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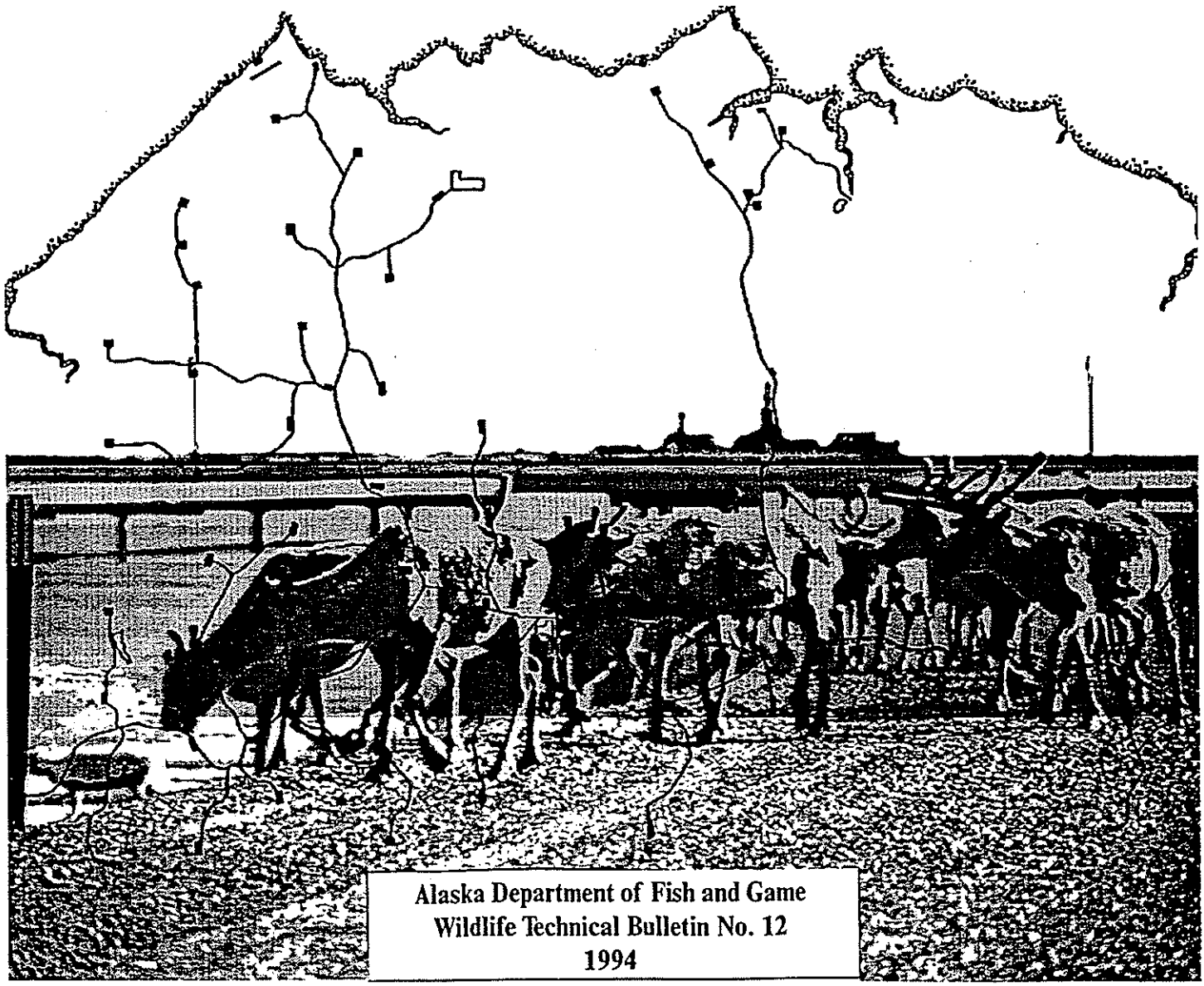

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EXECUTIVE SUMMARY

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

II. Preconstruction (1978-80)

A. Midsummer (3 Jul-10 Aug)

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

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

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

4. Except for some avoidance of local construction activity, distribution and sex/age composition appeared unaffected by development.

III. Initial Construction (1981-84)

A. Precalving (10-25 May)

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

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

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

B. Calving/Postcalving (2-30 Jun)

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

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

3. Few caribou or calves were observed crossing roads, even though increasingly numerous caribou were present in the Milne Point calving area.

C. Midsummer (1 Jul-7 Aug)

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

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

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

4. Although the Kuparuk River remained a node of road crossings throughout the period, most additional crossings of the road/pipeline observed were along the OR. In 1981 and 1982, after the construction of the Kuparuk Pipeline, most

large insect-harassed groups were unsuccessful in crossing the road/pipeline complex, depressing individual crossing success. By the end of the period, only about half of both individual caribou and groups of caribou crossed successfully. Crossing groups were predominantly of maternal cows, except within the Kuparuk floodplain.

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

IV. Advanced Construction (1985-90)

A. Precalving (11-24 May)

1. After construction of pipelines along the OR, sighting rate, group size, and calf percentage decreased to the lowest values recorded. When surveys were discontinued in 1986, most caribou were concentrated between CPF-1 and CPF-3 within the dust shadow caused by heavy traffic.

2. By 1986, the increasing complexity of the oilfield and heavy traffic reduced caribou occupancy along the road system to minimum numbers of highly habituated, nonmaternal caribou.

B. Calving (1-20 Jun)

1. After 1985, sighting rate, mean group size, and calf percentage declined and remained low until 1990, when sighting rate increased. However, the percentage of calves in groups observed from the road remained significantly lower 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 were the least successful.

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

C. Midsummer (1 Jul-6 Aug)

1. The proportion of caribou seen within 1,000 m of the road increased, but sighting rate and mean group size decreased to levels recorded during Initial Construction.

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

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

4. Although the number of observed road or pipeline crossing attempts declined after 1988, crossing success increased steadily after the marked declines observed immediately after construction of the Kuparuk Pipeline in 1981 and 1983. In 1990, both group and individual crossing success were the highest for the decade. Crossings involving separated roads and pipelines decreased after 1988 when crossing groups were thwarted by heavy vehicular traffic.

In summary, numbers of caribou observed from the road have decreased to Initial or Preconstruction levels, despite a 4- to 5-fold increase in herd size. Although there is evidence of some habituation to the road system, caribou avoid areas of intensive activity, especially before and during calving. This avoidance may have restricted access to the Milne Point calving area. By the end of this study, most insect-induced movements of large groups across the road transect occurred near Oliktok Point or within the Kuparuk floodplain, and caribou avoided central parts of the transect used during Preconstruction and Initial Construction.

V. Recommendations

A. Mitigation

Discourage the expansion of pipeline networks and facilities into the Milne Point calving grounds. If caribou are displaced to areas south of the Kuparuk complex, calving success should be monitored.

Maintain a 3-km wide zone of minimum surface development along the coast. Although current surface development within the Prudhoe Bay complex has become a virtual barrier to easterly movement by large insect-harassed groups, development of technology for pipeline burial and redesign of elevated pipelines, and placement of

nonessential facilities and roads in noncritical areas would help ensure continued access of caribou to the coast.

B. Future Studies

We recommend that precalving and calving surveys be suspended. Maternal group avoidance of the road noted at the onset of pipeline construction has persisted for 10 years, and a change appears unlikely. Annual or biennial transect data from helicopter surveys of Kuparuk calving areas should suffice as "snapshots" of regional calving distribution. However, annual road surveys during summer should continue as a means of monitoring changes in caribou abundance and composition along the road system, estimating regional sex and age composition, and documenting the movements of large insect-harassed groups of caribou within and adjacent to the oilfield complex.

CONTENTS

INTRODUCTION

The Central Arctic Herd (CAH) is a distinct subpopulation of approximately 23,400 caribou (*Rangifer tarandus granti*) (Valkenburg, in press) that ranges the Arctic Slope, principally between the Canning and Colville Rivers. Seasonal movements are generally north-south between wintering areas in the Brooks Range and calving/summer range on the Arctic Coastal Plain (Fig. 1) (Cameron and Whitten 1979).

Pregnant females, a few bulls and barren females, and numerous short yearlings move onto the coastal calving grounds in May (Whitten and Cameron 1985); calving usually occurs during the first 2 weeks of June within 50 km of the coast. Most of the remaining nonmaternal caribou arrive 2-4 weeks later.

Virtually the entire CAH remains within approximately 50 km of the Beaufort Sea during the insect season, which extends from late June through mid-August. On warm, calm days when mosquitoes (*Aedes* spp.) and oestrid flies (*Cephenomyia* sp. and *Oedemagena* sp.) are active, groups of caribou coalesce and move rapidly toward the coastal tidal flats, sand dunes, river deltas, and other less-vegetated habitats. The area within roughly 1 km of the coast is typically cooler, windier, and more humid than inland areas, and therefore less conducive to insect activity (Dau 1986). During extended periods of insect attack, large aggregations of caribou generally move along the coast into the prevailing northeasterly winds. With decreased insect activity, the groups fragment and caribou move inland to feed. Insect activity declines by mid-August of most years, and CAH caribou disperse inland toward wintering areas.

Given the widespread, intensive use of coastal areas by the CAH during spring and summer months, we have four major concerns regarding existing and future petroleum development near Prudhoe Bay: (1) displacement of maternal females from established calving areas, (2) disruption of insect-induced movements during summer, (3) overuse and depletion of vegetation areas where caribou movements are diverted or delayed by development and construction activities, and (4) the effectiveness of various mitigative measures designed to accommodate caribou.

Parturient and postpartum females are extremely sensitive to disturbance (de Vos 1960, Lent 1966, Bergerud 1974). Aerial survey observations on the Central Arctic Coastal Plain during the late 1970s and early 1980s indicate that densities of calving caribou within the area encompassing the Prudhoe Bay Oilfield were less than one-half of the next lowest density area and less than one-tenth of the highest density area (Whitten and Cameron 1985). While there is little reason to suspect that the immediate Prudhoe Bay region previously supported a particularly high abundance of calving caribou, it appears that the extremely limited use of the area may be due, in part, to the presence of a major oilfield complex.

Recent studies near Milne Point have demonstrated an avoidance response by cows and neonatal calves to a road (and later to an adjacent pipeline) constructed within an area of concentrated calving activity. Road placement caused mean caribou abundance to decline by more than two-thirds within 2 km and to nearly triple 4-6 km from the road (Dau and Cameron 1986, Cameron et al. 1992). The logical implication of these results is that an extensive, dense network of drill pads and transportation corridors in the coastal zone may well result in widespread loss of

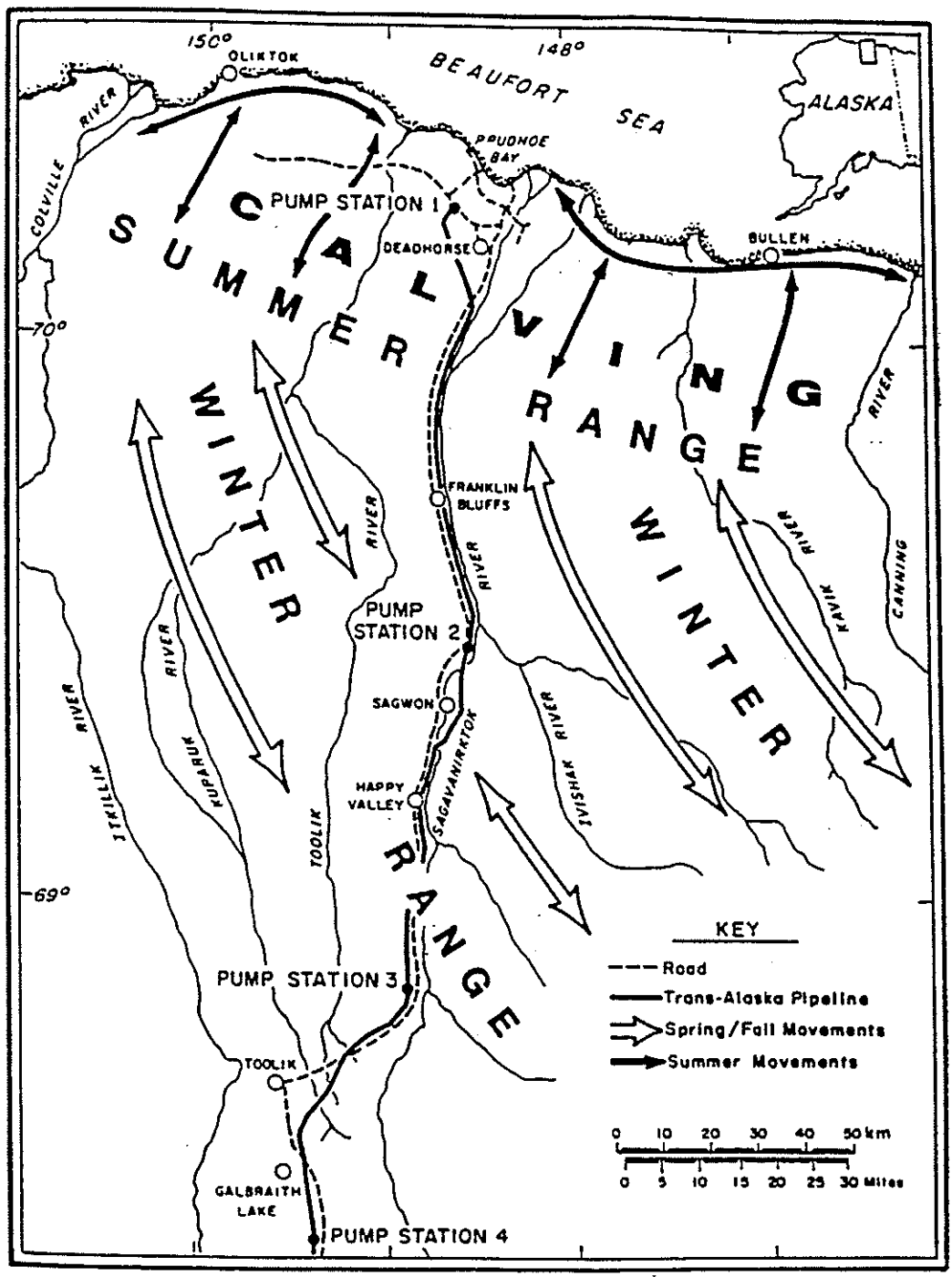

Fig. 1. The greater range and seasonal movements of the Central Arctic caribou herd.

calving habitat. In hindsight, we believe this occurred in the Prudhoe Bay complex as it evolved from a minor oilfield, with minimal support facilities, to the large industrial complex that it is today. Additional losses of habitat in the region may be forthcoming as adjacent oilfields expand and reach full production.

The habitat requirements of calving caribou are not well understood. Access to insect relief habitat, locally improved foraging conditions, advanced plant phenology, and lower predator numbers have been proposed as attributes of calving grounds (Kuropat and Bryant 1980, Bergerud and Page 1987, Eastland et al. 1989, Bishop and Cameron 1990, Fancy and Whitten 1991, Cameron et al. 1992, Whitten et al. 1992). It is extremely difficult to predict long-term effects of disturbance-related displacement on the CAH and to ascertain the availability and suitability of alternative calving areas. Nonetheless, the desirability of preserving the integrity of caribou calving grounds has long been recognized by wildlife biologists. Because these areas are used repeatedly and predictably, they are of presumed importance to the long-term reproductive success of a herd (Skoog 1968, Cameron 1983).

Access of the CAH to portions of summer range has also been impaired as a result of oil development (Shideler 1986). Within the Prudhoe Bay oilfield complex, caribou abundance and calf representation are lower than in adjacent areas (Smith and Cameron 1983). Elsewhere in the region, movements have been diverted or impeded by roads and pipelines (Smith and Cameron 1985*a,b*; Curatolo and Murphy 1986; Johnson and Lawhead 1989).

Interference with the summer movements of CAH caribou has potentially deleterious consequences. Presumably the energy cost of moving to coastal insect relief areas is more than offset by the energy savings associated with reduced exposure to insects. When insect activity declines, caribou promptly return inland to preferred foraging areas. In theory, these movements maximize energy retention during summer months (White et al. 1975, Roby 1978, Downes et al. 1986), which in turn influences female body condition attained by the fall breeding season, which influences reproductive success (Dauphine 1976; Reimers 1983*a,b*; Cameron et al. 1993).

Mitigation of the above conflicts requires a basic understanding of disturbances, including the types and intensities of development that constitute negative stimuli, the threshold levels of disturbance that might trigger range abandonment, the amount of displacement tolerable before overuse of remaining range occurs, and whether caribou will habituate to local disturbance over time. Despite an incomplete understanding of these fundamental concepts, practical short-term mitigation of existing or imminent problems is possible as site-specific data are accumulated. Changes in pipeline design and placement will hopefully promote physical passage of caribou, and strategic scheduling of construction activity should reduce disturbance-induced displacement. Continued coordinated study, both basic and applied, are needed to develop more comprehensive guidelines for petroleum development on the Arctic Slope.

This research program was initiated in 1978 within the Kuparuk Development Area (KDA), located immediately west of the main Prudhoe Bay oilfield. This new development unit was known to lie within both an active calving area (Gavin 1978, Whitten and Cameron 1985) and an important component of summer range (Cameron and Whitten 1979). We believed that detailed knowledge of regional

caribou distribution and movements would assist in developing and implementing practices that would better accommodate caribou. It would also provide an opportunity to identify and quantify sources of local disturbance and reactions of caribou to known stimuli. Finally, in conjunction with continued monitoring of CAH status, there would be an opportunity to document any related, long-term effects on population distribution, size, and productivity.

OBJECTIVES

1. To determine chronological changes in the distribution, movements, and sex/age composition of caribou within or near the KDA during precalving, calving, postcalving, and midsummer periods.

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

3. To characterize the responses of caribou to local structures and disturbance.

STUDY AREA

The KDA (Fig. 2) lies in the northern portion of Game Management Subunit 26B between the Sagavanirktok and Colville Rivers. This region is within the Arctic Coastal Plain physiographic province (Wahrhaftig 1965), a low, poorly drained area of numerous thaw lakes. The Dalton Highway and associated Trans-Alaska Pipeline extend southward along the Sagavanirktok River from the Prudhoe Bay Oilfield (Fig. 1).

Reservoir delineation of the Kuparuk River Production Unit began in 1976. In 1977, ARCO constructed the West Sak Road, later renamed the Spine Road (SR), from the west bank of the Kuparuk River to Mobil Test Pad X and added 10 km of roads to test wells to the south. In spring 1978, the SR was extended 23 km west, where three additional test wells were drilled. Phase I began with construction of the Central Processing Facilities (CPF-1) and five drill sites (Fig. 2). An airstrip and operations center were completed in winter 1979-80, and the Kuparuk Pipeline was constructed in winter 1980-81 to transport crude from CPF-1 to Pump Station 1, 50 km to the east. A construction camp and oil processing facilities were added after the 1981 sealift, and oil production started in December 1981.

In spring 1982, the road system was extended to include two future production areas: CPF-2, southeast of CPF-1, and CPF-3, to the north (Fig. 2). The Oliktok Road (OR) was extended beyond CPF-3 to Oliktok Point. CPF-2 was on line by October 1984, and CPF-3 was operational by December 1986. Since then, development has included the addition of seawater treatment and reinjection facilities, expansion of the three main production areas, and construction of a dock at Oliktok Point.

In winter 1981-82, Conoco built the Milne Point Road northward from the SR to two future well pads and a mine site near the coast. Buildings were in place on the Central Facilities Pad (CFP) by 1983, and the Milne Point Pipeline was constructed

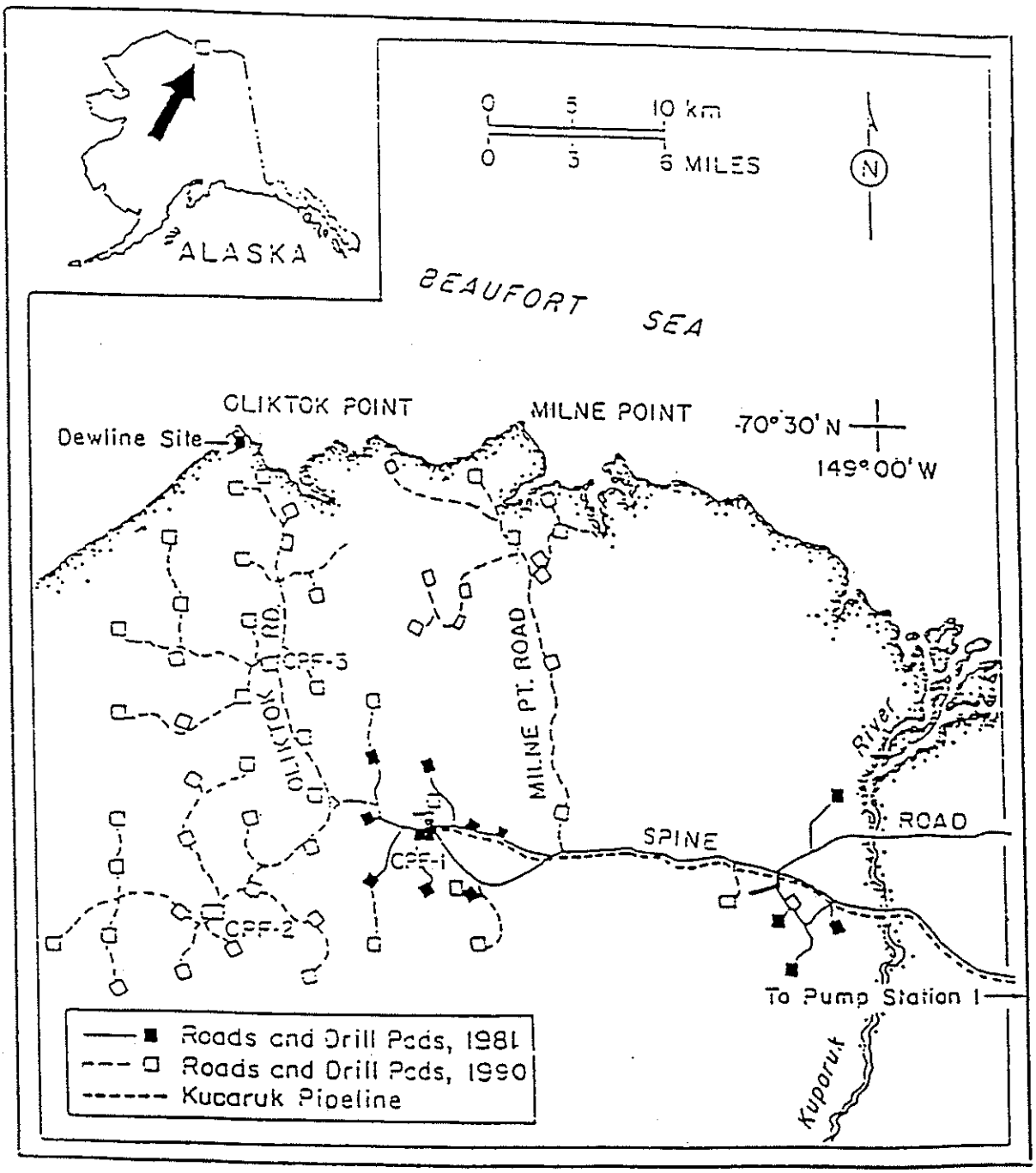

Fig. 2. The Kuparuk Development Area as of 1978 and 1990.

in 1984. Development of the Milne Point Unit has continued with expansion of production facilities to the north and west of the CFP.

METHODS

From 1978 through 1990, the SR was surveyed systematically by light truck between the east bank of the Kuparuk River and Drill Site 1A, 3 km west of CPF-1 (Fig. 2). Surveys were conducted up to twice daily during three periods: precalving (10-25 May), calving/postcalving (1-30 Jun), and midsummer (1 Jul-10 Aug). Beginning in 1982, coverage was extended to include the entire length of the OR.

One driver/observer searched both sides of the road at speeds ranging from 25 to 50 km/hr, depending upon road conditions and visibility. To ensure maximum coverage of the adjacent terrain, additional searches using binoculars were made at strategic points from which overall visibility of the area was best. For each sighting, the vehicle was stopped at a point approximately perpendicular to the group which was counted and classified using binoculars or a spotting scope. Caribou approaching roads and/or pipelines were observed until the termination of a crossing event or, in the case of an unsuccessful crossing, until it appeared that they were not soon likely to make another attempt. Observation time varied considerably with group size, observation distance, and degree of interaction with linear structures and traffic, but was generally between 5 and 20 minutes. The following data were recorded for each group observed:

1. Date
2. Time
3. Road location (calibrated odometer miles from starting point; later converted to km)
4. Group size
5. Sex and age composition (numbers of bulls, cows, calves, yearlings, unsexed adults, and caribou of unknown sex and age)
6. Initial distance from road (estimated in meters)
7. Predominant group activity (feeding, standing, lying, walking, or running)
8. Direction of movement (none, N, S, E, or W)
9. Location of any attempted road and/or pipeline crossing
10. Type of structure (road, pipeline, or road and pipeline)
11. Number and composition of caribou attempting to cross
12. Number and composition of caribou that crossed successfully

Also, for each group of caribou observed during midsummer, the level of insect harassment was estimated subjectively as none; light, 1; moderate, 2; or severe, 3, based on relative numbers of mosquitoes and oestrid flies present, the incidence of overt insect avoidance by caribou (i.e., running, shaking, head-down posture, etc.), and/or the degree of observer discomfort. However, for the purpose of depicting caribou distribution along the road(s), each entire survey was classified as to insect presence or absence. If any group was judged to be under moderate or severe harassment, that survey was designated "insects." Surveys characterized by no or light harassment were classified as "no insects."

The survey route was subdivided into 4-km intervals beginning at the east bank of the Kuparuk floodplain (milepost 0.0 km) and ending at Oliktok Point (milepost 56.0 km). Prominent landmarks along the route include the Kuparuk River (2.3 km), Sakonowyak River (9.4 km), Milne Point road junction (19.2 km), CPF-1 (29.0 km), start of the OR (34.2 km), and CPF-3 (42.6 km).

Two-way rates of vehicular traffic were determined using an automatic infrared trail counter (Scientific Dimensions, MC., Albuquerque, N.M.) positioned 6 km west of the Kuparuk River (1978, 1979, 1981), from records obtained from a security checkpoint on the Kuparuk floodplain (1980), or from a direct tally of vehicles that passed the survey truck during each survey (1982-90).

All data were entered on tabular forms or on an Epson HX-20 field recorder, and later filed as numeric fields on a Honeywell Model 20 computer or an IBM PC compatible microcomputer. Software was written in-house to retrieve and summarize various population parameters (e.g., caribou numbers, group size, sighting rates, calf percentage) on the basis of location, distance, and/or insect activity variables.

RESULTS AND DISCUSSION

The social organization of caribou changes with seasonal habitat use, weather, nutritional requirements, and the abundance of other animal species (Bergerud 1974). As well, the degree of social interaction may be influenced by seasonal migrations versus local movements, group size, group sex and age composition, and reactions to their biotic environment (Kelsall 1968, Skoog 1968). To describe how caribou respond to development within the KDA, we examined changes in caribou distribution and seasonal movements, group size, and sex/age composition as indicators of the effects of disturbance. Clearly a distinction must be made between observed changes in the responses of caribou to human activity and natural cyclic patterns of caribou behavior. Only then can a disturbance effect be inferred.

We used three population characteristics to determine if such changes were occurring along the SR and OR during the development of the KDA.

1. Calf Percentage (CP)

Maternal groups are particularly sensitive to disturbance (Lent 1966, Bergerud 1974, Cameron et al. 1985). Therefore, changes in numbers of calves in groups observed from the road should be a reflection of disturbance level. Although complete composition was often impossible to determine, adults and calves were readily distinguishable. We used calf percentage as an indicator of calf representation along the road system.

2. Sighting Rate (SRT)

Caribou distribution may change in response to disturbance (Shideler 1986). Because the number of surveys within seasons and periods varied due to funding, logistics, and weather, we calculated SRTs (no./km coverage) for all survey intervals, thereby allowing comparisons of the numbers of caribou observed among

seasons and periods. SRTs for individual 4-km road segments were used to identify movement corridors and any areas of avoidance or concentration.

3. Mean Group Size (MGS)

Although group size varies in response to a number of factors, insects can have an immediate dominating effect on group size. In July 1985, for example, approximately 3,000 caribou, in numerous subgroups, were crossing the Milne Point Road, 2 km north of its junction with the SR. The groups were strung out over 5-6 km, and about one-third of the caribou had crossed the road westbound within a 1.5-hour period when a front moved through, and the weather changed from cloudy and windy to warm and calm. Mosquitoes became active immediately. Within 20 minutes, the remaining caribou had crossed the road, joined to form a single group, and moved 5 km north as a tight, compact group. There was no traffic or local construction. The abrupt change in group size was driven totally by insect harassment.

The type of insect pest also has a marked effect on group size (White et al. 1975, Roby 1978, Curatolo and Murphy 1986, Murphy and Curatolo 1987). Mosquitoes, or mosquitoes and oestrid flies in combination, cause CAH caribou to form large, dense aggregations that generally move rapidly into the wind. Oestrids alone cause groups to disperse, often as singles or pairs. Therefore, the mere presence or absence of insects alone is not a completely accurate forecaster of changes in group size.

This 13-year analysis has been divided into three periods: (1) 1978-80, a baseline Preconstruction interval prior to pipeline construction; (2) 1981-84, an Initial Construction phase; and (3) 1985-90, an Advanced Construction phase.

I. Preconstruction (1978-80)

A. Midsummer

1. The mean calf percentage (CP) in groups observed along the SR decreased each year, but was similar to regional means determined by aerial survey (Table 1) (Smith and Cameron 1986). The sighting rate (SRT) also increased each year, but there was no temporal trend in mean group size (MGS).

2. An increasing proportion of all caribou were observed within 1,000 m of the road (Table 1). Trends for MGS, CP, and SRT for caribou within 1,000 m were the same as for all observations.

3. The distribution of caribou among 4-km segments of the road transect varied among years for both insect and non-insect conditions, but caribou consistently avoided areas of heavy construction activity, especially in the Kuparuk floodplain (Fig. 3; Cameron and Whitten 1980). In each of the 3 years, calves and all caribou were distributed similarly along the road transect (Fig. 3).

Table 1. Summary of caribou observations from the Spine and Oliktok Roads, Kuparuk Development Area, 1978-90.

Year	Inclusive dates	No. surveys[a]	All observations					Observations ≤1,000 m				
			No. groups	No. caribou	Mean group size	% Calves	Sighting rate (caribou /km)	No. groups	No. caribou[b]	Mean group size	% Calves	Sighting rate (caribou /km)
1978	18 Jul-10 Aug	25 (15)	148	1,437	9.7	24.8	1.80	61	344 (23.9)	5.6	24.0	0.43
1979	3 Jul- 9 Aug	26 (9)	360	2,373	6.6	23.2	2.85	234	1,106 (46.6)	4.7	24.6	1.38
1980	16 Jul- 8 Aug	40 (8)	335	4,184	12.5	19.4	3.27	232	2,459 (58.8)	10.6	19.6	1.92
1981	15 Jun-30 Jun	27	459	2,497	5.4	11.8	2.89	177	726 (29.1)	4.1	8.7	0.82
	1 Jul- 7 Aug	59 (19)	662	11,666	17.6	19.2	6.18	249	3,745 (32.1)	15.0	21.6	1.98
1982	15 May-25 May	11	249	825	3.3	22.3	1.34	171	591 (71.6)	3.5	21.8	0.96
	3 Jun-18 Jun	11	196	999	5.1	10.4	1.62	118	409 (40.9)	3.5	6.1	0.66
	1 Jul- 5 Aug	30 (12)	469	17,510	37.3	20.8	10.42	284	7,637 (43.6)	26.9	21.2	4.54
1983	10 May-25 May	14	287	1,156	4.0	19.0	1.47	179	770 (66.6)	4.3	21.4	0.98
	2 Jun-20 Jun	19	294	1,343	4.6	11.5	1.26	159	526 (39.2)	3.3	5.7	0.49
	1 Jul- 4 Aug	35 (12)	611	15,850	25.9	17.7	8.09	404	7,987 (50.4)	19.8	17.7	4.08
1984	12 May-24 May	12	581	2,913	5.0	24.9	4.33	422	2,173 (74.6)	5.1	25.9	3.23
	2 Jun-20 Jun	16	485	1,849	3.8	5.6	2.06	285	1,170 (63.2)	4.1	4.2	1.30
	1 Jul- 3 Aug	54 (23)	1,264	36,399	28.8	23.8	12.04	887	20,147 (55.4)	22.7	24.3	6.66
1985	11 May-24 May	13	420	1,955	4.7	24.5	2.69	281	1,386 (70.9)	4.9	24.7	1.90
	2 Jun-20 Jun	16	354	1,904	5.4	16.1	2.13	210	1,045 (54.9)	5.0	14.3	1.17
	1 Jul- 6 Aug	44 (12)	957	32,074	33.5	20.8	13.02	723	17,148 (53.5)	23.7	21.7	6.96

Table 1. Continued.

Year	Inclusive dates	No. surveys[a]	All observations: No. groups	All observations: No. caribou	All observations: Mean group size	All observations: % Calves	All observations: Sighting rate (caribou /km)	Observations ≤1,000 m: No. groups	Observations ≤1,000 m: No. caribou[b]	Observations ≤1,000 m: Mean group size	Observations ≤1,000 m: % Calves	Observations ≤1,000 m: Sighting rate (caribou /km)
1986	12 May-20 May	9	164	491	3.0	7.4	0.97	103	314 (64.0)	3.0	7.6	0.62
	2 Jun-18 Jun	16	381	1,261	3.3	2.2	1.41	209	741 (58.8)	3.5	2.0	0.82
	2 Jul- 2 Aug	31 (8)	813	28,532	34.8	13.8	16.32	598	14,988 (52.9)	25.1	13.2	8.63
1987	17 Jun-19 Jun	3	41	129	3.1	7.6	0.77	20	55 (42.6)	2.8	0.0	0.33
	1 Jul- 5 Aug	30 (11)	619	37,357	60.3	20.5	21.52	451	17,737 (45.9)	39.3	22.0	10.56
1988	1 Jun-15 Jun	9	326	1,071	3.3	3	2.13	250	816 (76.2)	3.3	2.1	1.62
	1 Jul-31 Jul	25 (8)	520	23,607	45.4	20.7	16.82	434	17,559 (75.1)	40.5	22.1	12.54
1989	2 Jun-17 Jun	13	314	901	2.9	0.7	1.24	196	527 (58.5)	2.7	0.8	0.72
	2 Jul-31 Jul	25 (10)	833	24,533	29.5	11.5	17.52	720	17,213 (70.2)	23.9	11.5	12.30
1990	3 Jun-17 Jul	12	415	2,440	5.9	6.6	3.63	352	1,960 (80.3)	5.6	7.1	2.91
	1 Jul- 1 Aug	25 (7)	910	13,397	17.4	17.4	9.57	770	10,518 (78.5)	13.7	19.4	7.51

[a] () = No. of surveys during which insects were present.

[b] () = % of total sighting rate.

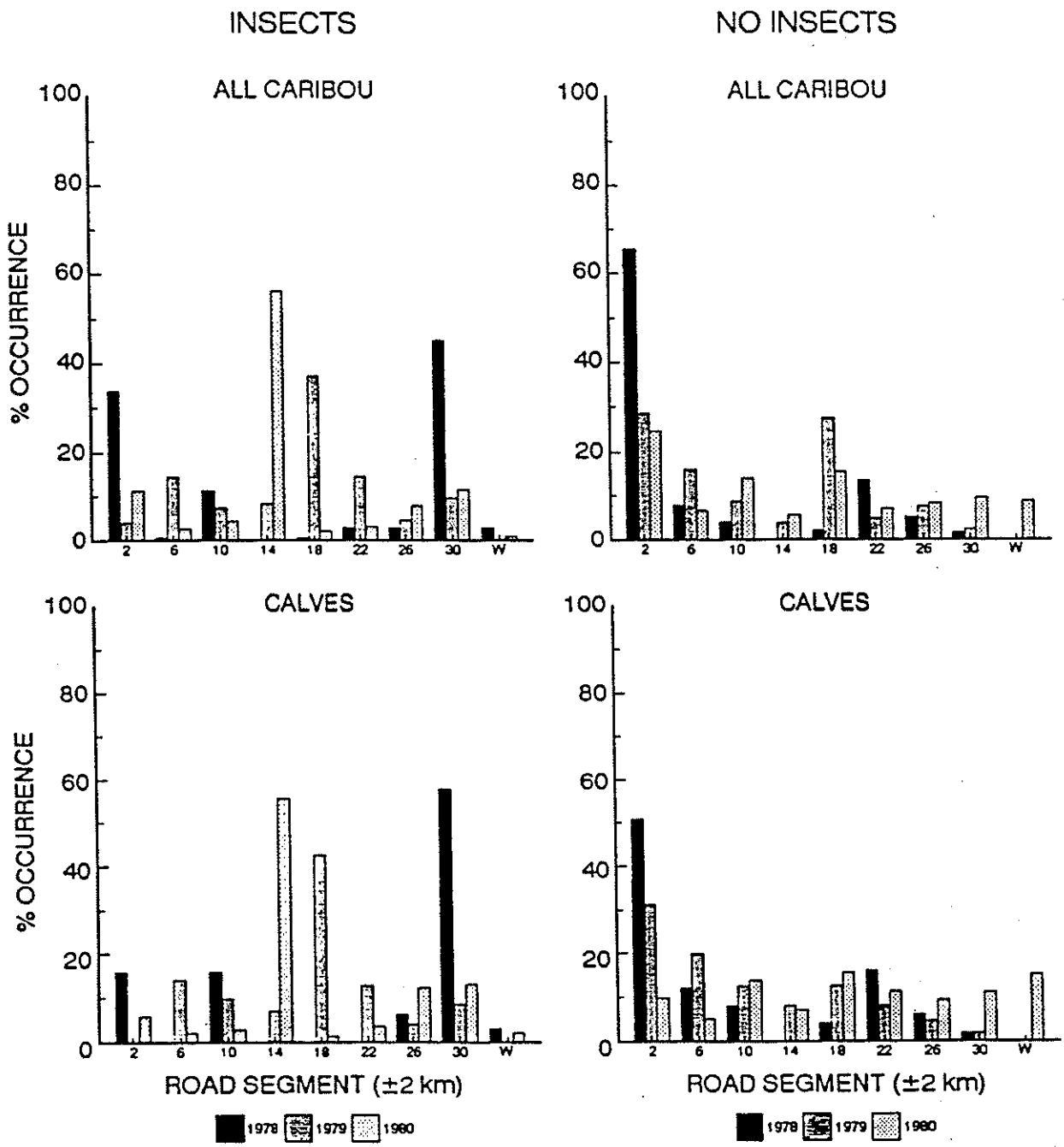

Fig. 3. Distribution of caribou along the Spine Road, midsummer, 1978-80.

4. In 1978 and 1979, most caribou were observed within two or three segments, whereas in 1980 they were more uniformly distributed along the road (Fig. 3).

5. Under insect conditions, caribou distribution along the road tended to be more clumped than during insect-free conditions (Fig. 3).

6. MGS was lower and CP higher for observations with insect harassment than for those with no insect conditions; there was no trend for SRT (Table 2).

7. SRT generally increased annually for both the 0-500 and 501-1,000 intervals under all insect conditions (Table 2); MGS and CP were variable.

8. Of the four significant differences for SRT, MGS, and CP between distance intervals, all occurred under insect harassment (Table 2); three of four were significantly lower for caribou closer to the road (SRT = 1 of 1, MGS = 1 of 1, and CP = 1 of 2).

9. Although relatively few caribou were observed under insect conditions, most road crossings were insect-induced (Table 3). The number of observed crossings increased annually. Although the number of groups crossing the road successfully increased, individual crossing success decreased.

10. Most crossings in any one year occurred in a single, but not the same, road segment (Fig. 4). Crossing sites were associated with intersecting drainages and away from areas of construction activity (Cameron et al. 1981). In 1978 and 1979, most crossings were in road segments where insect-harassed caribou were observed. (In 1980, a group of 338 paralleled the road and attempted to cross 7 km east of where they were first observed.) Only in the Kuparuk floodplains was calf representation in crossing groups lower than expected.

11. From 1978 through 1980, only two groups > 100 were observed, and both were unsuccessful in crossing the road (Smith and Cameron 1985*a*).

II. Initial Construction (1981-84)

A. Precalving (10-25 May)

1. MGS, CP, and SRT increased during the period, reaching maximum values in 1984 (Table 1).

2. More calves (short yearlings) were seen along the SR and OR than during either calving or midsummer (Table 1). Except for 1982, when heavy snow apparently delayed movements to the

Table 2. Comparison of caribou sighting rate, mean group size, and calf percentage among 3 distance intervals from the Spine Road, Kuparuk Development Area, midsummer, 1978-80.

		Insects					No insects				
Year	Category[a]	No. groups	No. caribou	Sighting rate (caribou/km)	Mean group size	% Calves	No. groups	No. caribou	Sighting rate (caribou/km)	Mean group size	% Calves
1978	SR	71	556	1.58	7.83	24.9	77	881	1.97	11.44	24.6
	A	23	76	0.21	3.30	18.4	16	62	0.14	3.88	29.0
	B	13	66	0.19	5.08	25.8	13	130	0.29	10.00	23.8
	C	35	414	1.18	11.83	27.3	48	689	1.54	14.35	23.8
Significant difference[b]:				n.s.	n.s.	n.s.			n.s.	n.s.	n.s.
1979	SR	104	445	1.55	4.28	28.1	256	1,928	3.54	7.53	21.7
	A	57	141	0.49	2.47	25.0	106	288	0.53	2.72	21.2
	B	10	101	0.35	10.10	34.7	60	575	1.06	9.58	24.3
	C	37	203	0.71	5.49	26.8	89	1,064	1.95	11.96	20.4
Significant difference[b]:				2	n.s.	1,2			n.s.	n.s.	n.s.
1980	SR	103	1,102	4.31	10.70	19.9	232	3,082	3.01	13.28	19.2
	A	43	121	0.47	2.81	19.0	81	738	0.72	9.11	18.8
	B	36	511	2.00	14.19	22.1	73	1,089	1.06	14.92	19.1
	C	24	470	1.84	19.58	17.1	78	1,255	1.23	16.09	19.6
Significant difference[b]:				n.s.	3	n.s.			n.s.	n.s.	n.s.

[a] SR = Spine Road, overall; A = 0-500 m; B = 501-1,000 m; C = >1,000 m.

[b] t-test, $P < 0.05$: 1 = A vs. B, 2 = B vs. C, 3 = A vs. C; n.s. = not significant.

Table 3. Crossing success of groups and individual caribou, Kuparuk Development Area, midsummer, 1978-80.

Year	No. of attempted crossings			% Successful	
	Groups	Individuals	On insect days[a] (%)	Groups	Individuals
1978	15	165	165 (100.0)	93.3	98.2
1979	40	215	193 (89.8)	95.0	94.2
1980	25	647	512 (79.1)	96.0	69.4

[a] Individuals.

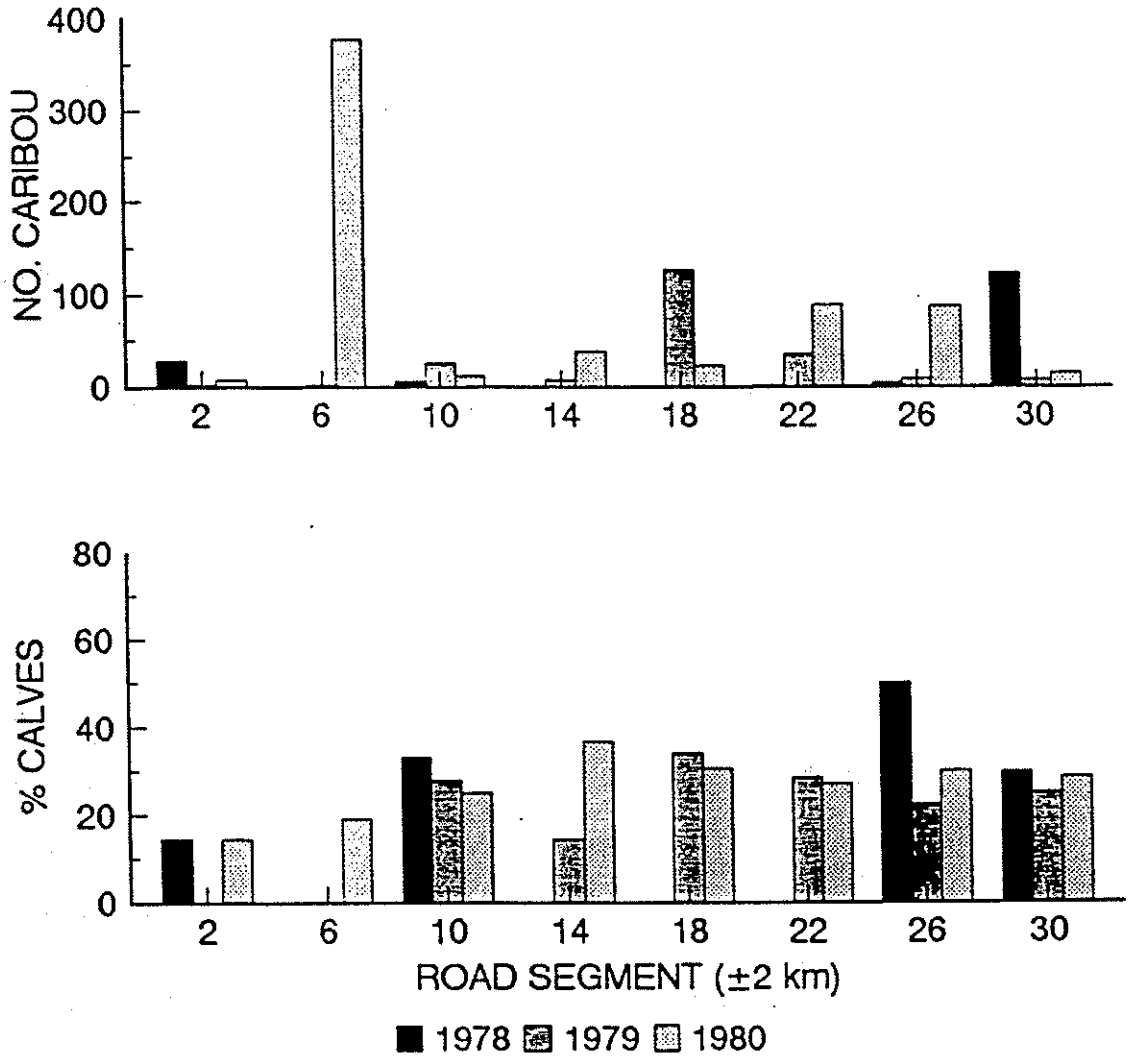

Fig. 4. Distribution of caribou crossing attempts of the Spine Road, and calf representation by road segment, midsummer, 1978-80.

coastal plain, MGS and SRT were higher than during calving but lower than midsummer.

3. MGS, CP, and SRT generally increased each year for groups < 1,000 m, suggesting habituation to roads (Table 1).

4. The highest percentage of caribou within 1,000 m of the road was recorded during precalving (Table 1); caribou were attracted to snow-free areas next to the road. Groups along the road were dominated by individuals less sensitive to disturbance: bulls, short yearlings, and barren cows.

5. Except for CP in 1984, SRT, MGS, and CP were higher along the OR than along the SR (Table 4).

6. In most instances, more caribou and calves in larger groups were seen within the closest distance interval (0-500 m) than during any other season (Table 4).

7. Of 14 significant differences among distance intervals for SRT, MGS, and CP, 11 were greater for caribou closer to the road (Table 4), again indicating an increasing proximity of caribou to roads during the period.

8. During the period, increasing numbers of caribou and calves were observed, as more caribou moved to calving areas north of the SR (Fig. 5). In 1982 and 1983, calf (i.e., short yearlings) representation increased more rapidly than total numbers of caribou, indicating that prepartum cows were moving away from the road to calve and leaving the previous year's calves behind. In 1984 there were no such differences between trends for CP and all caribou observed.

9. In 1982 and 1983, midroad concentrations of caribou and calves were observed along the SR and OR, corresponding to the southern and western fringes of the Milne Point calving concentration, and a third smaller concentration near Oliktok Point (Fig. 6). In 1984, when three times more caribou were seen than in the 2 previous years, caribou were evenly distributed along the SR except for a small concentration just west of CPF-1 and a single midroad OR concentration. In all years, the distribution of calves was similar to that for all caribou.

10. Increasing numbers of caribou were observed crossing the road and/or pipeline, but by 1984 they still represented only about 1% of all caribou observed. Crossing success for individual caribou was low; only 28.5%, 16.7%, and 44.4% successfully crossed the road during 1982, 1983, and 1984, respectively; and 50% and 30.8% crossed the road/pipeline in 1983 and 1984. Most road crossings occurred in the Kuparuk floodplain or the

Table 4. Comparison of caribou sighting rate, mean group size, and calf percentage among 3 distance intervals from the Spine and Oliktok Roads, Kuparuk Development Area, precalving, 1982-84.

Year	Category[a]	No. groups	No. caribou	Sighting rate (caribou/km)	Mean group size	% Calves
1982	SR	116	334	0.95	2.9	16.5
	A	63	198	0.56	3.14	14.6
	B	22	62	0.18	2.82	19.3
	C	31	74	0.21	2.39	18.9
	Significant difference[b]:			1,3	3	n.s.
	OR	133	491	1.86	3.7	26.4
	A	64	257	0.97	4.02	27.2
	B	22	74	0.28	3.36	24.3
	C	47	160	0.61	3.40	26.0
	Significant difference[b]:			2	n.s.	n.s.
1983	SR	154	579	1.29	3.8	16.4
	A	62	247	0.55	3.98	19.8
	B	30	111	0.25	3.70	17.1
	C	62	221	0.49	3.56	11.4
	Significant difference[b]:			1,2	n.s.	n.s.
	OR	133	577	1.72	4.3	21.6
	A	51	221	0.66	4.33	24.4
	B	36	191	0.57	5.31	22.5
	C	46	165	0.49	3.59	16.2
	Significant difference[b]:			n.s.	2	n.s.
1984	SR	327	1,405	3.66	4.4	27.2
	A	174	837	2.18	4.81	30.0
	B	52	177	0.46	3.40	25.4
	C	101	391	1.02	3.87	20.1
	Significant difference[b]:			1,2,3	1	3
	OR	254	1,508	5.23	5.9	22.8
	A	150	915	3.17	6.10	23.3
	B	46	244	0.84	5.30	22.1
	C	58	349	1.21	6.02	21.8
	Significant difference[b]:			1,3	n.s.	n.s.

[a] SR = Spine Road, overall; OR = Oliktok Road, overall; A = 0-500 m; B = 501-1,000 m; C = >1,000 m.

[b] t-test, $P < 0.05$: 1 = A vs. B; 2 = B vs. C; 3 = A vs. C; n.s. = not significant.

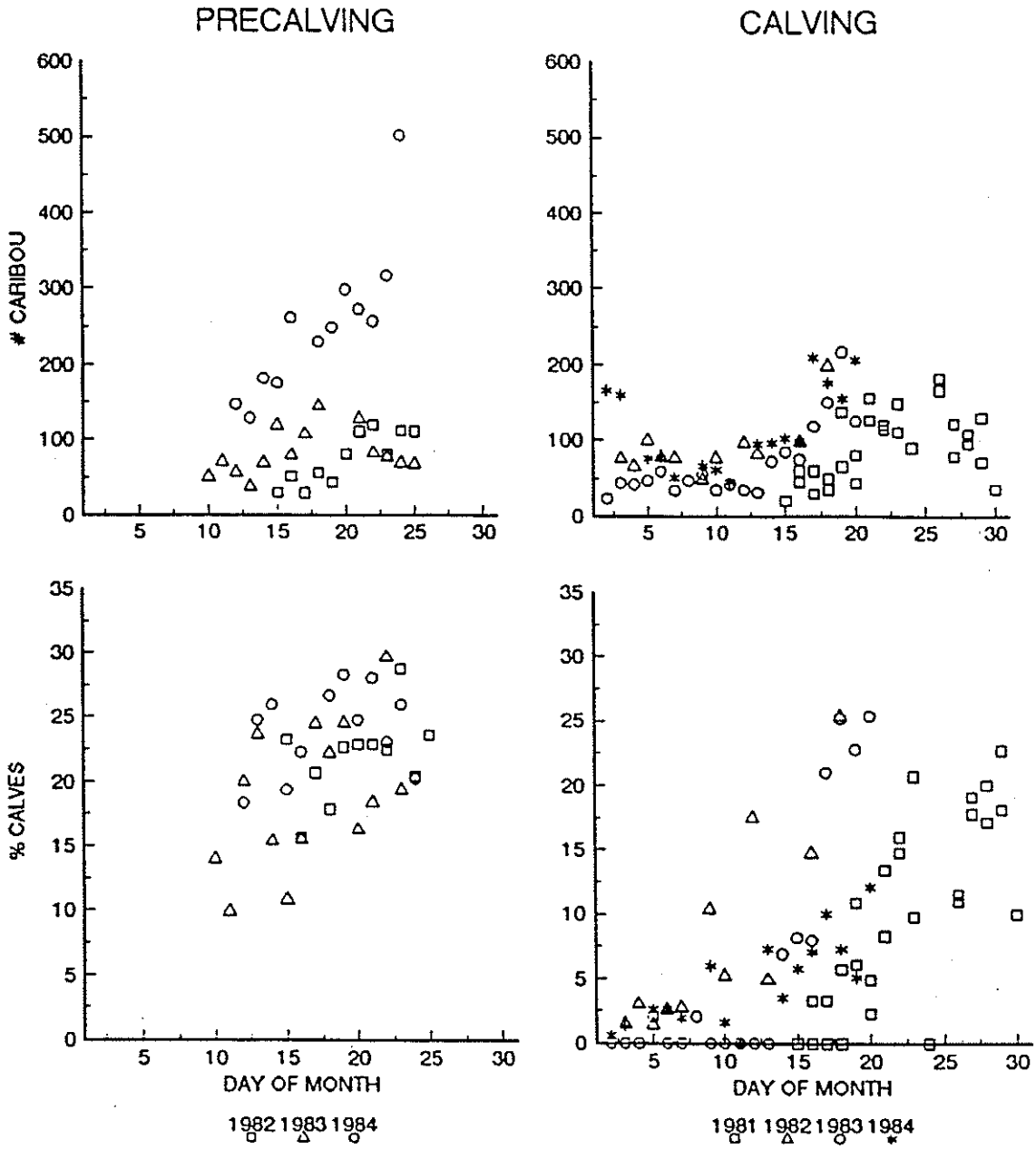

Fig. 5. Changes in caribou abundance and calf representation along the Spine and Oliktok Roads, precalving and calving, 1981-84.

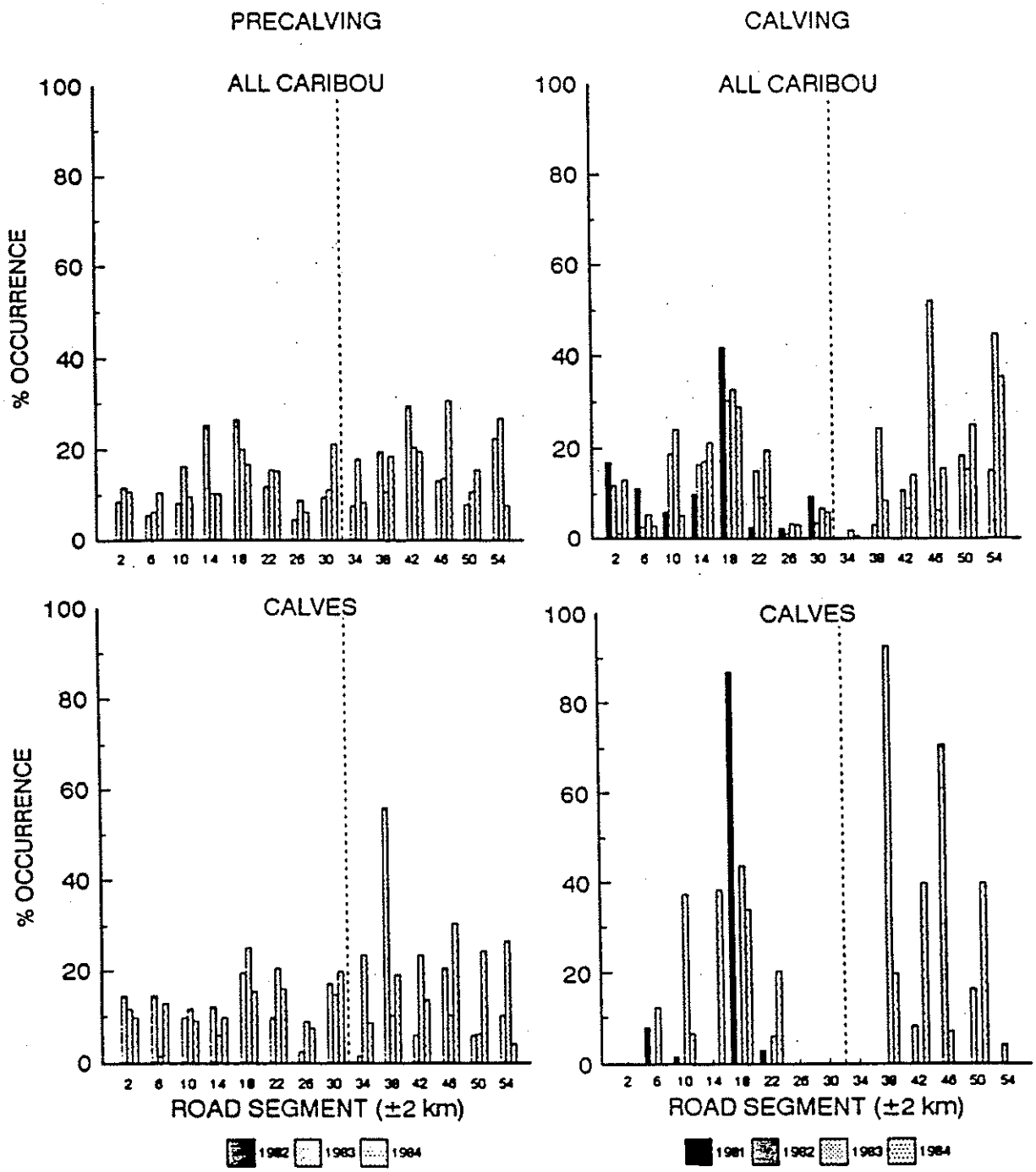

Fig. 6. Distribution of caribou along the Spine and Oliktok Roads, precalving and calving, 1981-84.

northern half of the OR, and the three road/pipe crossings occurred west of CPF-1.

B. Calving/Postcalving (2-30 Jun)

1. For logistical reasons, 1981 surveys were conducted only during the last 2 weeks of June, after most cows had calved (Table 1).

2. CP was lowest during calving; MGS was variable, but also tended to be lower during calving (Table 1).

3. MGS and CP generally decreased each year, being lowest in 1984 (Table 1). SRT was highly variable, probably reflecting differing snowcover and flooding on the coastal plain, which in turn influences the number of parturient cows that use the Milne Point calving area (Whitten and Cameron 1985, Cameron et al. 1992).

4. CP also decreased annually for caribou observed within 1,000 m, but MGS and SR showed no trends (Table 1).

5. Except for 1984, fewest caribou were seen within 1,000 m of the road during the calving period (Table 1).

6. In 1982, when there was no traffic on the OR, SRT, MGS, and CP were markedly higher on the OR than on the SR (Table 5). In 1983 and 1984 when traffic was light on the SR and heavy on the OR, SRT and MSG were almost equal on the two roads, and CP was much higher along the SR.

7. Except in 1984, larger groups with more calves were seen farther from the SR (Table 5). Of 12 significant differences for MGS, SRT, and CP, all were significantly higher for caribou >1,000 m from the road. Along the OR, a similar trend was seen in 1982 and 1983 (four of four were significantly higher for caribou farther from the road), but the trend was unclear in 1984 (only three of eight were significantly higher).

8. Few caribou and virtually no calves were seen during the first 14 days of June (Fig. 5). Numbers of all caribou and calves then increased as maternal groups moved closer to the road; however, CP of these groups was significantly lower than regional estimates determined by aerial surveys (Whitten and Cameron 1985, Dau and Cameron 1986, Smith and Cameron unpubl. data).

9. In most years, caribou were concentrated midroad along the SR and OR, but had shifted in distribution toward Oliktok Point by 1984 (Fig. 6). Calves were absent from the CPF-1 area in all years. The midroad concentrations correspond to the approximate points where the southern and western fringes of the Milne Point calving area contact the road, and the shift

Table 5. Comparison of caribou sighting rate, mean group size, and calf percentage among 3 distance intervals from the Spine and Oliktok Roads, Kuparuk Development Area, calving, 1981-84.

Year	Category[a]	No. groups	No. caribou	Sighting rate (caribou/km)	Mean group size	% Calves
1981	SR	459	2,497	2.89	5.4	11.8
	A	96	374	0.43	3.90	7.6
	B	81	352	0.41	4.35	9.9
	C	292	1,771	2.05	6.28	13.2
	Significant difference[b]:			2,3	3	n.s.
1982	SR	65	181	0.51	2.8	2.8
	A	19	42	0.12	2.21	0.0
	B	19	43	0.12	2.26	2.3
	C	27	96	0.27	3.56	4.2
	Significant difference[b]:			3	3	n.s.
	OR	131	818	3.10	6.2	12.4
	A	41	147	0.56	3.59	11.6
	B	39	177	0.67	4.54	4.4
	C	51	494	1.87	9.69	15.7
	Significant difference[b]:			n.s.	3	2
1983	SR	162	765	1.25	4.7	15.0
	A	53	147	0.24	2.77	6.1
	B	32	99	0.16	3.09	7.1
	C	77	519	0.85	6.72	19.8
	Significant difference[b]:			2,3	2,3	2,3
	OR	132	578	1.27	4.4	7.2
	A	47	176	0.39	3.74	8.0
	B	27	104	0.23	3.85	0.0
	C	58	298	0.65	5.14	9.4
	Significant difference[b]:			2	n.s.	2
1984	SR	246	880	1.72	3.6	10.1
	A	86	315	0.62	3.66	10.2
	B	43	145	0.28	3.37	8.3
	C	117	420	0.82	3.59	10.8
	Significant difference[b]:			2	n.s.	n.s.
	OR	239	969	2.52	4.05	1.6
	A	123	588	1.53	4.78	0.9
	B	33	122	0.32	3.70	0.0
	C	83	259	0.67	3.12	3.9
	Significant difference[b]:			1,2,3	1,3	1,2,3

[a] SR = Spine Road, overall; OR = Oliktok Road, overall; A = 0-500 m; B = 501-1,000 m; C = >1,000 m.

[b] t-test, $P < 0.05$: 1 = A vs. B, 2 = B vs. C, 3 = A vs. C; n.s. = not significant.

toward Oliktok Point in 1984 was probably in response to construction at CPF-3.

10. Although, in 1984, more than twice as many caribou were counted on the Milne Point calving grounds as in 1981, fewer caribou were observed crossing the road and/or pipeline (Table 6). When traffic was absent on the OR in 1982, relatively high numbers of caribou and newborn calves were observed crossing the road. By 1984, however, the crossing rate during calving was the lowest for any year or season.

11. Although only 14 of 29 caribou in two groups were observed crossing the road transect or pipelines in 1981, crossing success in 1982, 1983, and 1984 was high for both groups (100%, 80%, and 100%) and individuals (94%, 95%, and 100%).

C. Midsummer (1 Jul-7 Aug)

1. MGS, CP, and SRT were consistently higher in midsummer than during calving (Table 1). By this time, cow/calf groups were less sensitive to human activity, nonparous caribou had reached the coast, and caribou were aggregating in large groups in response to parasitic insects.

2. SRT increased each year except for 1983, but MGS and CP showed no trend (Table 1).

3. The percentage of caribou observed within 1,000 m increased during the period (Table 1), suggesting some habituation to the road system.

4. Both SRT and CP generally increased for caribou within 1,000 m and reached maximum values in 1984 (Table 1). MGS was highly variable.

5. Under insect harassment, SRT, MGS, and CP generally decreased through 1983 but rebounded in 1984 (Table 7). SRT, MGS, and CP along the OR were greater or equal to corresponding values along the SR.

6. With no insects present, SRT, MGS, and CP decreased along the SR through 1983, and then increased to maximum values in 1984 (Table 7). SRT, MGS, and CP increased along the OR in 1983, but only CP increased there in 1984. In 1982 and 1983, all three values were higher along the OR than along the SR, but this trend reversed in 1984.

7. During insect harassment, there were no consistent chronological trends in SRT, MGS, or CP for distance intervals. Of eight significant differences identified (Table 7), five were significantly higher for caribou closer to the road and three were significantly higher for more distant caribou. When

Table 6. Seasonal evaluation of attempted caribou crossings of the Spine and Oliktok Roads, Kuparuk Development Area, 1981-84.

Year	Road			Pipeline			Road/Pipeline			Total		
	No. groups	No. caribou	% Calves	No. groups	No. caribou	% Calves	No. groups	No. caribou	% Calves	No. groups	No. caribou	Crossing rate (caribou/km)
1981												
Calving[a]	3	14	0.0	0	0	--	3	15	0.0	6	29	0.034
Midsummer[a]	19	924	18.8	1	1	--	25	1,254	28.2	45	2,179	1.154
Total	21	934		1	1		28	1,268		50	2,203	
1982												
Precalving	1	7	57.1	0	0	--	0	0	--	1	7	0.003
Calving	9	29	10.3	0	0	--	1	4	0.0	10	33	0.053
Midsummer	38	3,036	22.5	0	0	--	24	871	19.8	62	3,709	2.232
Total	48	3,076		0	0		25	875		73	3,749	
1983												
Precalving	4	12	0.0	0	0	--	1	2	0.0	5	14	0.018
Calving	2	13	0.0	0	0	--	3	6	0.0	5	19	0.018
Midsummer	23	1,248	17.7	5	125	24.8	30	1,221	23.4	58	2,594	1.323
Total	29	1,273		5	125		34	1,229		68	2,627	
1984												
Precalving	6	18	16.6	0	0	--	2	13	38.5	8	31	0.046
Calving	3	6	0.0	0	0	--	2	8	0.0	5	14	0.011
Midsummer	59	9,626	27.2	19	901	30.0	43	1,644	29.6	121	12,171	4.025
Total	68	9,650		19	901		47	1,665		134	12,216	

[a] Spine Road data only.

Table 7. Comparison of caribou sighting rate, mean group size, and calf percentage among 3 distance intervals from the Spine and Oliktok Roads, Kuparuk Development Area, midsummer, 1981-84.

		Insects					No insects				
Year	Category[a]	No. groups	No. caribou	Sighting rate (caribou/km)	Mean group size	% Calves	No. groups	No. caribou	Sighting rate (caribou/km)	Mean group size	% Calves
1981	SR	232	4,359	7.16	26.03	20.1	430	7,307	5.71	16.99	18.5
	A	83	1,982	3.26	23.88	25.7	74	455	0.36	6.15	12.7
	B	26	617	1.01	23.73	15.2	66	691	0.54	10.47	21.1
	C	123	1,760	2.89	14.31	13.9	290	6,161	4.81	21.20	18.8
Significant difference[b]:				2	n.s.	n.s.			2,3	1,2,3	1
1982	SR	100	2,536	6.60	25.36	14.1	192	2,302	3.99	11.99	15.3
	A	42	735	1.91	17.50	23.0	61	329	0.57	5.39	12.2
	B	16	318	0.83	19.88	1.9	48	461	0.80	9.60	17.4
	C	42	1,483	3.86	35.31	11.2	83	1,512	2.62	18.21	15.3
Significant difference[b]:				n.s.	n.s.	1,3			2,3	2,3	n.s.
	OR	84	10,200	35.40	121.43	23.9	94	2,472	5.72	26.30	16.0
	A	32	666	2.31	20.81	19.7	35	601	1.39	17.17	16.3
	B	29	4,154	14.42	143.24	25.2	21	373	0.86	17.76	12.9
	C	23	5,380	18.67	233.91	23.2	38	1,498	3.47	39.42	18.5
Significant difference[b]:				n.s.	n.s.	n.s.			n.s.	n.s.	n.s.
1983	SR	186	4,103	10.69	22.06	14.0	154	2,045	2.78	13.28	15.2
	A	93	1,221	3.18	13.13	16.4	55	205	0.28	3.73	11.7
	B	38	1,400	3.65	36.84	11.9	42	696	0.95	16.57	7.2
	C	55	1,482	3.86	26.95	14.1	57	1,144	1.55	20.07	24.1
Significant difference[b]:				n.s.	3	n.s.			n.s.	3	2,3

Table 7. Continued.

Year	Category[a]	Insects					No insects				
		No. groups	No. caribou	Sighting rate (caribou/km)	Mean group size	% Calves	No. groups	No. caribou	Sighting rate (caribou/km)	Mean group size	% Calves
1983	OR	59	3,212	11.15	54.44	14.0	212	6,490	11.75	30.61	22.6
	A	28	343	1.19	12.25	18.4	72	828	1.50	11.50	22.0
	B	13	691	2.40	53.15	12.2	63	2,603	4.71	41.32	24.7
	C	18	2,178	7.56	121.00	13.8	77	3,059	5.54	39.73	20.8
	Significant difference[b]:			n.s.	n.s.	n.s.			1,3	2,3	n.s.
1984	SR	350	6,308	8.57	29.17	24.0	475	12,155	12.26	25.59	23.0
	A	191	1,155	1.57	6.05	18.4	186	2,952	2.98	15.87	24.0
	B	80	1,142	1.55	14.28	24.3	131	2,299	2.32	17.55	21.1
	C	79	4,011	5.45	50.77	25.7	158	6,904	6.96	43.70	23.1
	Significant difference[b]:			n.s.	2,3	3			n.s.	n.s.	1
	OR	191	12,437	22.33	65.12	24.7	248	5,499	7.39	22.17	23.7
	A	81	2,301	4.17	28.41	24.7	84	1,548	2.08	18.83	24.0
	B	64	7,266	13.16	113.53	26.1	70	1,484	1.99	21.20	25.2
	C	46	2,870	5.20	62.39	13.8	94	2,467	3.32	26.24	22.3
	Significant difference[b]:			n.s.	n.s.	3			n.s.	n.s.	n.s.

[a] SR = Spine Road, overall; OR = Oliktok Road, overall; A = 0-500 m; B = 501-1,000 m; C = >1,000 m.

[b] *t*-test, $P < 0.05$: 1 = A vs. B, 2 = B vs. C, 3 = A vs. C; n.s. = not significant.

insects were not present, however, caribou were farther from the road, in larger groups, and with relatively more calves. Of 19 significant differences in SRT, MGS, and CP, 16 were greater for caribou in the distance interval farther from the road.

8. During insect harassment, caribou were consistently concentrated near the Kuparuk River, with secondary concentrations near CPF-1 in 1981 and near the Milne Point Road junction in 1982 (Fig. 7); however, relatively few calves were seen in the Kuparuk floodplain, and they tended to be displaced to the west. Along the OR, caribou were most numerous at the coast and near the future CPF-3, and concentration areas were found closer to the coast in each succeeding year. Calves were distributed similarly.

9. When insects were absent, caribou numbers were consistently highest within the Kuparuk floodplain and east of CPF-1 (Fig. 7). Some cow/calf groups were again apparently displaced from the Kuparuk River to the west.

10. After 1981, few caribou were seen between CPF-1 and CPF-3, irrespective of insect conditions (Fig. 7).

11. In general, group and individual crossings of the road transect increased after the OR was added to the survey coverage in 1982 (Table 6). The CP of crossing groups was greater than or equal to the overall seasonal CP (Tables 1, 6), indicating that maternal cows were well represented in crossing groups.

12. Although the Kuparuk River remained a node of crossing activity throughout the period, most of the increase in road crossings occurred on the OR (Fig. 8). Only in the Kuparuk floodplain was calf representation in crossing groups consistently lower than expected.

13. The crossing success of groups approaching both road and pipeline was 80% for the period (Fig. 9). Individual success was considerably lower than group success because of the inability of large groups (>100 individuals) to cross either structure. Both group and individual crossing success for road/pipeline complexes were generally less than for either road or pipeline alone, as both small and large groups were unable to cross. Although group success was variable through 1984, the number of individual caribou crossing increased, indicating some habituation to the pipeline, road, and traffic.

III. Advanced Construction (1985-90)

A. Precalving (11-24 May)

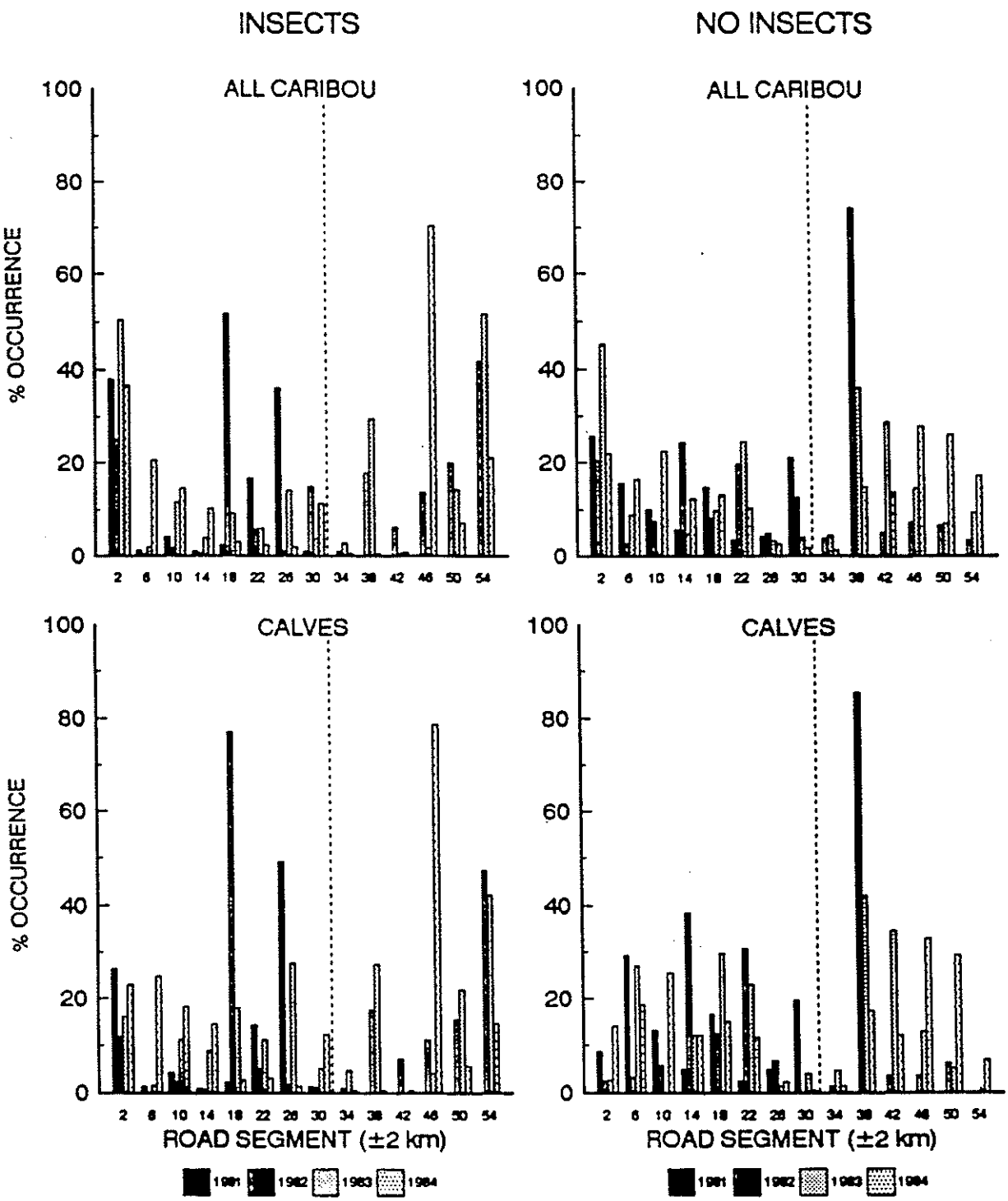

Fig. 7. Distribution of caribou along the Spine and Oliktok Roads, midsummer, 1981-84.

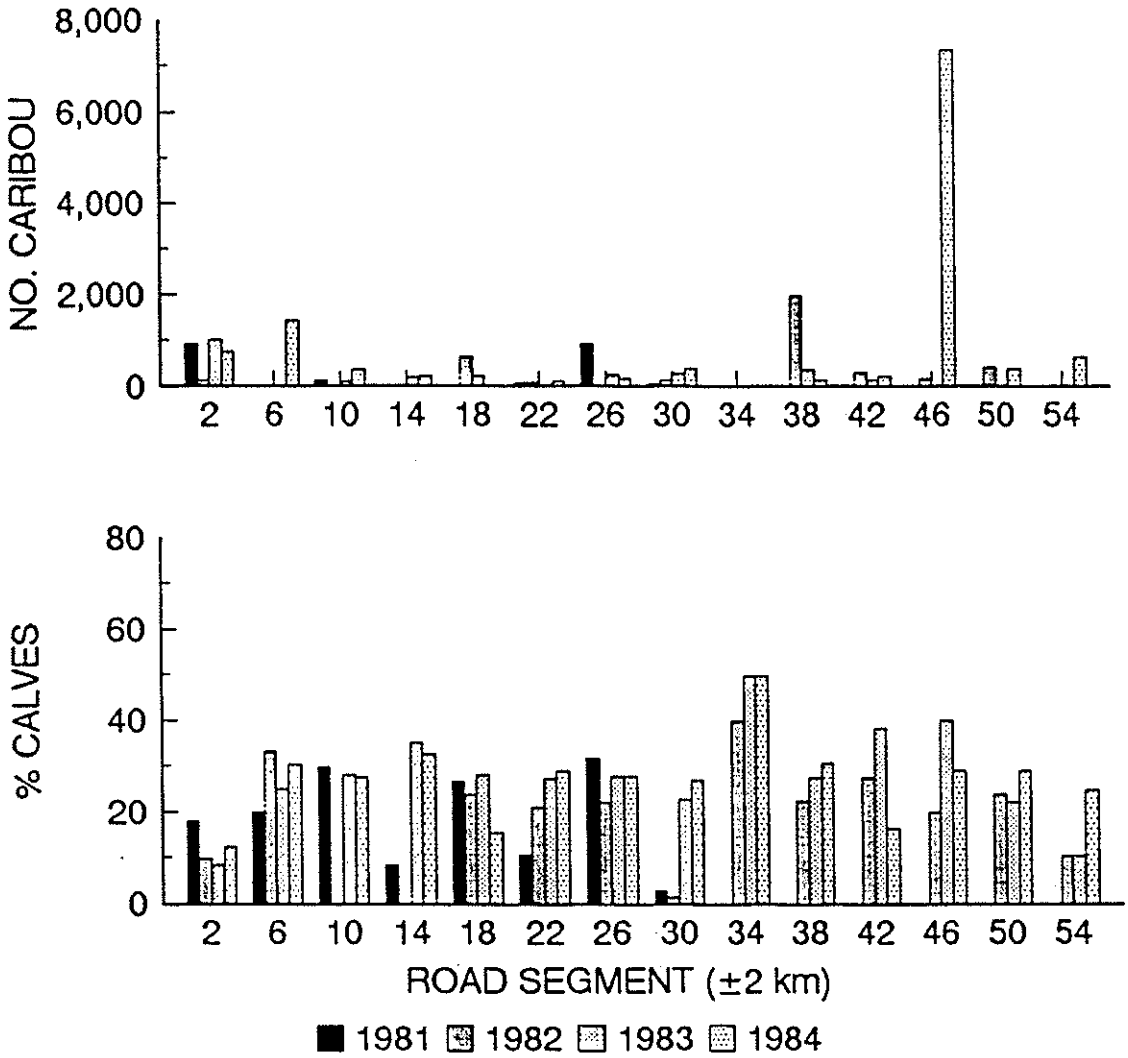

Fig. 8. Distribution of caribou crossing attempts of the Spine and Oliktok Roads, and calf representation by road segment, midsummer, 1981-84.

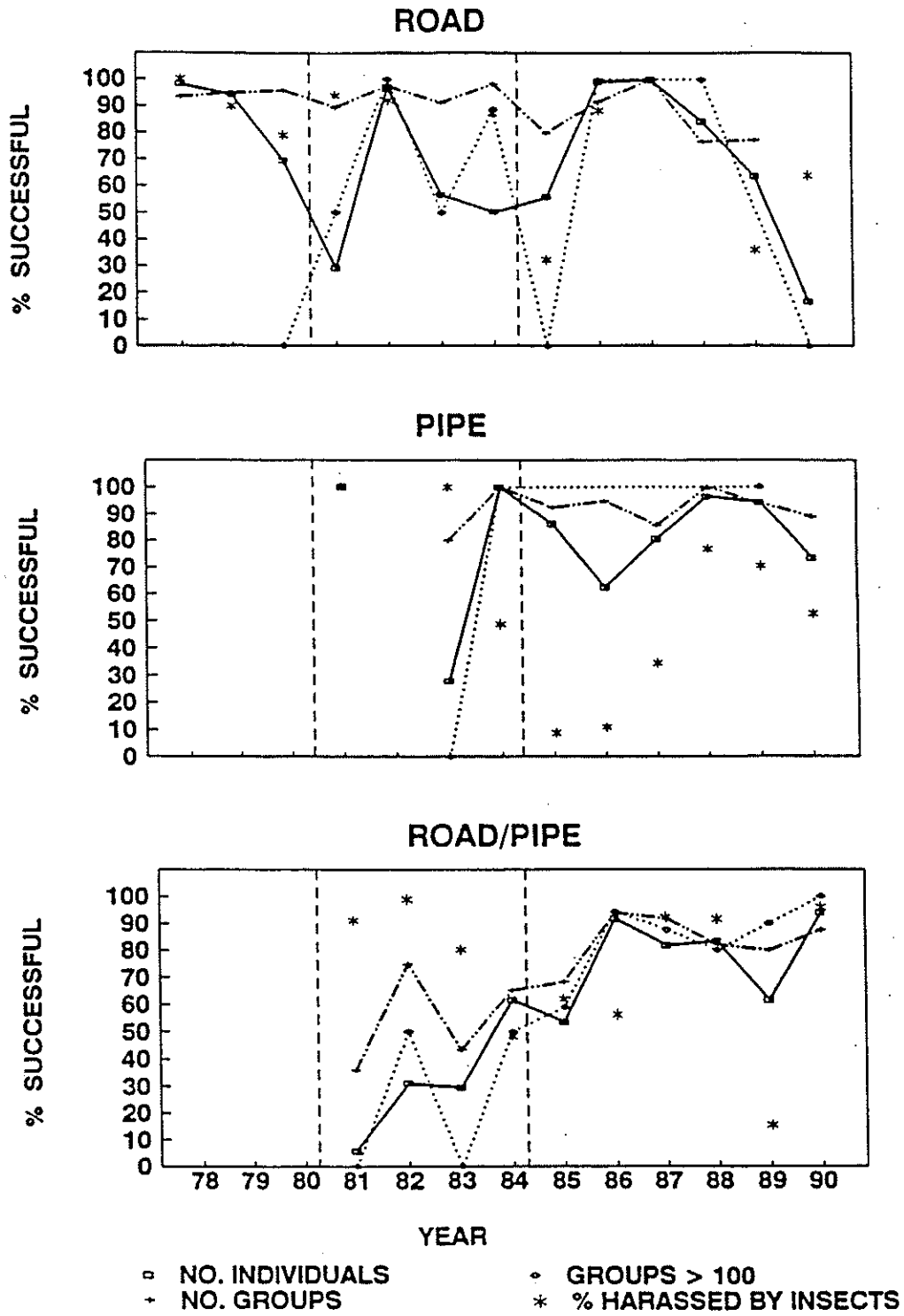

Fig. 9. Road and/or pipeline crossing success of caribou, Kuparuk Development Area, midsummer, 1978-90.

1. When precalving surveys were terminated in 1986, SRT, MGS, and CP for all caribou and those within 1,000 m were the lowest observed since that coverage began in 1982 (Table 1).

2. Numbers of caribou and calves observed during daily surveys were fairly stable throughout the period, in contrast to the increases noted during previous development phases (Fig. 10).

3. In 1985, caribou were evenly distributed along the SR and OR; the distribution of short yearlings was similar to that of all caribou (Fig. 11). In 1986, caribou were concentrated near the Kuparuk River, west of CPF-1, and near Oliktok Point. Calves were too few (n = 8) along the OR to make any meaningful comparisons among road segments.

4. SRT and MGS were greater along the OR than along the SR; while relatively more short yearlings were observed in groups along the SR (Table 8).

5. During precalving there were no obvious trends in SRT, MGS, and CP for the various distance intervals (Table 8); three of eight were significantly lower for caribou in intervals closer to the road.

6. Few caribou were seen attempting to cross the road and/or pipeline (Table 9); in 1985, 42.9% of groups and 39.1% of individuals crossed successfully, and in 1986 71.4% in one group were successful.

B. Calving/Postcalving (2-20 Jun)

1. Disregarding the few surveys conducted in 1987 (n = 3), MGS, CP, and SRT decreased from relatively high values in 1985 to a low plateau through 1989, and then rebounded in 1990 to maximum levels for SRT and MGS, together with higher CP values (Table 1).

2. MGS, CP, and SRT for groups within 1,000 m followed the same pattern as for all observations (Table 1). The percentage of caribou observed within 1,000 m was variable, but highest in 1990.

3. Few total caribou or calves were seen along the road transect during the first 2 weeks of June (Fig. 10). CP in these groups was considerably lower than the regional calf percentage of 37.8% determined by aerial calving surveys (Smith and Cameron, unpubl. data).

4. By the end of the period, caribou tended to be clustered near the middle of the SR and just south of CPF-3 on the OR (Fig. 11). As in the previous period, calves were absent from the CPF-1 area and concentrated near the middle of the OR.

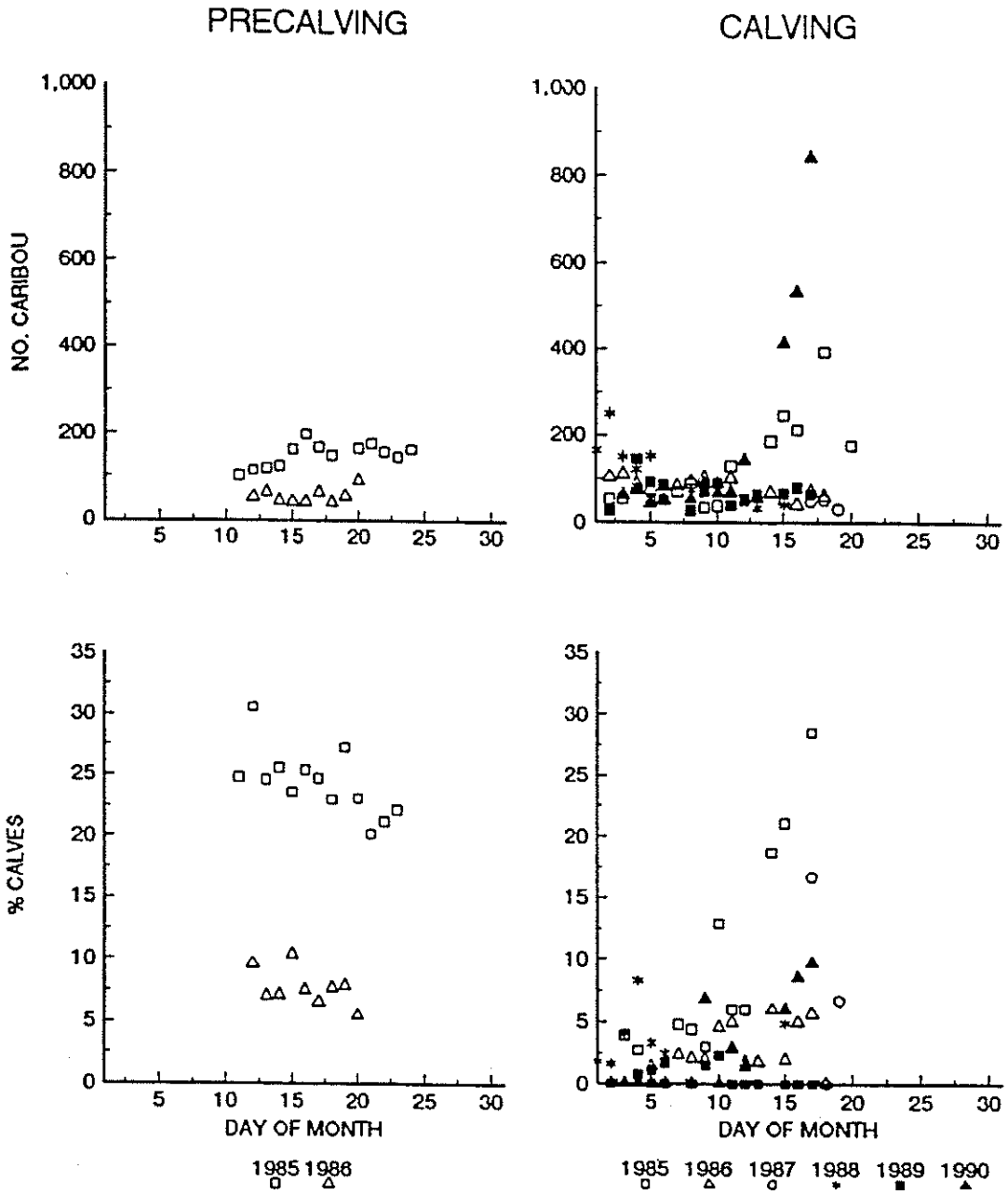

Fig. 10. Changes in caribou abundance and calf representation along the Spine and Oliktok Roads, precalving and calving, 1985-90.

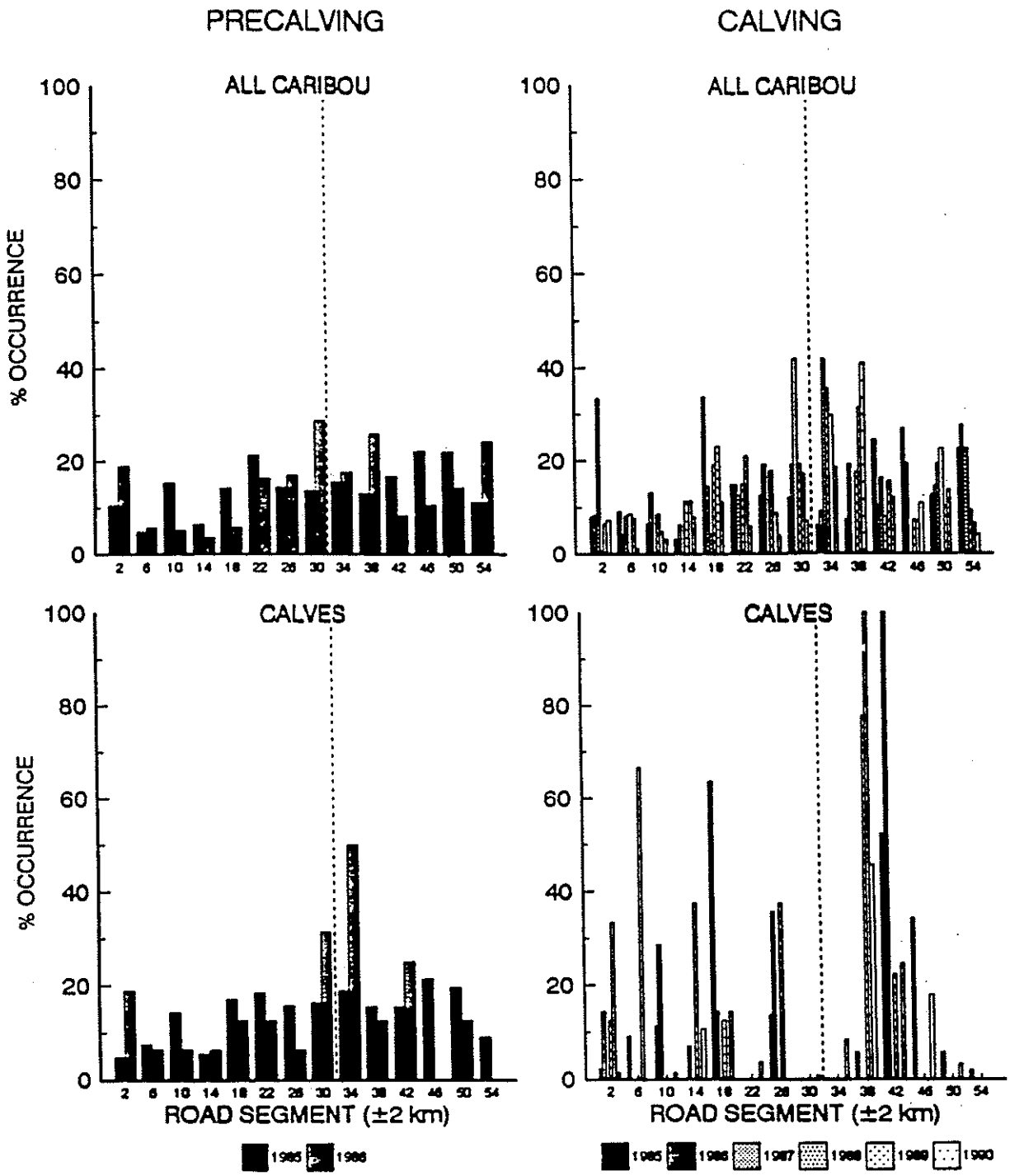

Fig. 11. Distribution of caribou along the Spine and Oliktok Roads, precalving and calving, 1985-90.

Table 8. Comparison of caribou sighting rate, mean group size, and calf percentage among 3 distance intervals from the Spine and Oliktok Roads, Kuparuk Development Area, precalving, 1985-86.

Year	Category[a]	No. groups	No. caribou	Sighting rate (caribou/km)	Mean group size	% Calves
1985	SR	209	848	2.04	4.1	27.6
	A	79	315	0.76	4.0	27.6
	B	39	164	0.39	4.2	36.0
	C	91	369	0.89	4.1	22.4
	Significant difference[b]:			2	n.s.	1,2
	OR	211	1,107	3.55	5.2	22.0
	A	101	624	2.00	6.2	20.8
	B	62	283	0.91	4.6	23.3
	C	48	200	0.64	4.2	23.7
	Significant difference[b]:			1,3	1,3	n.s.
1986	SR	90	264	0.92	2.9	10.6
	A	24	75	0.26	3.1	12.0
	B	23	68	0.24	3.0	10.3
	C	43	119	0.41	2.8	9.7
	Significant difference[b]:			n.s.	n.s.	n.s.
	OR	74	229	1.06	3.1	3.9
	A	34	93	0.43	2.7	5.4
	B	22	78	0.36	3.6	3.8
	C	18	58	0.27	3.2	1.7
	Significant difference[b]:			n.s.	3	n.s.

[a] SR = Spine Road, overall; OR = Oliktok Road, overall, A = 0-500 m; B = 501-1,000 m; C = >1,000 m.

[b] t-test, $P < 0.05$: 1 = A vs. B, 2 = B vs. C, 3 = A vs. C; n.s. = not significant.

Table 9. Seasonal evaluation of attempted caribou crossings of the Spine and Oliktok Roads, Kuparuk Development Area, 1985-90.

	Road			Pipeline			Road/Pipeline			Total		Crossing rate (caribou /km)
	No. groups	No. caribou	% Calves	No. groups	No. caribou	% Calves	No. groups	No. caribou	% Calves	No. groups	No. caribou	
1985												
Pre-calving	2	13	15.4	0	0	--	5	15	26.7	7	28	0.038
Calving	4	8	0.0	2	5	0.0	5	130	40.0	11	143	0.160
Midsummer	15	517	21.3	39	87	23.0	54	6,978	25.2	108	7,582	3.077
Total	21	538		41	92		64	7,123		126	7,753	
1986												
Pre-calving	0	0	--	0	0	--	1	7	14.3	1	7	0.014
Calving	0	0	--	0	0	--	6	25	0.0	6	25	0.030
Midsummer	24	827	8.2	38	202	10.4	63	7,600	19.5	125	8,629	4.970
Total	24	827		38	202		70	7,632		132	8,661	
1987												
Calving	0	0	--	0	0	--	0	0	--	0	0	0.000
Midsummer	22	7,752	21.4	7	31	22.6	24	4,305	18.8	53	12,088	7.195
Total	22	7,752		7	31		24	4,305		53	12,088	
1988												
Calving	2	3	0.0	2	7	0.0	2	8	0.0	6	18	0.036
Midsummer	25	3,209	24.3	24	169	14.2	50	11,275	22.2	99	14,653	10.468
Total	27	3,212		26	176		52	11,283		105	14,671	
1989												
Calving	0	0	--	0	0	--	2	3	0.0	2	3	0.004
Midsummer	30	332	10.8	67	564	8.5	53	9,113	11.4	150	10,009	7.149
Total	30	332		67	564		55	9,116		152	10,012	
1990												
Calving	3	6	0.0	2	27	7.4	3	14	0.0	8	47	0.064
Midsummer	31	1,628	20.0	18	49	18.4	40	1,888	22.4	89	3,565	2.546
Total	34	1,634		20	76		43	1,902		97	3,612	

5. After 1985, SRT, MGS, and CP remained low along both the SR and OR, but rebounded in 1990 (Table 10); CP remained relatively low. By 1990, these variables were all higher along the OR than along the SR.

6. Of 17 significant differences for SRT, MGS, and CP among distance intervals, 10 were greater for caribou in intervals closer to the road (Table 10). Generally more caribou (6 of 8) but fewer calves (4 of 6) were seen in the closer interval. Except for along the OR in 1988, few or no calves were observed within 500 m of the road system.

7. The road/pipeline crossing rate continued to be low during the calving period (Table 9). Groups had greater success than individuals due to the continued difficulties of larger groups to cross the road and/or pipeline.

C. Midsummer (1 Jul-6 Aug)

1. SRT and MGS increased through 1987 but declined to Initial Construction levels by 1990 (Table 1). CP was variable.

2. For groups within 1,000 m, MGS and SRT increased until 1988 and 1989 and then decreased to 1985 levels (Table 1). CP was again variable.

3. The percentage of caribou observed within 1,000 m generally increased during the period, peaking in 1990 (Table 1).

4. Under insect harassment, increasing numbers of caribou and calves were observed near the Kuparuk River, north of CPF-3, and in a few road segments near CPF-1 (Fig. 12). With no insects present, caribou and calves were evenly distributed. The four highest peaks in abundance were the result of large groups observed just after insect harassment ceased. After 1987, few caribou were observed in road segments between 8.1 and 16.0 km, regardless of insect condition, possibly because of drill pad and feeder pipeline construction in those road segments.

5. In 1985 and 1986, SRT, MGS, and CP were highest along the OR under all insect conditions, but the reverse was true in 1987 (Table 11). After 1987, SRT and MGS were occasionally higher along the OR, but no obvious trends were apparent either along the SR or the OR with insect harassment.

6. With insect harassment, SRT, MGS, and CP varied among years and between road sections (Table 11). However, SRT and MGS were similar for the SR and OR. Although CP frequently differed for the SR and OR, the values tended to increase or decrease together.

Table 10. Comparison of caribou sighting rate, mean group size, and calf percentage among 3 distance intervals from the Spine and Oliktok Roads, Kuparuk Development Area, calving, 1985-90.

Year	Category[a]	No. groups	No. caribou	Sighting rate (caribou/km)	Mean group size	% Calves
1985	SR	179	871	1.70	4.9	15.9
	A	74	248	0.48	3.4	6.5
	B	29	182	0.36	6.3	15.4
	C	76	441	0.86	5.8	22.6
	Significant difference[b]:			n.s.	3	3
	OR	175	1,033	2.69	5.9	16.3
	A	69	317	0.83	4.6	12.9
	B	38	298	0.78	7.8	21.5
	C	68	418	1.09	6.2	15.0
	Significant difference[b]:			n.s.	n.s.	n.s.
1986	SR	212	741	1.45	3.5	3.1
	A	74	286	0.56	3.9	2.1
	B	44	141	0.28	3.2	5.7
	C	94	314	0.61	3.3	2.9
	Significant difference[b]:			1,2	n.s.	n.s.
	OR	169	520	1.01	3.1	1.0
	A	43	180	0.35	4.2	0.0
	B	48	134	0.26	2.8	0.7
	C	78	206	0.40	2.6	1.9
	Significant difference[b]:			n.s.	1,3	n.s.
1987	SR	24	76	0.79	1.3	13.2
	A	4	18	0.19	4.5	0.0
	B	3	6	0.06	2.0	0.0
	C	17	52	0.54	3.1	19.2
	Significant difference[b]:			n.s.	n.s.	n.s.
	OR	17	55	0.74	3.1	0.0
	A	12	29	0.40	2.4	0.0
	B	1	2	0.03	2.0	0.0
	C	4	24	0.31	5.5	0.0
	Significant difference[b]:			n.s.	n.s.	n.s.

Table 10. Continued.

Year	Category[a]	No. groups	No. caribou	Sighting rate (caribou/km)	Mean group size	% Calves
1988	SR	170	585	2.03	3.4	2.2
	A	107	369	1.28	3.5	1.4
	B	26	84	0.29	3.2	3.6
	C	37	132	0.46	3.6	3.8
	Significant difference[b]:			n.s.	n.s.	n.s.
	OR	156	486	2.25	3.1	3.9
	A	83	256	1.19	3.1	2.7
	B	34	107	0.50	3.2	1.9
	C	39	123	0.57	3.2	8.1
	Significant difference[b]:			n.s.	n.s.	2,3
1989	SR	174	507	1.22	2.9	1.0
	A	84	251	0.60	3.0	0.8
	B	20	49	0.12	2.5	2.0
	C	70	207	0.50	3.0	1.1
	Significant difference[b]:			1,2	n.s.	n.s.
	OR	140	394	1.26	2.8	0.3
	A	72	163	0.52	2.3	0.0
	B	20	64	0.21	3.2	1.6
	C	48	167	0.54	3.5	0.0
	Significant difference[b]:			1	n.s.	n.s.
1990	SR	227	1,240	3.23	5.5	5.1
	A	164	630	1.64	3.8	3.2
	B	33	304	0.79	9.2	8.2
	C	30	306	0.80	10.2	5.9
	Significant difference[b]:			1,3	n.s.	1
	OR	188	1,202	4.16	6.4	8.3
	A	119	572	1.99	4.8	7.2
	B	36	454	1.58	12.6	11.7
	C	33	174	0.60	5.3	3.4
	Significant difference[b]:			3	n.s.	2,3

[a] SR = Spine Road, overall; OR = Oliktok Road, overall, A = 0-500 m; B = 501-1,000 m; C = >1,000 m.

[b] t-test, $P < 0.05$: 1 = A vs. B, 2 = B vs. C, 3 = A vs. C; n.s. = not significant.

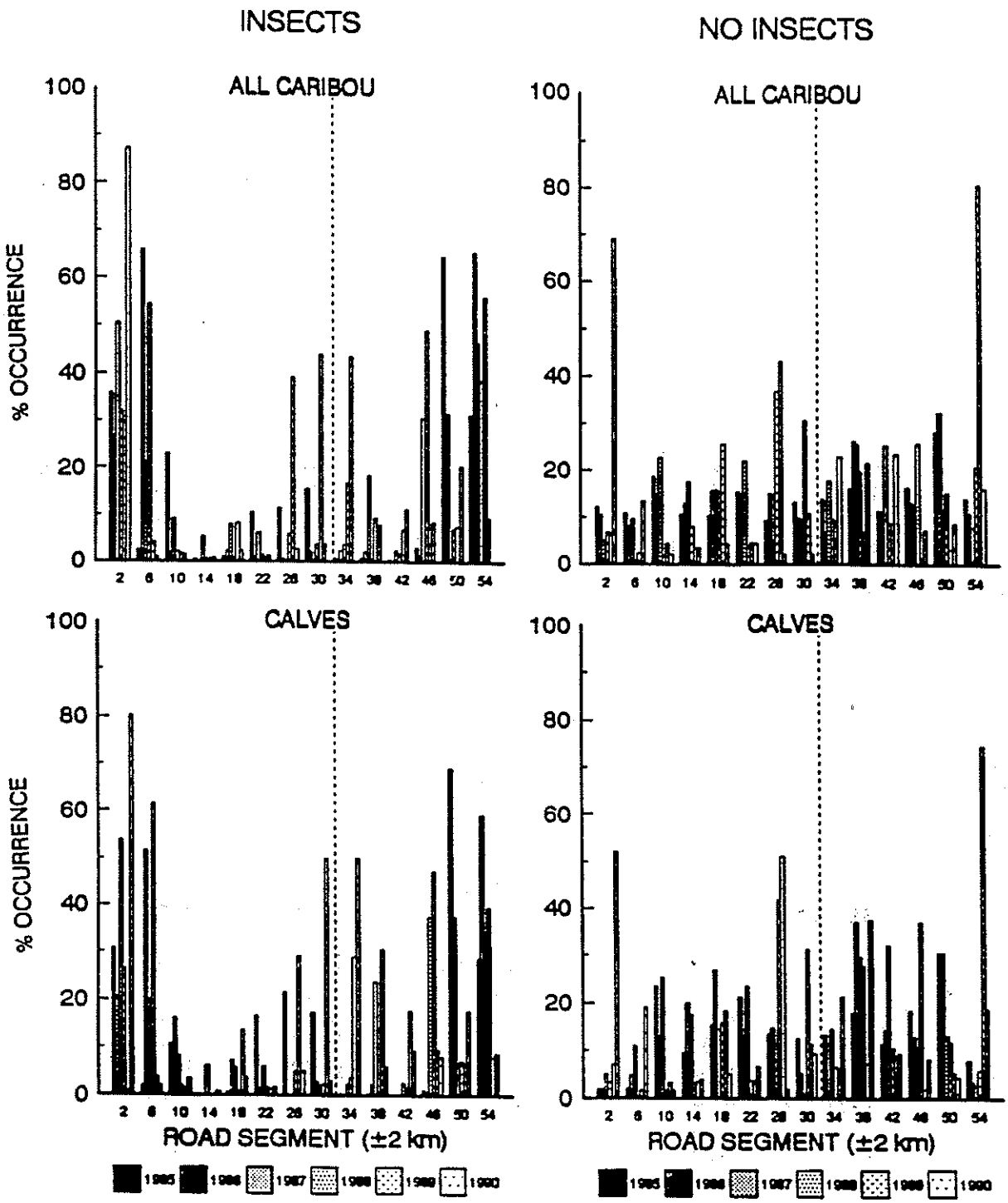

Fig. 12. Distribution of caribou along the Spine and Oliktok Roads, midsummer, 1985-90.

Table 11. Comparison of caribou sighting rate, mean group size, and calf percentage among 3 distance intervals from the Spine and Oliktok Roads, Kuparuk Development Area, midsummer, 1985-90.

		Insects					No insects				
Year	Category[a]	No. groups	No. caribou	Sighting rate (caribou/km)	Mean group size	% Calves	No. groups	No. caribou	Sighting rate (caribou/km)	Mean group size	% Calves
1985	SR	99	6,000	15.63	60.61	15.8	435	6,418	6.28	14.8	16.2
	A	47	375	0.98	7.98	9.9	201	2,392	2.34	11.9	15.8
	B	19	431	1.12	22.68	23.7	122	2,053	2.01	16.8	18.3
	C	33	5,194	13.53	157.39	15.0	112	1,973	1.93	17.6	14.2
Significant difference[b]:				n.s.	n.s.	1,2			n.s.	n.s.	n.s.
	OR	85	9,973	34.66	117.32	24.7	338	9,683	12.61	28.7	22.3
	A	52	3,491	12.12	67.13	23.6	181	3,124	4.07	17.3	21.9
	B	14	2,075	7.20	148.21	27.6	87	3,207	4.18	36.9	23.1
	C	19	4,407	15.34	231.95	23.3	70	3,352	4.36	47.9	21.6
Significant difference[b]:				n.s.	1	n.s.			n.s.	3	n.s.
1986	SR	56	2,032	7.94	36.29	5.2	420	8,186	11.12	19.5	12.4
	A	34	464	1.81	13.65	12.3	214	2,211	3.00	10.3	9.6
	B	7	284	1.11	40.57	0.7	93	2,449	3.33	26.3	14.6
	C	15	1,284	5.02	85.60	3.4	113	3,526	4.79	31.2	12.6
Significant difference[b]:				n.s.	3	1,3			n.s.	1,3	n.s.
	OR	58	9,462	49.29	163.13	18.0	279	8,852	16.20	31.7	14.3
	A	42	3,743	19.50	89.12	16.2	133	2,174	3.94	16.4	10.6
	B	4	34	0.18	8.5	14.7	71	3,629	6.74	51.1	14.0
	C	12	5,685	29.61	473.75	21.7	75	3,049	5.52	40.7	17.1
Significant difference[b]:				1	n.s.	n.s.			n.s.	3	3

Table 11. Continued.

Year	Category[a]	Insects					No insects				
		No. groups	No. caribou	Sighting rate (caribou/km)	Mean group size	% Calves	No. groups	No. caribou	Sighting rate (caribou/km)	Mean group size	% Calves
1987	SR	80	22,093	62.76	276.16	19.7	282	4,913	8.08	17.4	24.2
	A	41	4,035	11.46	98.41	20.8	149	2,091	3.44	14.0	25.5
	B	23	6,409	18.21	278.65	23.3	51	825	1.36	16.2	24.2
	C	16	11,649	33.09	728.06	15.4	82	1,997	3.28	24.4	22.6
Significant difference[b]:				n.s.	2,3	2,3			1	n.s.	n.s.
	OR	61	8,613	32.63	141.20	18.5	196	1,738	3.81	8.9	22.0
	A	44	2,193	8.31	49.84	17.2	87	788	1.73	9.1	20.8
	B	10	1,052	3.99	105.20	21.4	46	344	0.75	7.5	22.1
	C	7	5,368	20.33	766.86	11.1	63	606	1.33	9.6	23.4
Significant difference[b]:				n.s.	n.s.	n.s.			1	n.s.	n.s.
1988	SR	75	5,533	19.46	73.77	21.9	164	4,297	8.39	26.2	17.7
	A	52	3,760	13.06	72.31	23.9	97	894	1.74	9.2	12.0
	B	10	210	0.97	21.00	26.7	30	1,695	3.31	56.5	20.2
	C	13	1,563	5.43	120.23	16.4	37	1,708	3.34	46.2	18.4
Significant difference[b]:				n.s.	2	3			n.s.	3	1
	OR	82	11,116	51.46	135.56	21.7	199	2,661	5.20	13.4	18.8
	A	55	4,140	19.17	75.27	24.0	128	1,257	2.46	9.8	22.4
	B	23	4,936	22.85	214.61	22.4	39	667	1.30	17.1	13.5
	C	4	2,040	9.44	510.00	15.3	32	737	1.44	23.0	17.4
Significant difference[b]:				n.s.	n.s.	2,3			n.s.	n.s.	1

Table 11. Continued.

Year	Category[a]	Insects					No insects				
		No. groups	No. caribou	Sighting rate (caribou/km)	Mean group size	% Calves	No. groups	No. caribou	Sighting rate (caribou/km)	Mean group size	% Calves
1989	SR	172	4,779	13.58	27.78	10.6	326	6,372	14.22	19.6	12.9
	A	127	2,689	7.64	21.17	9.0	213	2,407	5.37	11.3	11.7
	B	29	1,687	4.79	58.17	11.0	60	1,828	4.08	30.5	14.8
	C	16	403	1.15	25.19	20.3	53	2,137	4.77	40.3	12.5
	Significant difference[b]:			n.s.	n.s.	3			n.s.	3	n.s.
	OR	117	5,278	19.99	24.93	4.4	218	8,104	24.12	37.2	12.8
	A	90	470	1.78	5.22	10.6	158	6,948	20.68	44.0	12.1
	B	17	660	2.50	38.82	1.8	26	524	1.56	20.2	19.1
	C	10	4,148	15.71	414.80	3.1	34	632	1.88	18.6	14.4
	Significant difference[b]:			n.s.	n.s.	2			n.s.	n.s.	n.s.
1990	SR	164	3,460	13.52	21.10	12.9	245	7,142	13.12	29.2	18.5
	A	125	2,224	8.69	17.79	15.3	173	2,407	4.42	13.9	24.3
	B	16	440	1.72	27.50	13.2	26	2,929	5.38	112.7	15.8
	C	23	796	3.11	34.61	5.9	46	1,806	3.32	39.3	14.6
	Significant difference[b]:			n.s.	n.s.	1,2,3			n.s.	n.s.	1,3
	OR	227	1,675	8.73	7.38	25.1	274	1,120	2.75	4.1	19.8
	A	190	1,322	6.89	6.95	26.2	197	614	1.51	3.1	19.5
	B	18	266	1.39	14.78	23.7	25	316	0.77	12.6	23.9
	C	19	87	0.45	4.58	13.8	52	190	0.47	3.7	17.7
	Significant difference[b]:			1,3	n.s.	2,3			3	n.s.	2

[a] SR = Spine Road, overall; OR = Oliktok Road, overall; A = 0-500 m; B = 501-1,000 m; C = >1,000 m.
[b] t-test, $P < 0.05$: 1 = A vs. B, 2 = B vs. C, 3 = A vs. C; n.s. = not significant.

7. With no insects present, SRT and MGS were relatively low and remained stable for both roads during the entire period (Table 11). CP varied among years, but values were virtually identical for the two roads after 1986.

8. Of 24 significant differences in SRT, MGS, and CP noted under insect harassment, 17 were higher for caribou in intervals closer to the road (Table 11); these included three of three sighting rates and 14 of 16 calf percentages. All five MGS comparisons were significantly higher for caribou in the more distant of the paired intervals. With no insects present, trends were similar. All three differences in SRT and four of six differences in CP were significantly higher for caribou in intervals closer to the road, while six of six comparisons of MGS were significantly higher for the more distant caribou.

9. Increasing numbers of caribou were observed crossing the road and/or pipelines until 1988, when the number of attempted crossings declined (Table 9). Most crossings occurred near the Kuparuk River and north of CPF-3 (Fig. 13). Calf representation in crossing groups was generally greater or equal to the annual estimated regional calf percentages (Table 9; Smith and Cameron, unpubl. data).

10. Numbers of individuals, groups, and groups >100 individuals that successfully crossed the SR or OR all increased in 1986, remained high through 1988, and then declined (Fig. 9). Caribou were consistently successful in crossing pipelines during the period, and crossing success of the road/pipeline complex increased steadily, reaching highest levels in 1990.

CONCLUSIONS

Precalving

In 1982, we began road surveys along the SR/Kuparuk Pipeline and the newly constructed OR to monitor movements of maternal caribou into the Milne Point calving concentration area. Relatively few parturient caribou (adult females with hard antlers) were observed during precalving surveys. Most groups consisted of stationary bulls, short yearlings (without females), or mixed parous and nonparous cows. SRTs during precalving increased through 1984, but thereafter declined, becoming the lowest for any season or construction period when surveys were discontinued in 1986.

As previous data indicated that a road/pipeline complex might present a barrier to caribou movements (Child 1973, Fancy 1983, Smith and Cameron 1985*a*), we identified a subobjective to determine if the newly constructed Kuparuk Pipeline would affect movements of maternal caribou to the Milne Point calving area. During Initial Construction, CP and SRT were markedly higher along the OR than along the SR/Kuparuk Pipeline complex, indicating the caribou were moving to the

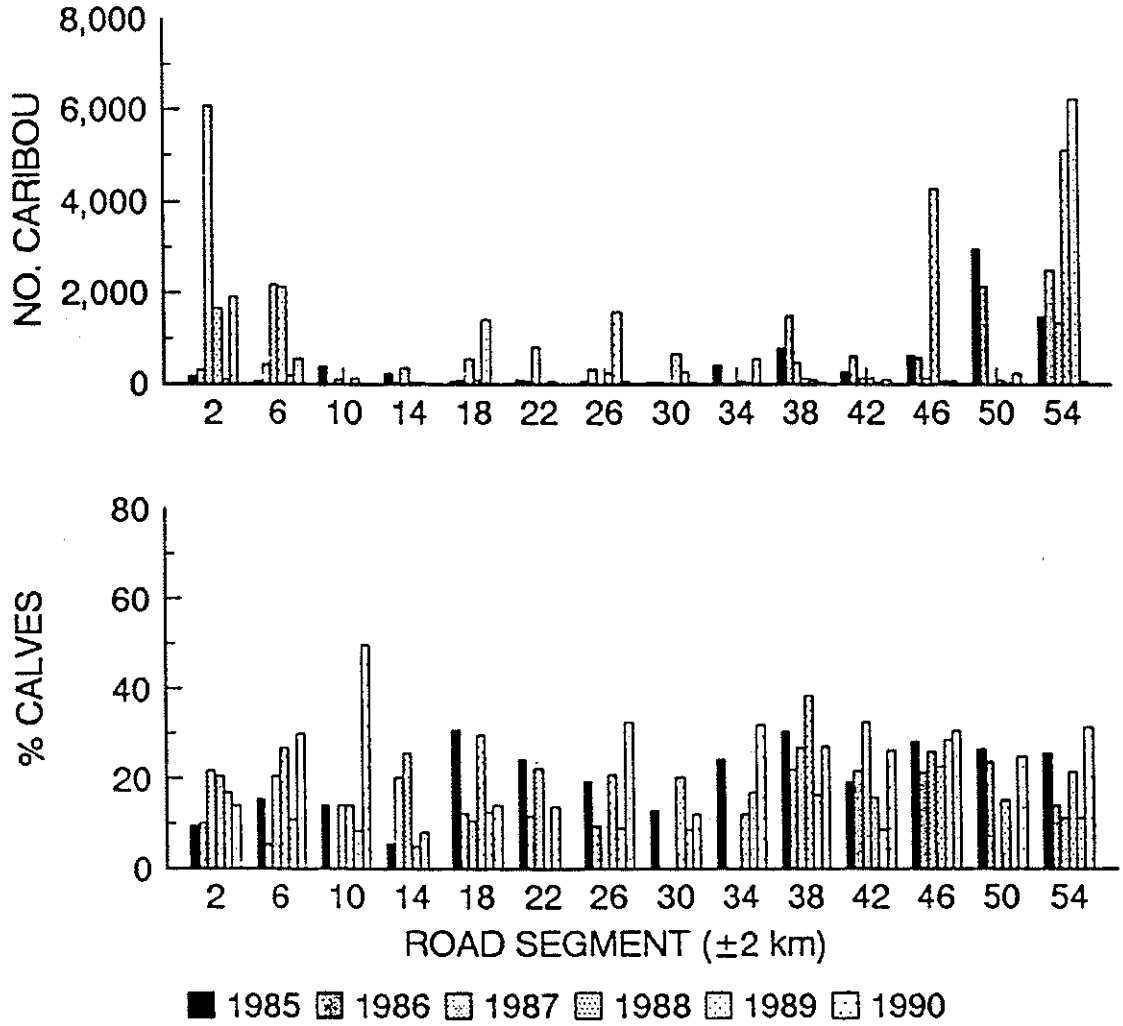

Fig. 13. Distribution of caribou crossing attempts of the Spine and Oliktok Roads, and calf representation by road segment, midsummer, 1985-90.

Milne calving grounds by crossing the OR and, in doing so, avoiding the pipeline. Although there is some evidence that caribou moved north/south across the SR to get to coastal areas during summer (Cameron et al. 1981), maternal groups traditionally may have moved to the Milne Point calving grounds from the west in May and June. However, after the construction of OR pipelines, SRTs equalized along the OR and SR, and more short yearlings were seen along the more heavily traveled SR. Maternal cows could no longer select the pipeline-free route along the OR to the Milne Point calving area and were equally abundant along the two roads. When surveys were discontinued in 1986, both CP and SRT had declined to period lows.

Caribou were attracted to snow-free areas adjacent to the road created by the "dust shadow" from vehicular traffic. During the 5 years of precalving surveys, higher proportions of caribou were seen closer to the road than during either calving or midsummer. However, these groups were dominated by the caribou that were less sensitive to disturbance; namely bulls, nonparous cows, and short yearlings. Better foraging conditions were not sufficient to attract maternal cows to the vicinity of roads.

Initially, we had hoped to identify movement corridors intersecting the road transect. Unfortunately, however, only about 1% of all caribou observed crossed the road/pipeline. Apparently most crossings occurred during nonsurvey periods in late evening and early morning when traffic levels were very low. It is noteworthy that during Initial Construction, both the number of caribou and the proportion of calves increased during the survey period (Fig. 5), indicating that short yearlings either were leaving maternal bands to feed in the dust shadow or had arrived in the area in separate groups. After construction of pipelines along the OR, neither caribou numbers nor CP changed, and most observations were repeat sightings of bulls, nonparous cows, and short yearlings grazing within the dust shadow. Apparently, maternal caribou moved directly to calving areas during hours of low activity and did not linger by the road system.

Calving/Postcalving

The dynamics of caribou groups along the road system during calving/postcalving are best described in subperiods: the first 14 days of June, when maternal groups avoid the road system; and the rest of June, before the onset of insect harassment when maternal groups begin moving away from calving sites and nonmaternal caribou begin to filter in from the south. In surveys during the first 14 days of June 1982-90, the mean CP along the road transect was 2.9%. By comparison, the mean annual CP observed during 10-15 June aerial surveys of the Milne Point calving grounds was 39.8%. After 14 June, however, mean annual CP increased to 10.4%, as maternal cows became less sensitive to human activity and approached within sighting distance of the road system; this percentage was still significantly lower than regional estimates.

The number of caribou observed from the road transect was highly correlated with the number of caribou seen on annual aerial surveys of the Milne Point calving concentration area. This is not surprising as caribou must cross the SR and OR to reach that area. However, since most caribou observed from the road were nonparous, a constant proportion of nonmaternal caribou probably arrive in the

area with maternal groups, but they remain near the road system to feed in the dust shadow.

The number of caribou moving to coastal calving areas varies annually, principally because of differences in snow cover and local flooding (Cameron et al. 1992). By 1989, however, SRTs and CPs along the road system and within the Milne Point calving area in general reached lowest values recorded for the decade, irrespective of snow conditions. This occurred during a nearly threefold increase in herd size. In 1990, the earliest breakup since we began surveys in 1978 left the coastal plain snowfree and dry by 1 June. We recorded record numbers of caribou during aerial surveys and along the road system, indicating that most maternal caribou still have access to portions of the main calving concentration area that are distant from the road system. However, even with unprecedented numbers of caribou on the calving ground during the first 14 days of June, both SRT and CP were near record lows. Clearly, there has been no habituation of maternal cows to the road system during calving, and occupancy of areas near the road has progressively decreased, despite the increase in herd size.

During Initial Construction, most caribou and calves were seen in the middle portions of the SR and OR (Fig. 5) except for nearly complete avoidance of the high traffic road between CPF-1 and CPF-3. Numbers of bulls near Oliktok Point increased. By 1990, small groups of habituated bulls, yearlings, and nonmaternal cows had begun using the expanded dust shadow between CPF-1 and CPF-3 (Fig. 11), but calves were never observed within the core traffic areas. The few calves observed were on the fringes of the Milne Point calving ground adjacent to the road system.

As during precalving, our efforts to locate movement corridors were frustrated by the small numbers of caribou observed crossing the road/pipeline. However, daily tracking of pregnant cows equipped with satellite transmitters indicates they made direct movements across the road as late as 8 June to calve in the Milne Point calving concentration area. Again, the small sample of satellite locations did not permit the identification of movement corridors.

Midsummer

During the preconstruction period, there were relatively minor changes in the sex/age composition and distribution of caribou along the SR. Only in the Kuparuk floodplain, adjacent to the only site of continuous construction activity, did we document a progressive and marked decline in numbers of caribou and calves. As in other studies of localized or "point" disturbances (Wright and Fancy 1980, Fancy 1983), caribou groups moved only a few kilometers from local construction. Occupancy of areas corresponding to 4-km segments of the SR changed in response to the location of construction activity (Cameron et al. 1981).

Unlike avoidance of the Dalton Highway transportation corridor by cow/calf groups (Cameron et al. 1979, Cameron et al. 1985), during Preconstruction, the relative number of calves appeared to be unaffected by traffic along the SR. Annual CP declined from 24.9 to 19.4 (Table 1) and a similar decrease was noted in the sex/age composition of postcalving aggregations within the KDA. Thus, maternal groups appeared to be normally represented in caribou surveyed along the SR.

By 1980, maternal groups were avoiding heavy construction within the Kuparuk floodplain, although there was no obvious change in the abundance of calves along the SR (Fig. 3). When insects were absent, the most calves within any segment of the road transect were observed in groups west of the SR, indicating that maternal groups were displaced to the southwest or west of CPF-1.

Insect activity markedly affected the numbers and distribution of caribou along the SR. In 1978, long periods of continuous insect harassment kept caribou near coastal habitats and away from the road. Fewer insect days in 1979 and 1980 allowed caribou to remain at preferred inland feeding sites near the road, and SRTs increased markedly. Additionally, periods of insect activity were of short duration, and caribou moved immediately inland when insect activity abated in the evenings.

Insect harassment was also associated with both increases in MGS and clumping of caribou in areas where large mosquito-harassed groups crossed the road (Table 1, Fig. 3). More than 90% of observed road crossings occurred under insect harassment, generally in riparian areas away from local construction. Crossing success of both individuals and groups was high until 1980, when a group of 337 attempted to cross the SR, but was thwarted by vehicular traffic. This lowered the observed individual crossing success for that summer to <70%, a portent of future problems with movements of large insect-harassed groups through the oilfield complex.

Insect activity continued to dominate caribou distribution and movements during Initial Construction. During midsummer 1978-80, caribou moved north across the SR to coastal insect relief habitat and returned directly south when harassment ceased, along north/south-oriented riparian systems (Cameron et al. 1981). Beginning in 1981, a different pattern of movements was apparent. Insect-harassed caribou moved to the coast from areas west of CPF-1, as well as along the Kuparuk floodplain. When insect harassment ceased, caribou returned inland to within a few kilometers of the SR, paralleled the SR until west of the CPF-1 complex, and then turned south; except for the road segment within the Kuparuk floodplain, there were few southbound crossings of the SR (Smith et al. 1985, 1986). These circular movements north of the SR occurred up to three times each summer.

In 1983 and 1984, large, insect-harassed aggregations (ca. 6,000 in 1983, 7,000 in 1984) moved from the Kuparuk Delta toward the West Dock area, west of Prudhoe Bay. Although some caribou penetrated part of the pipeline/road complex, their continued eastward movements were apparently blocked, and groups eventually returned to the west (Smith et al. 1985).

Calf representation along the SR and OR changed after construction of the Kuparuk pipeline. Although the proportion of calves observed along the SR was similar to regional estimates during Preconstruction, it fell substantially below regional estimates between 1981 and 1983, but returned to regional levels in 1984 (Smith et al. 1984, 1985). 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 SR. However, with an increase in construction activity in the Kuparuk floodplain during Initial Construction, the calf percentage for that road segment decreased. This change is consistent with observations along the TAP Corridor and within the Prudhoe Bay Complex that cow/calf groups avoid areas of heavy construction and traffic during summer (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 1985). 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 floodplain before intensive construction activity began in the area, and as bulls appear normally represented in upland areas, we conclude that low calf percentages in the Kuparuk floodplain are due to avoidance of construction activity by cow/calf groups.

Movement patterns of caribou groups to and from insect relief habitat continued to change during Advanced Construction. After construction of CPF-3 and the Oliktok pipelines, it appears from the movements of radio-collared caribou that the portion of the CAH west of the Sagavanirktok River began staging for the onset of the insect season southwest of the Kuparuk facilities. The entire western portion of the CAH frequently moved to the Colville Delta for relief from insects. Although the oilfield area continued to be traversed, a change in access was discernible. During Preconstruction and Initial Construction, the first large, insect-harassed groups of the year approached the road transect in middle sections, whereas during Advanced Construction, most large groups were observed at the extremes of the transect (Figs. 3, 7, 12). Insect-harassed caribou appeared to avoid the core areas of industrial activity.

Although the rate of increase of the CAH declined during the late 1980s, the CAH continued to increase during Advanced Construction. Numbers of caribou observed from the road increased through 1987 and then declined in 1990 to Initial Construction levels; this coincided with the first major use of the Colville Delta. Since the percentage of caribou observed within 1,000 m reached a decade high in 1990 (Table 1), it appears that fewer, but more highly habituated, caribou occupied the area near the road system at the end of Advanced Construction.

By the end of Advanced Construction, caribou were no longer more common along the OR. Through 1986, SRT, MGS, and CF remained highest along the OR under all insect conditions; but as the production infrastructure began to intensify, no trends were discernible in any of the three variables (Table 11). Even though larger groups moved away from the road, CP was higher at closer road intervals.

Although the rate of road/pipeline crossing success reached a decade high in 1990, the *number* of caribou observed crossing decreased to Initial Construction levels (Fig. 9; Tables 6, 9). Most crossings occurred in the two corridors with little production infrastructure, the Kuparuk floodplain and near Oliktok Point (Fig. 13). However, success crossing the road only plummeted to new lows as large groups continued to be thwarted by heavy traffic. It is our impression that some habituated caribou successfully cross the road/pipe complex but large groups are avoiding the Kuparuk Development Area when other options are available.

RECOMMENDATIONS

A. Mitigation

1. Calving Distribution

Continue to discourage surface development in the vicinity of the calving concentration area near Milne Point. If caribou are displaced southward, monitor calf survival and document any decreases that might be linked to higher levels of predation.

2. Summer Movements

a. To the extent possible (given the facilities now in place), maintain a 3-km wide zone of minimum surface development along the coast in an attempt to accommodate the east-west movements of large, insect-harassed groups of caribou (Note: This recommendation was also made by ADF&G in reference to potential ANWR development). At all costs, avoid the proliferation of roads, above-ground pipelines, and processing facilities that characterize the Prudhoe Bay complex.

b. Discourage additional construction within the two major road crossing areas currently in use (i.e., Oliktok Point/CPF-3 and Kuparuk floodplain) by caribou entering and exiting the KDA.

c. In general, minimize the future "network effect" of the KDA by siting new support and processing facilities in areas that are already intensively developed and by restricting production-unrelated facilities (including subcontractors) to the main industrial complex near Deadhorse airport.

d. Reduce vehicular traffic within the KDA through security screening, convoying, and bussing.

e. Continue to promote the development of technology for pipeline burial, and encourage the redesign and evaluation of elevated pipelines (e.g., greater clearances, road/pipeline separation, ramps of varying height and length). This study and a recent site-specific evaluation of movements within the CPF-1, 2, and 3 areas (Johnson and Lawhead 1989) indicate that mitigation measures to enhance the movement of large groups through congested industrial development (e.g., road/pipe separations and buried pipe crossings) have not been evaluated, have not been constructed according to optimal design, or have been shown to be ineffective. We still have not established which techniques will enhance the movements of large insect-harassed groups through an oilfield complex. Each year large insect-harassed groups of up to 12,000 caribou move eastward into the prevailing winds and become trapped within the first few miles of pipelines and roads at the northwestern edge of the Prudhoe Bay Complex near West Dock. Depending upon insect conditions, they may remain there for days, moving between patches of habitat

partitioned by racks of pipelines, before eventually exiting the area to the west.

The best mitigative approach to aid passage remains uncertain. An "optimal design" proposed for a buried pipeline crossing near Oliktok Point was not constructed when expansion of CPF-3 was postponed. While it appears that caribou do cross the OR, CPF-1 has already reached a level of complexity that deters most groups from crossing near this facility (Johnson and Lawhead 1989). Johnson and Lawhead (1989) noted that separation of pipelines from roads, another mitigative measure, did not improve crossing success. Clearly, if free passage of caribou through industrial complexes is important for the well-being of the CAH, we must better understand the dynamics of large groups. Furthermore, we do not know if entrapment of large groups of caribou in small areas near Prudhoe Bay and delayed movement of large groups near Oliktok Point significantly affect foraging opportunity and summer nutrition. Conoco has recently buried feeder pipelines in roads from production pads near Milne Point, and we have not observed problems with movements of large caribou groups there as we have observed repeatedly at West Dock and Oliktok Point.

B. Future Studies

1. Curtail Road Surveys During the Calving Period

It is clear from the June data that consistently few caribou, and virtually no calves, are present along the KDA road system during the first 2 weeks of June, in sharp contrast to the abundance of maternal groups observed in areas distant from oilfield structures and facilities. Toward the end of the survey period, additional caribou usually occupy roadside areas when bulls, nonparous cows, and yearlings arrive on the coastal plain. Calves become more numerous as maternal females, with older offspring, apparently accommodate somewhat to disturbance; even so, calves remain significantly underrepresented locally relative to regional estimates. This was especially evident in 1990 when calving areas adjacent to the Kuparuk Oilfield were completely snowfree and dry. Although we counted a record number of caribou and calves in these areas during aerial surveys, virtually no maternal caribou or calves were seen from the road system.

This pattern has persisted, with no evidence of habituation. We therefore believe that there is little more to be learned by continuing road surveys during this period. Annual or biennial transect data obtained by helicopter should suffice as "snapshots" of calving distribution in the KDA.

2. Continue Surveys During Midsummer

Annual road surveys during July and early August are necessary for at least four reasons:

a. To determine changes in the relative abundance and group composition of caribou along the road system. This is essential

for any chronological assessment of habitat use within an oilfield complex that will continue to expand and intensify as overlapping and contiguous reserves are exploited.

b. To monitor changes in the distribution of road/pipeline crossings and crossing success as structural complexity within the KDA increases. Mitigation attempts notwithstanding, there may well be a point in the progress of development beyond which access to, or exit from, some areas becomes impossible. Documenting such occurrences is central to a complete evaluation of ultimate impacts.

c. To obtain estimates of midsummer sex/age composition of the western portion of the CAH as part of a maintenance S&I program. This would also provide follow-up data on calf survival.

It should be noted that, because of other concurrent field activities, midsummer road surveys can be accomplished with existing staff. Caribou capture related to routine CAH collaring and body condition assessment will continue for the foreseeable future; in fact, much of this work can be done cost-effectively by darting insect-harassed caribou from the road system in conjunction with the subject surveys. Also, radio-tracking flights will be made throughout the period to monitor calf survival as part of ongoing research, to obtain routine data on the seasonal distribution and productivity of CAH caribou, and for pre-photo reconnaissance in census years.

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