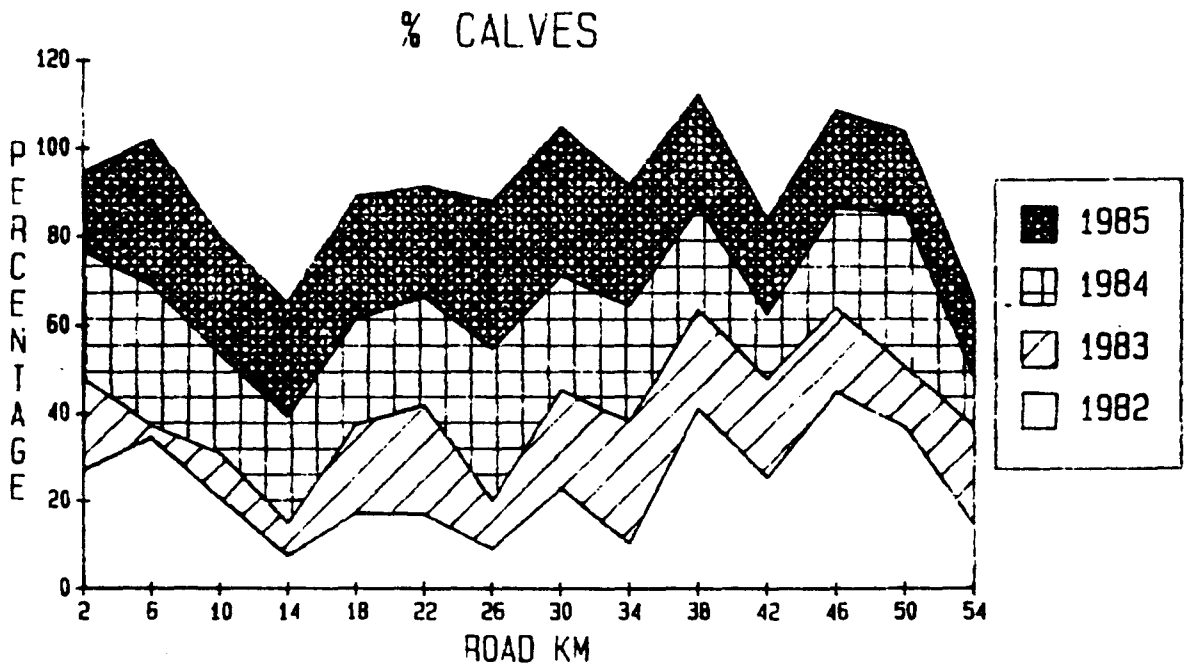
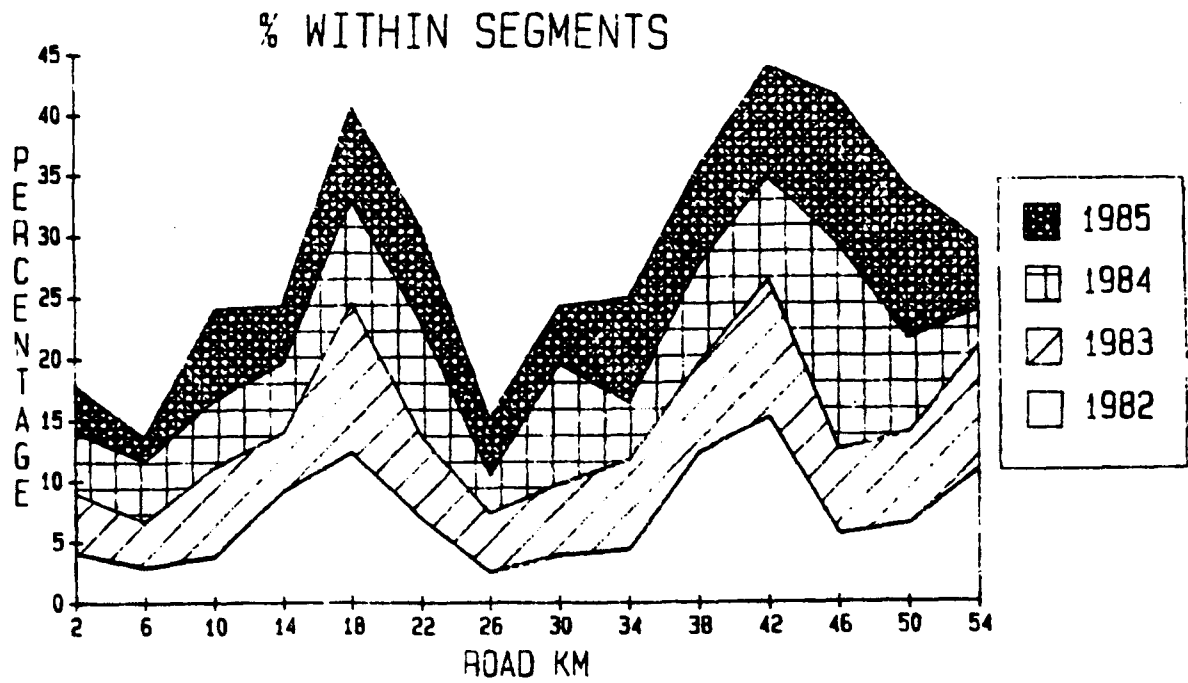


Fig. 5. Distribution of caribou among 4-km segments of the West Sak and Oliktok Roads, and calf percentages for each segment, precalving (see Table 1) 1982-85.

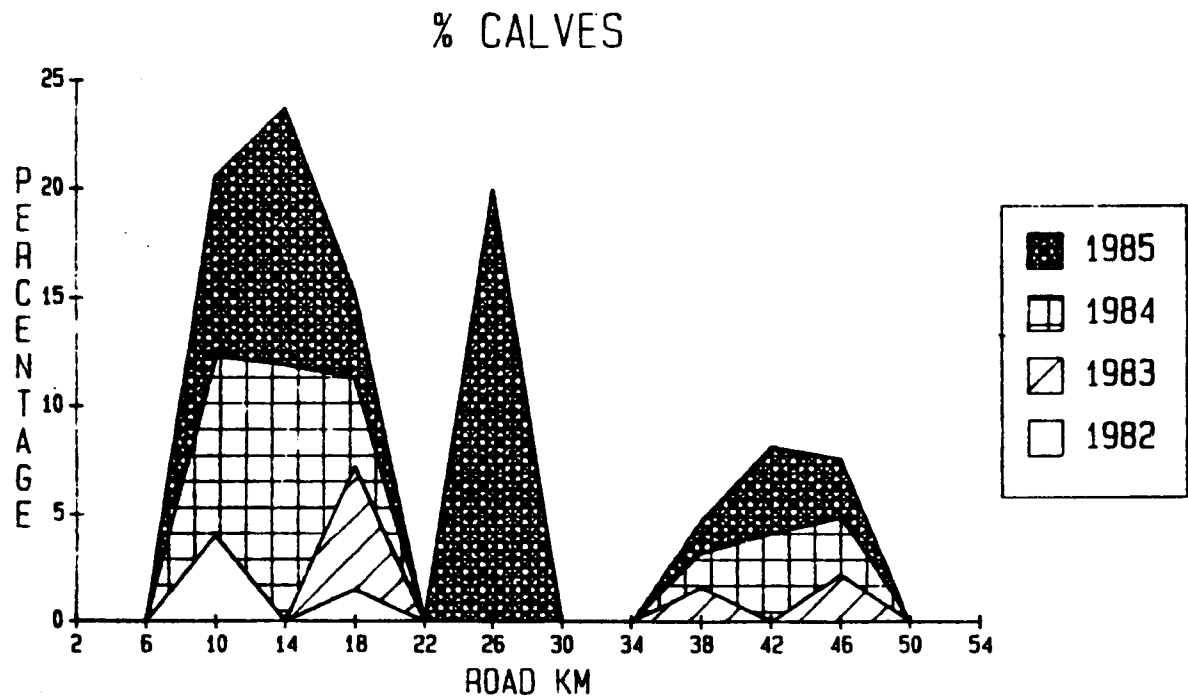
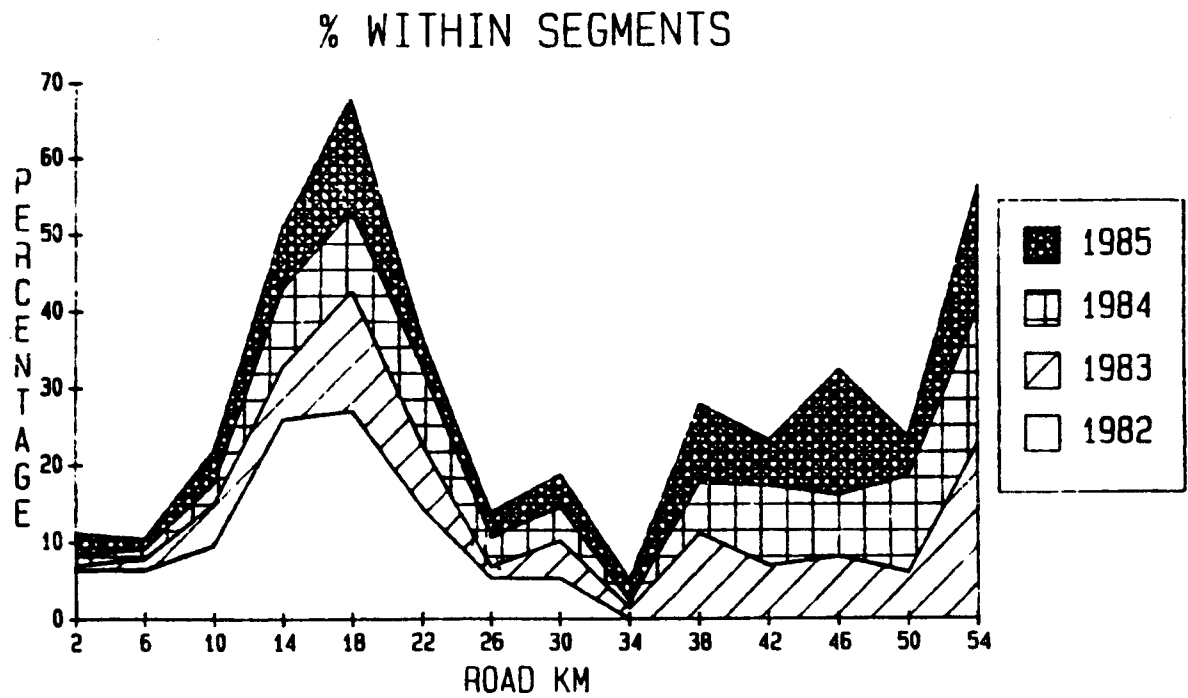
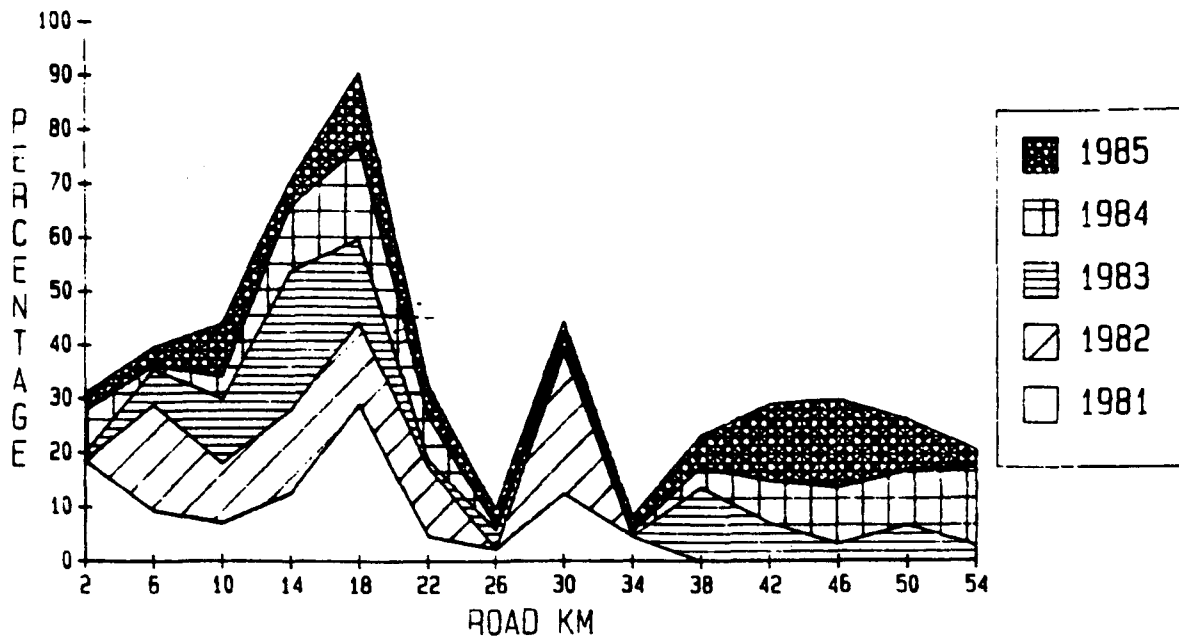


Fig. 6. Distribution of caribou among 4-km segments of the West Sak and Oliktok Roads, and calf percentages for each segment, calving (see Table 2) 1982-85.

% WITHIN SEGMENTS



% CALVES

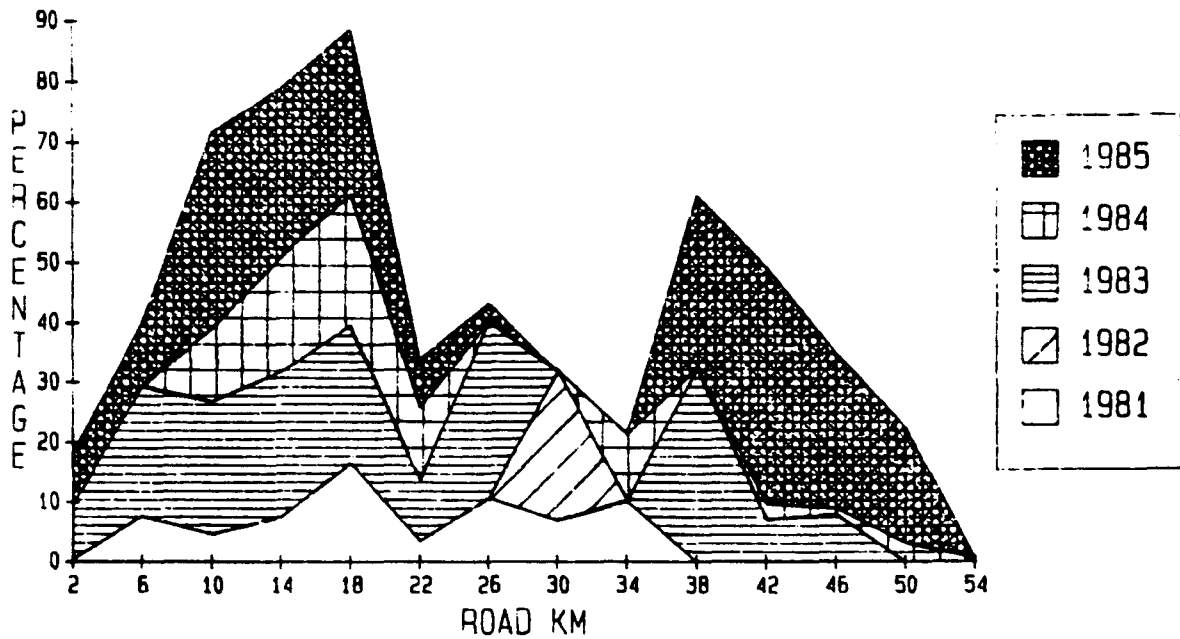
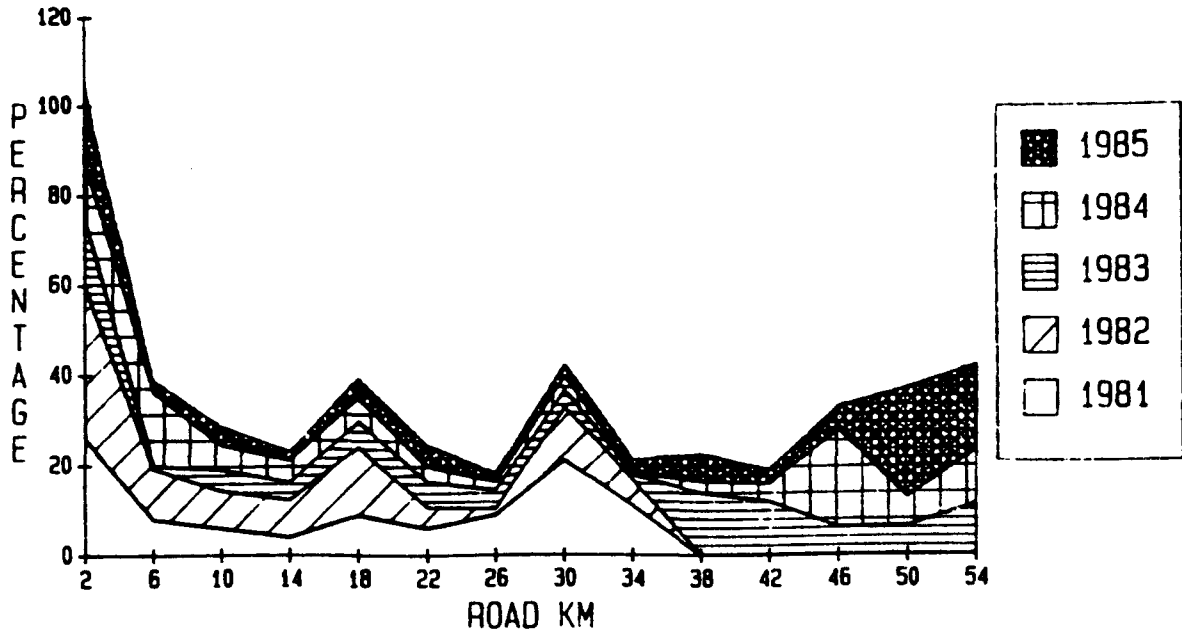


Fig. 7. Distribution of caribou among 4-km segments of the West Sak and Oliktok Roads, and calf percentages for each segment, postcalving (see Table 3) 1981-85. Note: only the West Sak Road was surveyed in 1981 and 1982.

% WITHIN SEGMENTS



% CALVES

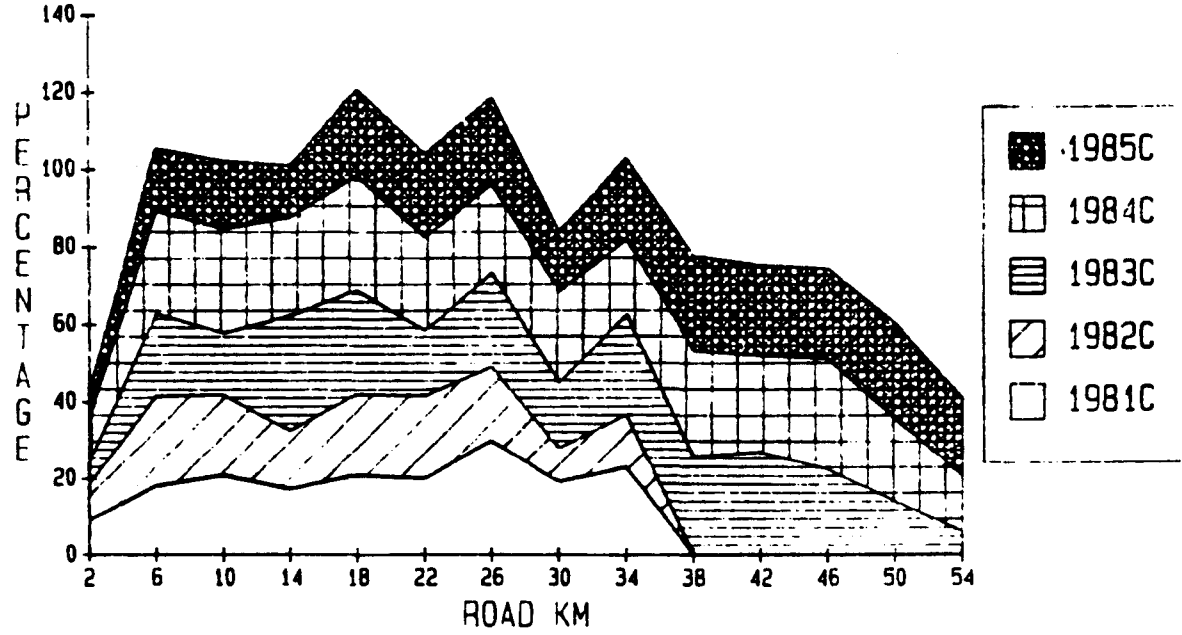


Fig. 8. Distribution of caribou among 4-km segments of the West Sak and Oliktok Roads, and calf percentages for each segment, insect season (see Table 4) 1981-85. Note: only the West Sak Road was surveyed in 1981 and 1982.

ATTEMPTED ROAD/PIPELINE CROSSINGS

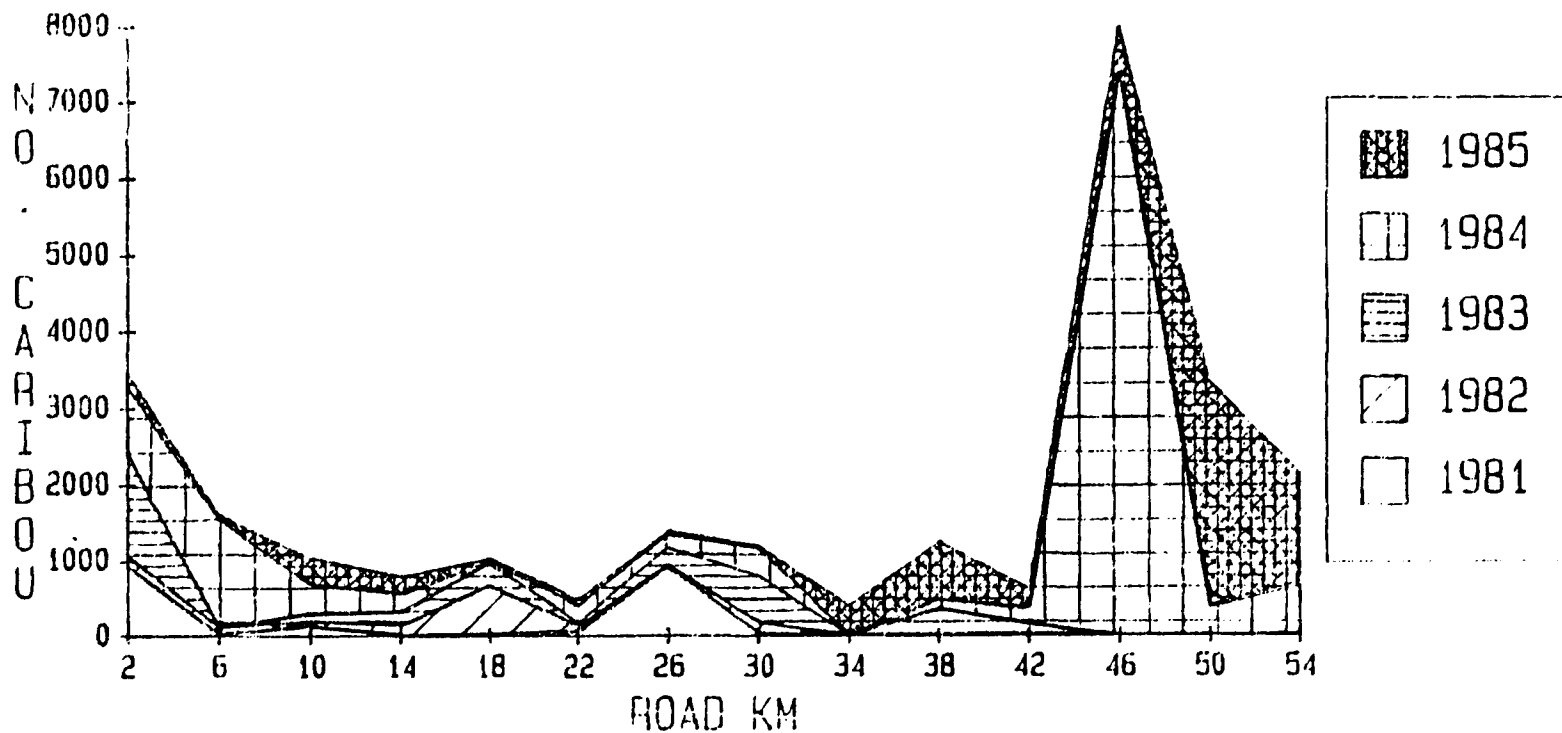


Fig. 9. Distribution of attempted road and road/pipeline crossings by caribou along the West Sak and Oliktok Roads during the insect season, 1981-85.

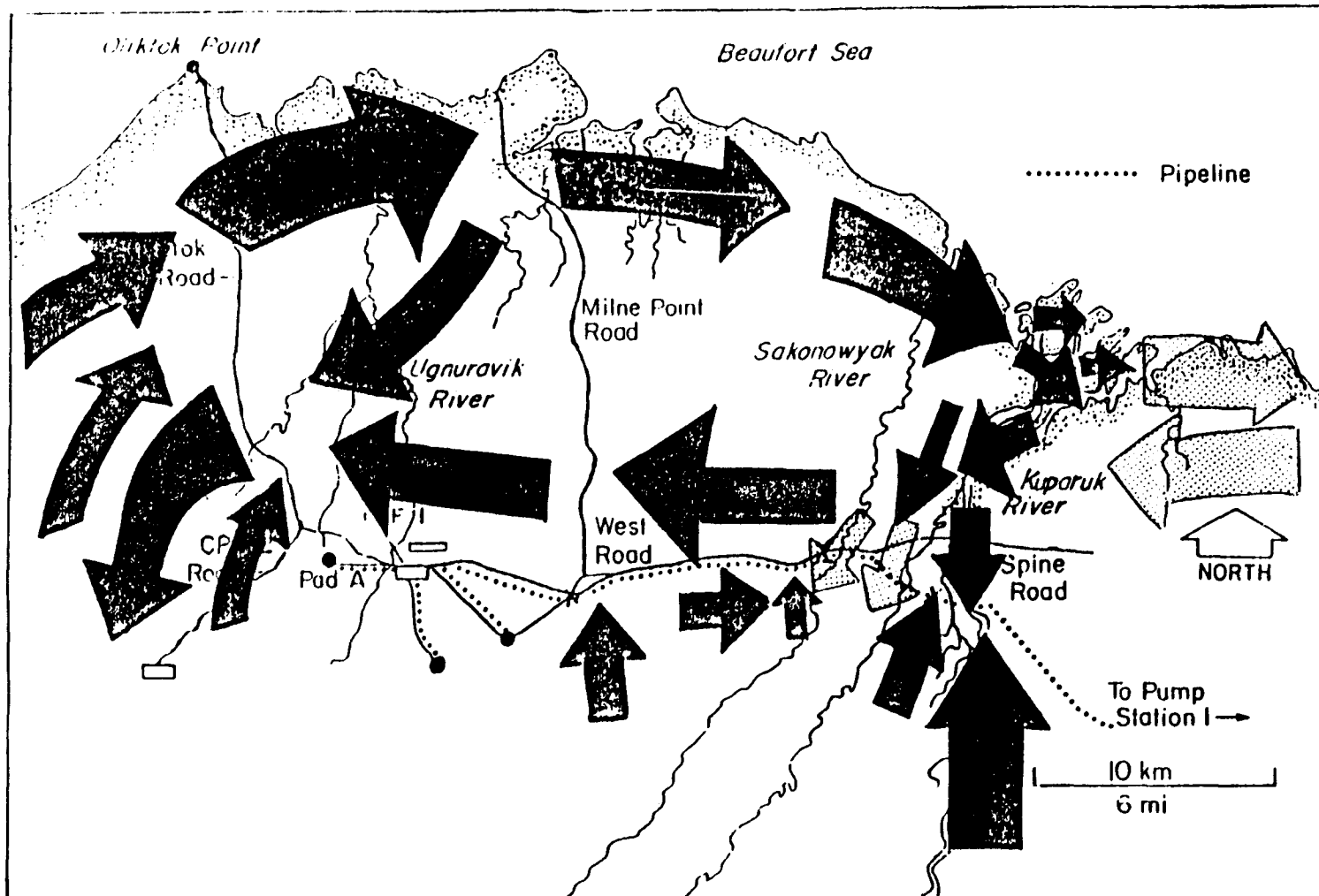


Fig. 10. Movements of caribou in response to insect harassment, Kuparuk Development Area. Dark arrows represent generalized movement patterns first observed in 1981. Stippled arrows are 1983 and 1984 movements. From Smith et al. 1985.

Table 1. Population characteristics of caribou observed along the West Sak and Oliktok Roads during precalving, 1982-85.

Year	Date	Category	Number of surveys	Number of groups	Number of caribou	Mean group size	Sighting rates (caribou/km)	Percent calves ^a
1982	13-26 May	Total ^b	13	266	895	3.4	1.32	17.6
		WSR ^c	13	135	409	3.0	0.98	17.6
		OR ^d	11	131	486	3.7	1.84	28.8
		0-1000m ^{c,e}	13	98	312	3.2	0.75	17.3
		0-2000m ^{c,f}	13	122	374	3.1	0.91	17.3
1983	10-25 May	Total ^b	14	287	1,156	4.0	1.47	19.0
		WSR ^c	14	154	579	3.8	1.29	16.4
		OR ^d	14	133	577	4.3	1.75	21.6
		0-1000m ^{b,e}	14	179	770	4.3	0.98	21.4
		0-2000m ^{b,f}	14	255	1,052	3.1	1.34	20.1
1984	12-25 May	Total ^b	13	624	3,129	5.0	4.30	24.9
		WSR ^c	13	370	1,621	4.4	3.90	27.1
		OR ^d	13	254	1,508	5.9	4.83	22.8
		0-1000m ^{b,e}	13	456	2,364	5.2	3.25	26.1
		0-2000m ^{b,f}	13	559	2,817	5.0	3.87	25.7
1985	11-24 May	Total ^b	13	420	1,955	4.6	2.69	24.5
		WSR ^c	13	209	848	4.1	2.04	27.6
		OR ^d	13	211	1,107	5.2	3.55	22.0
		0-1000m ^{b,e}	13	281	1,386	4.9	1.90	24.7
		0-2000m ^{b,f}	13	380	1,790	4.7	2.46	24.4

Table 1. Continued.

- ^a Based on groups with no unclassified (unknown) caribou.
- ^b Includes caribou observed along both the West Sak and Oliktok Roads.
- ^c Caribou observed along the West Sak Road only.
- ^d Caribou observed along the Oliktok Road only.
- ^e Caribou observed within 1000 m of the road.
- ^f Caribou observed within 2000 m of the road.

Table 2. Population characteristics of caribou observed along the West Sak and Oliktok Roads during calving, 1982-85.

Year	Date	Category	Number of surveys	Number of groups	Number of caribou	Mean group size	Sighting rates (caribou/km)	Percent calves ^a
1982	3-14 Jun	WSR ^b	18	100	264	2.6	0.46	0.8
		OR ^{c,d}	10	131	727	5.6	3.03	8.4
		0-1000m ^{b,e}	18	57	135	2.4	0.23	0.8
		0-2000m ^{b,f}	18	91	243	2.7	0.42	0.7
1983	2-14 Jun	Total ^g	13	177	569	3.2	0.78	1.2
		WSR ^b	13	88	250	2.8	0.60	2.0
		OR ^c	13	89	319	3.6	1.02	0.6
		0-1000m ^{e,g}	13	106	335	3.2	0.46	1.5
		0-2000m ^{f,g}	13	149	474	3.2	0.76	1.1
1984	2-14 Jun	Total ^g	11	297	934	3.1	1.52	2.5
		WSR ^b	11	141	413	2.9	1.17	3.9
		OR ^c	11	156	521	3.4	1.97	1.3
		0-1000m ^{e,g}	11	136	451	3.3	0.74	0.7
		0-2000m ^{f,g}	11	241	747	3.1	1.22	1.7
1985	2-14 Jun	Total ^g	12	211	873	4.1	1.30	7.4
		WSR ^b	12	94	380	4.0	0.99	10.8
		OR ^c	12	117	493	4.2	1.71	4.9
		0-1000m ^{e,g}	12	110	419	3.8	1.62	6.9
		0-2000m ^{f,g}	12	177	692	3.9	1.03	7.3

Table 2. Continued.

- ^a Based on groups with no unclassified (unknown) caribou.
- ^b Includes caribou observed along the West Sak Road only.
- ^c Caribou observed along the Oliktok Road only.
- ^d Data from personal communication, M. Robus, Alaska Biological Research.
- ^e Caribou observed within 1000 m of the road.
- ^f Caribou observed within 2000 m of the road.
- ^g Caribou observed along both the West Sak and Oliktok Roads.

Table 3. Population characteristics of caribou observed along the West Sak and Oliktok Roads during postcalving, 1981-85.

Year	Date	Category	Number of surveys	Number of groups	Number of caribou	Mean group size	Sighting rates (caribou/km)	Percent calves ^a
1981	15-30 Jun	WSR ^b	27	459	2,497	5.4	2.89	11.8
		0-1000 ^{b,c}	27	177	726	4.1	0.84	8.7
		0-2000m ^{b,d}	27	290	1,234	4.3	1.43	8.9
1982	15-20 Jun	WSR ^b	4	18	46	2.6	0.36	6.5
		0-1000m ^{b,c}	4	8	15	1.9	0.12	0.0
		0-2000m ^{b,d}	4	12	25	2.1	0.20	0.0
1983	15-20 Jun	Total ^e	6	117	774	6.6	2.30	20.1
		WSR ^b	6	74	515	7.0	2.68	22.5
		OR ^f	6	43	259	6.0	1.80	15.7
		0-1000m ^{c,e}	6	53	191	3.6	0.57	13.1
		0-2000m ^{d,e}	6	98	517	5.3	1.54	17.0
1984	15-20 Jun	Total ^e	6	198	952	4.8	2.83	8.4
		WSR ^b	6	115	504	4.4	2.63	14.3
		OR ^f	6	83	448	5.4	3.11	1.8
		0-1000m ^{c,e}	6	152	729	4.8	2.17	6.3
		0-2000m ^{d,e}	6	192	926	4.8	2.76	8.5
1985	15-20 Jun	Total ^e	4	143	1,031	7.2	4.60	22.9
		WSR ^b	4	85	491	5.8	3.84	16.7
		OR ^f	4	58	540	9.3	5.61	25.7
		0-1000m ^{c,e}	4	100	626	6.3	2.80	19.2
		0-2000m ^{d,e}	4	134	971	7.2	4.34	22.6

Table 3. Continued.

- a Based on groups with no unclassified (unknown) caribou.
- b Includes caribou observed along the West Sak Road only.
- c Caribou observed within 1000 m of the road.
- d Caribou observed within 2000 m of the road.
- e Caribou observed along both the Oliktok and West Sak Roads.
- f Caribou observed along the Oliktok Road only.

Table 4. Population characteristics of caribou observed along the West Sak and Oliktok Roads during summer, 1981-85.

Year	Date	Category	Number of surveys	Number of groups	Number of caribou	Mean group size	Sighting rates (caribou/km)	Percent calves ^a
1981	1 Jul-7 Aug	WSR ^b	60	662	11,666	17.6	6.07	19.2
		0-1000m ^{b,c}	60	249	3,745	15.0	1.95	21.6
		0-2000m ^{b,d}	60	486	6,698	13.8	3.49	20.7
1982	1 Jul-5 Aug	WSR ^b	60	522	8,801	16.9	4.58	16.2
		0-1000m ^{b,c}	60	318	3,642	11.4	1.90	17.5
		0-2000m ^{b,d}	60	480	6,461	13.4	3.37	16.9
1983	1 Jul-4 Aug	Total ^e	61	930	22,694	24.4	8.37	18.1
		WSR ^b	60	655	12,992	19.8	6.77	16.9
		OR ^f	33	275	9,702	35.3	12.25	19.7
		0-1000m ^{c,e}	61	598	10,599	17.7	3.91	17.6
		0-2000m ^{d,e}	61	839	18,739	22.3	6.91	18.1
1984	1 Jul-4 Aug	Total ^e	57	1,327	38,492	29.0	12.06	23.2
		WSR ^b	57	888	20,556	23.1	11.27	22.3
		OR ^f	57	439	17,936	40.8	15.27	24.4
		0-1000m ^{c,e}	57	917	20,891	22.8	6.52	24.1
		0-2000m ^{d,e}	57	1,225	32,081	26.2	10.05	24.0
1985	1 Jul-6 Aug	Total ^e	43	957	32,074	33.5	13.32	20.8
		WSR ^b	43	534	12,418	23.2	9.03	16.8
		OR ^d	43	423	19,656	46.5	19.05	23.4
		0-1000m ^{c,e}	43	723	17,148	23.7	7.12	21.7
		0-2000m ^{d,e}	43	907	23,871	26.3	9.91	20.9

Table 4. Continued.

- a Based on groups with no unclassified (unknown) caribou.
- b Includes caribou observed along the West Sak Road only.
- c Caribou observed within 1000 m of the road.
- d Caribou observed within 2000 m of the road.
- e Caribou observed along both the West Sak and Oliktok Road.
- f Caribou observed along the Oliktok Road only.

Table 5. Seasonal evaluation of attempted caribou crossings of the West Sak and Oliktok Roads, Alaska, 1981-85.

	Road		Pipeline		Road/Pipeline		Total	
	Number of groups	Number of caribou	Number of groups	Number of caribou	Number of groups	Number of caribou	Number of groups	Number of caribou
<u>1981</u>								
Jun ^{a, b}	2	10	0	0	3	14	5	24
Jul-Aug ^a	19	924	1	1	25	1,254	45	2,179
Total	21	934	1	1	28	1,268	50	2,203
<u>1982</u>								
May	0	0	0	0	0	0	0	0
Jun ^{a, b}	0	0	0	0	1	4	1	4
Jul-Aug ^a	17	240	0	0	34	1,078	51	1,318
Total	17	240	0	0	35	1,082	52	1,322
<u>1983</u>								
May ^b	4	12	0	0	1	2	5	14
Jun ^b	2	13	0	0	3	6	5	19
Jul-Aug	26	1,404	6	126	45	1,823	77	3,353
Total	32	1,429	6	126	49	1,831	87	3,386
<u>1984</u>								
May ^b	6	18	0	0	2	13	8	31
Jun ^b	3	6	0	0	2	8	5	14
Jul-Aug	60	9,739	19	901	46	1,790	125	12,430
Total	69	5,063	19	901	50	1,811	138	12,475
<u>1985</u>								
May ^b	2	13	0	0	5	20	7	33
Jun ^b	3	7	2	5	5	130	10	142
Jul-Aug	15	517	39	87	54	6,978	108	7,582
Total	20	537	41	92	64	7,128	125	7,757

^a West Sak Road data only.

^b Combined calving and postcalving periods.

Appendix A

EFFECTS OF A ROAD SYSTEM ON
CARIBOU DISTRIBUTION DURING CALVING

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

Key words: caribou, calving, roads, disturbance.

INTRODUCTION

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

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

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

METHODS

The study area is ca. 45 km northwest of Prudhoe Bay, lying north of the West Sak Road between the Oliktok Road and Kuparuk River (Fig. 1). Terrain ranges from sea level to 25 m elevation. Vegetation is typical of the Arctic Coastal Plain (Wahrhaftig, 1965) and similar to that described for the Prudhoe Bay region (Neiland and Hok, 1975; Webber and Walker, 1975).

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

The study area was partitioned into 40 quadrats of 1036 ha each (Fig. 2). Median percentages of caribou observed within the seven quadrats that include the present road system (i.e., "road quadrats") were compared between the pre- and postconstruction periods using the Mann-Whitney test; the Z test statistic is reported when ranks were tied (Conover, 1980).

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

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

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

RESULTS

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

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

Linear relationships between caribou density and distance from roads were significantly different between 1978-81 and 1982-85 for all caribou, and for calves (Table 1). The annual variability in these relationships within each four-year period was not significant for all caribou, but was nearly significant for calves ($P = 0.053$). The latter may have resulted from yearly differences in levels of human activity in the study area after 1981. Nevertheless, differences in these relationships were greater between periods than among years within periods (Table 1).

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

The similar results obtained for total number of all caribou and number of calves (Fig. 3) indicate that the distribution of maternal caribou was not appreciably different from the distribution of all caribou. This is not surprising considering that most adult (>2 years) caribou in the study area during June were maternal females (minimum mean = 69%; $SD = 0.15$).

The relationships between number of maternal groups per km^2 and distance from roads differed significantly between 1978-81 and 1982-85, a difference that cannot be attributed to within-period variability (Table 2). No such difference was found for nonmaternal groups, either between or within the pre- and postconstruction periods. Furthermore, there was no linear correlation between the number of maternal or non-maternal groups per km^2 and distance during 1978-81; nor was there any correlation for nonmaternal groups during 1982-85. In 1982-85, however, the number of maternal groups per km^2 was highly correlated with distance from roads (Fig. 4).

DISCUSSION

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

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

Extrapolating these local effects to a regional level requires some speculation. The logical implication is that an extensive, dense network of roads will result in widespread, partial displacement of maternal caribou from calving grounds unless they begin to tolerate these structures and associated activities (Cowan 1974). Unfortunately, there is no evidence for habituation by maternal caribou. On the contrary, numbers of CAH females calving within the Prudhoe Bay oil field have remained consistently low (Whitten and Cameron, 1985, unpublished data), despite nearly a decade of exposure to manmade structures.

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

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

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

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Table 1. Analysis of variance examination of the relationships between numbers of all caribou and calves, per km², and distance from roads, Milne Point, Alaska, June 1978-85.

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

Table 1. Continued.

^a Each model tests simple, linear relationship(s), where the dependent variable is the square root of caribou density (numbers/km²) and the independent variable is distance from the road site (km).

^b Fits a linear model with data pooled across all years; H₀: the eight relationships are not significantly different.

^c Fits a separate linear model for each period; H₀: the two relationships are not significantly different. The Entering F value tests for the significance of this model beyond the significance of the Basic model.

^d Fits a separate linear model for each year within each period; H₀: the four relationships are not significantly different. The Entering F value tests for the significance of this model beyond the significance of the Reduced model.

^e Tests H₀: the variation in linear models between periods is not significantly greater than the variation in linear models among years within each period.

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

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

^{a-e} See footnotes to Table 1.

Appendix B. Numbers and sex/age composition of caribou observed during aerial surveys^a of the calving grounds within the Kuparuk Development Area, June 1981-85.

Date	Number of groups	Number of caribou	Number of				Number/100 cows		
			bulls	cows	calves	yrlds	bulls	calves	yrlds
6/11/81	136	1562	26 (1.7)	746 (47.8)	652 (41.7)	138 (8.8)	3	87	19
6/11/82	168	1103	60 (5.4)	542 (49.1)	377 (34.2)	124 (11.2)	11	70	23
6/11-12/83	183	1859	72 (3.9)	810 (43.6)	737 (39.6)	240 (12.9)	9	91	30
6/12-13/84	277	2692	111 (4.1)	1207 (44.8)	1071 (39.8)	303 (11.3)	9	89	25
6/13-14/85	238	2357	162 (6.9)	983 (41.7)	867 (36.8)	345 (14.6)	16	88	35

^a Cameron et al. 1985; Whitten and Cameron 1985.

Note: () = % of total.