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

by

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SUMMARY

In lieu of a standard Progress Report, we offer 3 papers on various aspects of our caribou research in the Kuparuk region.

Appendix A:

Smith, W. T., and R. D. Cameron. 1985. Reactions of large groups of caribou to a pipeline corridor on the Arctic Coastal Plain of Alaska. Arctic. In press.

Appendix B:

Whitten, K. R., and R. D. Cameron. 1985. Distribution of caribou calving in relation to the Prudhoe Bay oil field. In A. M. Martell and D. E. Russell, eds. Proc. First North American Caribou Workshop, Whitehorse, 1983. Can. Wildl. Serv., Ottawa. In press.

Appendix C:

Smith, W. T., and R. D. Cameron. 1985. Factors affecting pipeline crossing success of caribou. In A. M. Martell and D. E. Russell, eds. Proc. First North American Caribou Workshop, Whitehorse, 1983. Can. Wildl. Serv., Ottawa. In press.

Key words: caribou, disturbance, oil field, pipelines, traffic.

CONTENTS

APPENDIX A

Reactions of Large Groups of Caribou to a Pipeline Corridor on the Arctic Coastal Plain of Alaska

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Arctic (in press)

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ABSTRACT. We describe in detail two instances in which large groups of mosquito-harassed caribou (*Rangifer tarandus granti*) were followed for 8-12 h as they repeatedly attempted to cross an elevated pipeline in the Kuparuk Development Area near Prudhoe Bay, Alaska. In 1981, 46% of a group of 917 eventually crossed beneath elevated portions of the pipeline in 26 separate attempts, 13% crossed a section of buried pipe in two attempts, 22% trotted parallel to the pipeline for 32 km and did not cross, and 19% separated from the group and were not accounted for. In 1982, 26% of a group of 655 crossed under elevated portions of the pipeline in 36 attempts, 37% crossed at a buried section in one attempt, and 37% left the main group and could not be accounted for. The majority of crossing attempts occurred near intersections of lakes with the road/pipeline complex, but crossing success was highest at a section of buried pipe isolated from road traffic.

Key words: caribou, pipeline, petroleum development, insect harassment, Kuparuk Oil Field

INTRODUCTION

Numerous barren-ground caribou (*Rangifer tarandus granti*) of the Central Arctic Herd (CAH) (ca. 9,000 head in 1981; Whitten and Cameron, 1983) use coastal portions of Alaska's Arctic Slope for calving and summer range. In late spring, most CAH cows move from inland wintering areas into the coastal zone where they remain throughout the summer, usually until early fall (Cameron and Whitten, 1979).

Weather-induced variations in insect activity strongly influence the summer movements of CAH caribou (White *et al.*, 1975; Roby, 1978). On warm, calm days beginning in late June, caribou aggregate and move northward from inland feeding areas to sparsely vegetated shore lines, river deltas, and offshore islands where cool onshore breezes offer relief from mosquitoes (*Aedes* spp.). When lower temperatures and/or stronger winds reduce mosquito activity, caribou return inland where grazing conditions are presumably more favorable. These oscillatory movements continue until late July when warble flies (*Oedemagena tarandi*) and nose bots (*Cephenomyia trompe*) replace mosquitoes as the dominant insect pests. Caribou under attack by parasitic flies tend to disperse in small groups, and movements to and from the coast become less predictable. West of the Kuparuk River, insect-related movements bring caribou into frequent contact with the roads and pipelines of a rapidly developing oil field.

Varying degrees of negative reaction by caribou to roads, traffic and/or pipelines have been reported (Tracy, 1977; Roby, 1978; Cameron *et al.*, 1979; Cameron and Whitten, 1980; Klein, 1980; Horejsi, 1981; Smith and Cameron, 1983). Additional studies have focused specifically on the responses of caribou to roads and elevated pipelines on the Arctic Coastal Plain, but results are contradictory or inconsistent. Child (1973) reported that caribou did not pass freely beneath a simulated pipeline, whereas Curatolo and Murphy (1983) concluded that pipelines elevated 1.5 m or more did not restrict movements, provided that vehicular traffic was absent; and Fancy (1983) observed that the majority of caribou groups approaching a road and pipeline crossed the first structure encountered. These disparities are difficult to reconcile because of differences in structural configuration and the criteria chosen for crossing success (Smith and Cameron, 1984).

In this paper, we describe, in detail, the responses of two large, mosquito-harassed groups of caribou to a road/pipeline complex near Prudhoe Bay, Alaska.

STUDY AREA AND METHODS

The West Sak Road (WSR) is a 32-km extension of the Prudhoe Bay Spine Road (Fig. 1) into an oil field region known as the Kuparuk Development Area (KDA). The WSR was built in winter 1977-78. During the next three years a construction camp, permanent living quarters, oil/gas processing facilities, and an airstrip were added at the Central Processing Facility (CPF-1) pad.

The Kuparuk Pipeline (KP), constructed during winter 1980-81, transports crude oil from CPF-1 to the origin station of the Trans-Alaska Pipeline, some 44 km to the east. For most of the first 30 km, the pipeline closely parallels the WSR. Vertical supports for the 50-cm pipeline are 20 m apart. Surface-to-pipe clearance is 1.5 m in most areas, but may exceed 2.1 m (Fig. 2*), particularly where rivers and creeks are traversed.

Rates of one-way traffic on the WSR were estimated using an automatic infrared trail counter (Scientific Dimensions, Inc., Albuquerque, NM) in 1981 and through security checkpoint records in 1982. Respective mean values were 20 vehicles per hour (18 July, 0900-2200) and 21 vehicles per hour (13 July, 1200-2400). Traffic on the pipeline access road east of the Mobil Airstrip was extremely light, perhaps only two or three vehicles per hour.

Hourly weather records for Deadhorse Airport (45 km east of CPF-1) were obtained from the Arctic Environmental Information Data Center, University of Alaska, Anchorage. Based on ambient temperature and wind velocity for each hour during the two observation periods (means: 20°C and 8.2 $km.h^{-1}$, 0900-2100, 18 July 1981; 13°C and 7.0 $km.h^{-1}$, 1000-1900, 13 July 1982), insect harassment was moderate or severe (White _et al_., 1975).

The caribou groups described below were originally observed during twice-daily systematic surveys of the WSR by pickup truck (inclusive dates: 15 June-7 August 1981, 1 July-5 August 1982). After completing the routine survey, we returned and followed the groups until they left the vicinity of the pipeline corridor. To minimize observer influence, we watched the groups at the greatest distance possible using binoculars or a spotting scope. Road curvature and berms, the pipeline, and terrain obstructions occasionally prevented continuous observation, but most crossing sites and numbers of caribou attempting to cross were recorded. To assist in group identification, adults and calves were counted whenever possible.

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* Not given. Photograph of part of a group of 603 caribou adjacent to an elevated section of the Kuparuk Pipeline.

RESULTS

1981

Between 0800 and 0900 on 18 July, a group of 917 caribou was first seen just east of the CPF-1 by security personnel; we first observed them at 1115 (Fig. 3). The caribou continued to mill at the same location in a large, fragmenting group until 1400. During this period, there were numerous attempts to cross the elevated pipeline to the north. All successful crossings were recorded, but the movements of numerous subgroups prevented documentation of every attempt. At 1345, 151 caribou broke away from the main group and were last seen at 1415 running east.

At 1400 the remaining 560 caribou also began to move east, paralleling the road and elevated pipeline. By the time the group reached the Sakonowyak River at 1900, an additional 256 caribou had crossed the pipeline to the north after a total of 13 attempts. The main group continued east, paused at the section of buried pipe near the Mobil Airstrip, but did not cross. During subsequent eastward movements, two groups of 32 and 54 crossed to the north and continued to trot east within 20 m of the pipe; within 15 minutes, however, most of these recrossed to the main group. At the buried section of pipeline near the Kuparuk River, 122 caribou crossed to the north. Shortly thereafter, a single adult crossed under an elevated section of pipe. The remaining 201 continued east, swam the Kuparuk River, ran parallel to the pipeline, and were out of sight at 2130.

In summary, during 12 h of observation, starting with the original group of 917 caribou, an estimated 419 (46%) crossed elevated sections of pipeline (without recrossing) in 26 separate attempts, 122 (13%) crossed at buried sections of pipeline in two attempts, and 201 (22%) trotted or ran parallel to the elevated pipe for at least 32 km without crossing. Approximately 175 (19%) caribou split from the main group and could not be accounted for. Overall, less than 60% of the original group was known to have crossed the KP.

1982

At 1030 on 13 July, a group of 515 caribou was observed milling within 20 m of the pipeline, approximately 5 km east of CPF-1 (Fig. 4a). Within an hour, they began moving eastward along the pipeline and were joined by 88 caribou from the south. After four unsuccessful crossing attempts, the group moved south approximately 2 km, along the western margin of a lake, and was joined by an additional 52 caribou. The group, now numbering 655, moved north to the pipeline, and 29 caribou crossed under the pipe. The remaining 628, including one cow-calf pair that had recrossed, turned south and ran out of sight.

Just after 1400, two groups trotted north and approached the road/pipeline (Fig. 4b). Combined, the groups were of a similar size and calf percentage as the group that had disappeared (644, 26% calves vs. 628, 24% calves), and the western group included a collared bull, YB17, that had been observed in the original group of 515 (Fig. 4a). The eastern group of 166 made four attempts to cross the pipeline, but only 10 individuals were successful. At 1445, the remainder of the group ran east out of sight. The western group of 478 made 12 crossing attempts while paralleling the road/pipeline to the west; 91 caribou moved off to the southwest, and 109 caribou in four subgroups crossed and ran north. By 1530, the remaining caribou had moved 2 km south of the pipeline.

Almost immediately thereafter, this group of 278 ran north and attempted numerous crossings (Fig. 4c), but only 23 individuals were successful. At about 1600, the remaining 255 caribou circled a lake, ran/trotted to the east, and continued paralleling the KP for 17 km; three crossing attempts were made enroute. At 1825, the entire group, including YB17, crossed a 32-m section of buried pipeline, ran north, and subsequently crossed the WSR northbound.

To summarize, during 8 h of observation, 37 group crossing attempts were recorded. In 36 of these attempts, 169 caribou (26%) crossed northbound under the pipe (without recrossing). In one attempt, an entire group of 249 caribou (37%) crossed northbound at a buried section of pipe. An estimated 247 caribou (37%) separated from the main group of 655, and their crossing success could not be determined. In total, we observed 64% of the group crossing the road/pipeline complex.

The only other 1982 observation of a group >100 individuals attempting to cross the KP was made on 21 July. Based on sightings at midday and again in early evening, that group of 141 bulls/adults under mosquito harassment was unsuccessful in negotiating the KP corridor.

DISCUSSION

Group crossing attempts were generally infrequent during the midsummer periods in 1981 and 1982. Of the combined total of 1899 groups seen during systematic surveys, only 102 (5%) attempted to cross the WSR and/or KP. Similarly, of 38 groups >100 individuals observed, only the three groups described above (8%) attempted to cross the road/pipeline (Smith and Cameron, 1984). Thus, the proportion of crossing attempts among large groups was comparable to that for all groups observed.

The episodes detailed above indicate that large, mosquito-harassed groups of caribou do not readily cross beneath elevated pipelines. This conclusion is supported by the observations of Child (1973) and Fancy (1983) that no entire group of >100 caribou crossed an elevated pipeline or pipeline simulation when harassed by insects (Smith and Cameron, 1984). In both of the latter studies, however, numerous groups simply detoured around the relatively short structures involved (i.e., 3.1-4.8 km). In contrast, the KP is more than 40 km long, and caribou can and do move parallel to the pipeline for long distances.

For many of the caribou in both groups, interactions with the KP resulted in a substantial increase in energy expenditure. In 1981, for example, more than 20% of the original group trotted or ran along the pipeline for 32 km, while ostensibly trying to cross to the north. This excludes several excursions to the south and a number of detours around lakes. Such unproductive activity occurred during the midsummer period of rapid growth and fattening (Dauphine, 1976; Reimers et al., 1983), when forage availability and quality are high (Chapin et al., 1975; Whitten and Cameron, 1980). Extensive detours and protracted periods of running, particularly if repeated several times during a summer, would result in a net decrease in fat accumulation unless followed by compensatory increases in forage intake. Concerns regarding a possible change in energy status are consistent with Reimers' (1983) conclusion that environmental conditions during summer, including the degree of stress, are the primary determinants of growth rate and body size of Rangifer.

Some might argue that the caribou described in this report would have trotted or run the same total distance had they crossed the pipeline without difficulty. However, we have often observed that CAH caribou substantially decrease the frequency and speed of movement when they reach suitable insect relief areas along the coast. Apparently the lower insect activity in these areas results in a reduction in harassment-induced movement, with a corresponding increase in feeding opportunity.

During both attempts to cross the road/pipeline, the original aggregations progressively fragmented into numerous small subgroups. Since summer aggregation tends to reduce the exposure of individuals to biting insects (Baskin 1970), these disruptions may have increased the net susceptibility of group members to insect attack.

In both years, the majority of crossing attempts by caribou paralleling the KP/WSR occurred at or near intersections with north-south oriented lakes. Usually the lakes funneled caribou to the road where local circumstances (e.g., traffic, topography, pipe configuration) appeared to determine crossing success. Such areas should therefore be considered prime sites for placement of special pipeline crossing structures.

Caribou were more successful crossing sections of buried pipeline than elevated sections. Combining data from both years, 37% of the caribou crossed elevated sections of pipeline in 62 attempts, whereas 24% crossed buried sections in only three attempts; it is noteworthy that buried pipe constitutes <1% of the total length of the KP. The particular buried section used by caribou (Fig. 3, 4c) was 50% wider than the next widest buried section (i.e., 32 m vs. 21 m) and was located at least 3 km from the road and traffic. Therefore, it is not possible to determine whether crossing success was enhanced by the physical characteristics of this crossing site (e.g., width, berm height, configuration of adjacent pipe) or the absence of other disturbance stimuli (e.g., road traffic, construction activity). Nevertheless, it does appear that well-designed buried crossings, particularly those isolated from human and vehicular activity, will increase the ability of CAH caribou to negotiate the increasing number of pipelines encountered during summer movements within the KDA.

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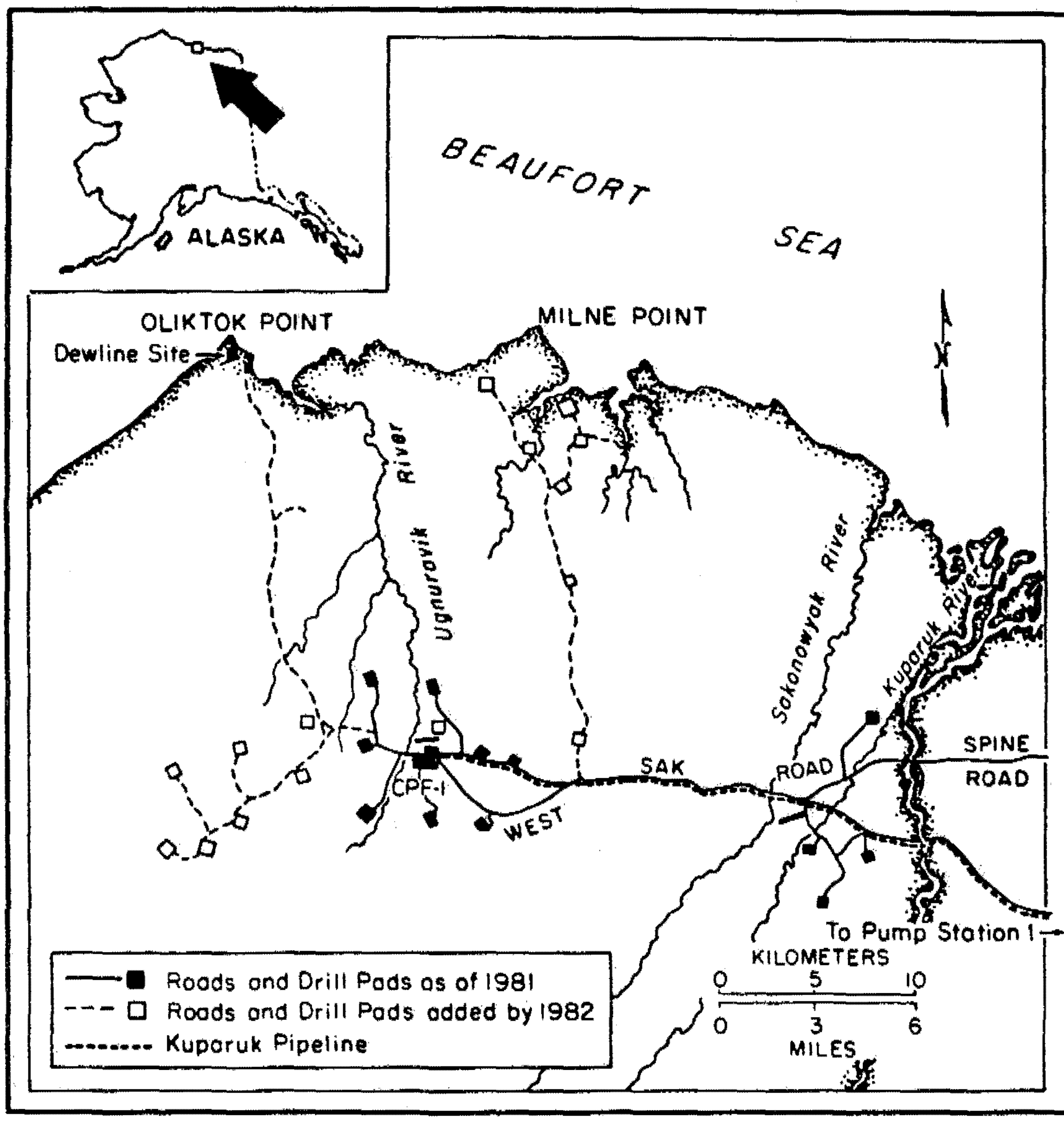

Fig. 1. The Kuparuk Development Area, 1981 and 1982.

Note: Fig. 2 (a photograph) is not included as a part of this report.

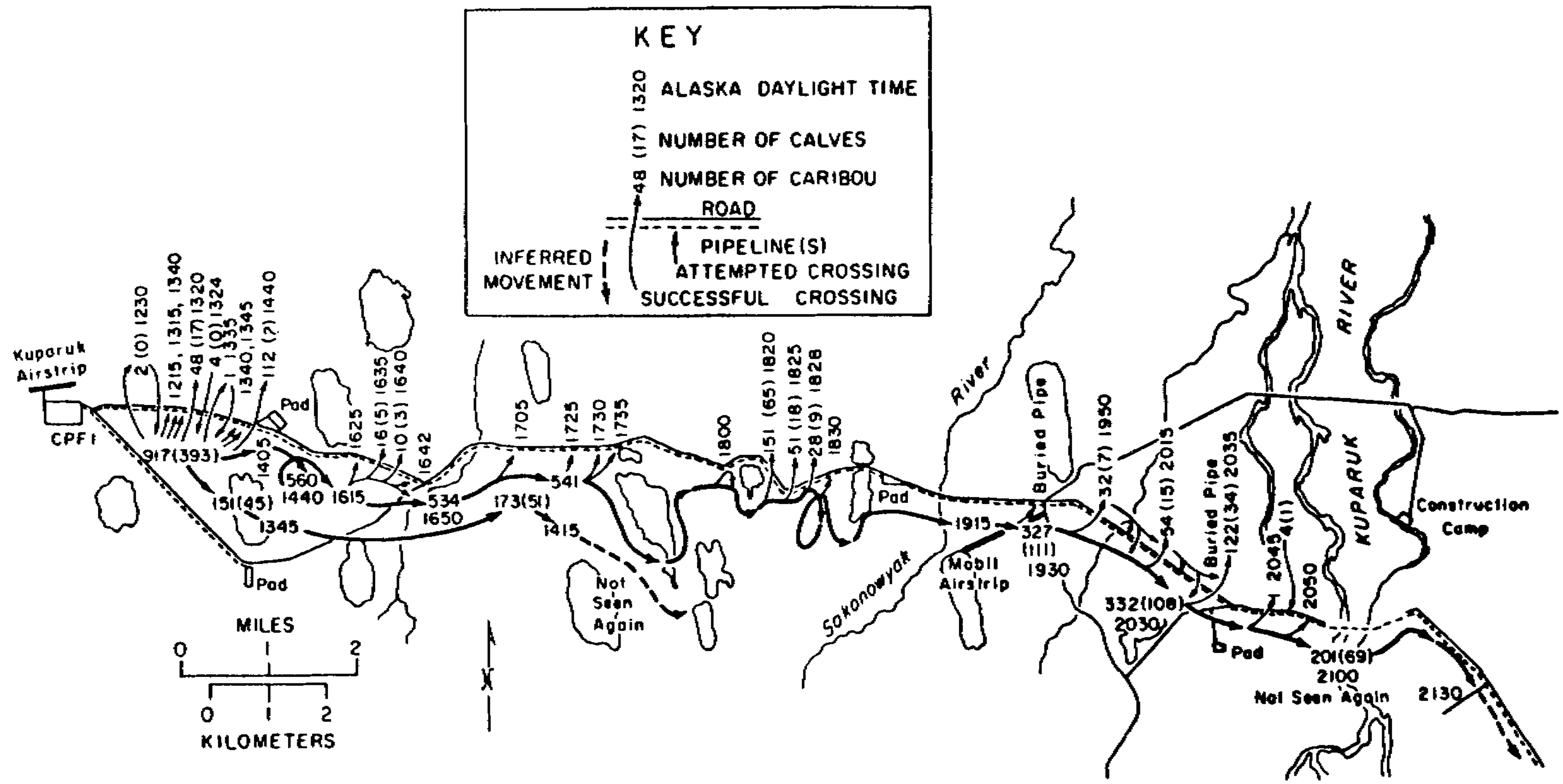

Fig. 3. Movements of caribou in relation to the Kuparuk Pipeline corridor, 18 July 1981, 0900-2130.

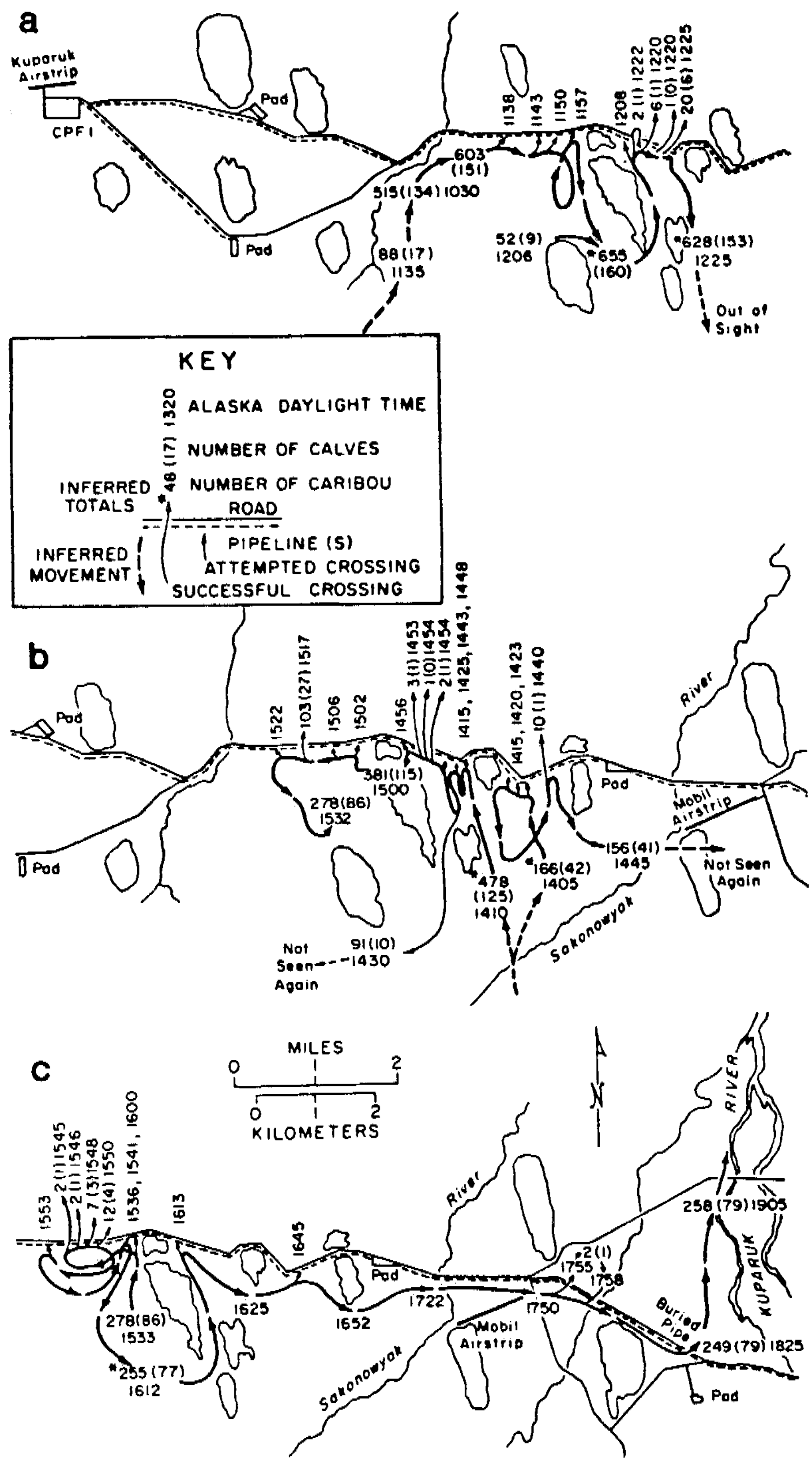

Fig. 4. Movements of caribou in relation to the Kuparuk Pipeline corridor, 13 July 1982; 1030-1225(a), 1405-1532(b), 1533-1905(c).

APPENDIX B

Distribution of Caribou Calving in Relation to the Prudhoe Bay Oil Field

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Alaska Department of Fish and Game

In A. M. Martell and D. E. Russell, eds.
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Abstract. The calving grounds of the Central Arctic Herd (CAH) were surveyed annually from 1978 to 1982 to determine caribou distribution and density. Consistently low numbers of caribou and generally low percentages of calves were observed in the Prudhoe Bay Oil Field. Mean densities of caribou in 5 other regions of the calving grounds were 2 to 18 times higher than at Prudhoe Bay, suggesting avoidance of the oil field by parturient cows. So far, displacement of calving caribou from Prudhoe has been to adjacent areas already used for calving. The CAH has increased rapidly in spite of displacement from part of its calving grounds. This paradox is best explained by the relatively low density of the CAH on its calving grounds. Effective density of CAH caribou on calving grounds is about one-third to one-fifth that of the nearby Western Arctic and Porcupine Caribou Herds, suggesting that CAH caribou have more options for selection of a calving site.

BACKGROUND

Biologists throughout the Arctic have expressed concern about industrial development and other disturbances on caribou calving grounds, the most consistently used component of caribou range. Other seasonal ranges and migration routes are used more sporadically and unpredictably (Skoog 1968, Kelsall 1968). Biologists have assumed that traditional use of calving grounds has an evolutionary or selective advantage and displacement from calving grounds would, therefore, be disadvantageous (Cameron 1983). Consequently, regulations and/or permit stipulations restricting petroleum and mineral exploration, aircraft overflights, placement of permanent facilities, etc., on caribou calving grounds have become standard requirements.

Little was known about caribou in the central Arctic area of Alaska in the 1960's when oil was discovered at Prudhoe Bay. Portions of both the Western Arctic (WAH) and Porcupine Herds (PH) were thought to use the central Arctic Slope during midsummer (Hemming 1971, Gavin 1973), and caribou calving near the developing oil field were dismissed as insignificant offshoots of these 2 large herds.

Concern about possible ill effects of petroleum development centered on disruption of seasonal caribou migrations due to construction of a pipeline from Prudhoe Bay to Valdez (Klein 1971, Weeden and Klein 1971). As a result, intensive research on caribou in this region was initiated in 1974 and soon revealed that the WAH and PH no longer used the area near Prudhoe Bay. Instead, a small population of caribou was found to inhabit the central Arctic Slope throughout the entire year. Calving occurred on the coastal plain and in the foothills between the Canning and Colville Rivers. With its own calving grounds and little or no seasonal overlap with adjacent populations, these caribou met the accepted definition of a caribou herd (Skoog 1968) and became known as the Central Arctic Herd (CAH) (Cameron and Whitten 1979).

Thus, we were provided the unexpected opportunity to study large-scale disturbance on caribou calving grounds. Preliminary results were paradoxical. CAH cows and calves avoided disturbed areas, including that portion of the calving grounds near Prudhoe Bay (Cameron et al. 1979, Cameron and Whitten 1980, Whitten and Cameron 1983b), yet the CAH increased by about 13% per year (Whitten and Cameron 1983a). This paper summarizes the results of calving ground surveys conducted from 1978 through 1982 and provides an explanation for the continued growth of the CAH.

METHODS

Intensive, standardized surveys of the CAH calving grounds were conducted 11-14 June each year between 1978 and 1981. Distribution of calving caribou was determined by flying a series of north-south transects extending inland from the arctic coast. Transects were located at 9.7 km (6 mi) intervals between the National Petroleum Reserve-Alaska (NPR-A) boundary on the west and Camden Bay on the east (Fig. 1). Transect designations and locations were the same each year, but not all transects were flown each year (Table 1). Transects were 3.2 km wide (i.e., 1.6 km to either side of the flight line); length varied, but always included at least the area within 24 km of the coast.

All transects were flown by Bell 206-B helicopter. The pilot and front-seat observer searched primarily in the direction of flight, and 2 rear-seat observers searched to either side of the aircraft. USGS 1:63,360 maps were used for navigation and recording locations of caribou groups. Airspeeds of 110-130 km/hour and altitudes of 30-50 m agl were maintained until a group of caribou was sighted. Composition was then determined while making a lower, slower pass or by hovering briefly near the group. Individuals were classified on the basis of genitalia, body size, and/or antler development as bulls, cows, calves, or yearlings.

In 1981, the southern limit of the coastal calving area was estimated by flying east-west or southeast-northwest transects beginning roughly along the southern edge of the north-south transects (Fig. 1). These transects were flown by Cessna 180 with pilot and 1 observer. Locations of caribou were noted on 1:250,000 USGS maps; only group size and number of calves were recorded. In other years, the approximate inland limits of calving distribution were noted during fixed-wing reconnaissance flights and during relocations of radio-collared cows.

Intensive coverage was limited to the Kuparuk Oil Field region in 1982; only the results of reconnaissance and radio-tracking flights are reported here.

RESULTS

Use of the coastal plain for calving was greatly affected by weather. Extensive snow cover and flooding conditions prevailed during calving in 1978, 1980, and 1982, while the calving grounds were snow-free and dry in 1979 and 1981. Early snowmelt and dry conditions resulted in greater numbers of caribou near the coast. During the dry year of 1981, almost all calving occurred within 40 km of the coast. Conversely, late snowmelt and/or flooding resulted in a more inland distribution, with calving extending up to 160 km inland during the late breakup of 1982. However, even in years of late snowmelt, the density of caribou was highest near the coast.

To illustrate distribution of caribou within this high density calving zone near the coast, data from all years were combined for the northernmost 24 km of each transect (Table 1). Most transects, except those on the eastern and western fringes of the calving grounds, were sampled in an equal number of wet and dry years. Bias due to the effects of weather on distribution relative to the coast was, therefore, minimal. The Kuparuk and Canning Delta regions supported the greatest number of caribou and the highest percentages of calves. Density in the Prudhoe Bay region was lower than the other regions by a factor of 2 to 18.

The entire calving area of the CAH within 40 km of the coast was sampled with equal intensity in 1981, when essentially all calving occurred within 40 km of the coast (Fig. 2). Most caribou in the Kuparuk, Mikkelsen Bay, and Canning Delta regions were within 24 km of the coast. In the Colville, Prudhoe Bay, and Camden Bay regions, many caribou calved between 24 and 40 km inland. The more southerly distribution of caribou in the Colville Delta region was partly a result of flooding along the river, and partly because 1 transect extended into the foothills and intersected a small concentration of caribou calving in a well-drained upland area. The Camden Bay region included little or no coastal plain habitat, and the few caribou there were scattered over inland tussock tundra areas. In the Prudhoe Bay region, no such natural factor affecting caribou calving distribution was apparent. The entire length of each transect covered similar coastal plain habitats with similar runoff conditions. Considerable calving occurred south of the oil field (i.e., more than 24 km from the coast), but very little was noted within it. Comparable data on calving distribution in the years 1978-80 were available only for the Kuparuk and Prudhoe Bay regions (Fig. 3). The more inland distribution at Prudhoe Bay, with few if any calves near the coast in the oil field, occurred in all years. In contrast, calving in the adjacent Kuparuk region extended relatively more inland in wet years (1978 and 1980) but, nevertheless, was skewed toward the coast in all years.

DISCUSSION

Displacement of Calving

Calving distribution may be affected by tradition, chance, or other less tangible factors. Calving in most caribou herds appears to be confined to certain areas which cannot be clearly distinguished from other areas in any systematic fashion (Fleck and Gunn 1982). The Mikkelsen Bay region, for example, appears to be excellent calving habitat, yet it was used much less than the Kuparuk and Canning Delta regions (Table 1). Thus, the possibility that the scarcity of CAH calving in the Prudhoe region was due to mere chance cannot be totally discounted.

Nevertheless, certain natural and man-made features explain most of the variation in density on the CAH calving grounds. Surface runoff conditions probably affect calving distribution among regions, just as snow cover/flooding affects overall use of the coastal plain in different years. Flooding in the Colville Delta certainly reduces availability of calving habitat. The Prudhoe region as a whole, lying in the poorly drained area between the Kuparuk and Sagavanirktok Rivers, may be less suitable habitat than the well-drained Kuparuk and Canning Delta regions. Habitats and runoff conditions within and south of the oil field are similar, however. Thus, habitat features may explain in part the low density of calving in the Prudhoe region as a whole, but not the near absence of calving in the area within 24 km of the coast, essentially all of which is occupied by the Prudhoe Oil Field itself.

Prudhoe Bay is not a small development. It is the largest oil field in North America, with 2,000-5,000 workers, numerous large buildings, gravel roads with heavy traffic (much of it large trucks and other oversize vehicles), 2 busy jet airports, a maze of aboveground pipelines, operating flare fields visible for several kilometers, and more. The oil field is the least used of any region within the coastal plain portion of the CAH calving grounds (Table 1), yet similar habitats immediately to the south continue to be used for calving (Figs. 2 and 3). Caribou densities within the oil field have been consistently low regardless of spring weather patterns. The few calves found within the Prudhoe Oil Field tend to be away from man-made structures, and newborn calves along the road system are rare. Furthermore, cow/calf avoidance of the Prudhoe Oil Field in midsummer has been well documented (Smith and Cameron 1983). Large postcalving aggregations of caribou have been observed moving along the coastline to the east and west of Prudhoe Bay, but none have ever been observed to pass through the oil field (Whitten and Cameron 1983b). That the largest oil field in North America occupies an area nearly devoid of parturient cows would appear to be more than coincidence. The conclusion that the Prudhoe Bay Oil Field has displaced CAH calving is unavoidable.

Effects of Displacement

But what have been the consequences of displacement? The CAH has increased by about 13% per year since 1978 (Whitten and Cameron 1983a). How can a herd forced out of a traditional calving grounds not experience a reduction in productivity and a consequent population decline? If calving grounds are arbitrarily chosen and have no intrinsic survival value, or if their survival value lies in the concentration of calving into a confined area regardless of its environmental or physiographic particulars, then no explanation is needed. However, we feel that calving grounds are important, and offer the following explanations.

First, the CAH has been displaced from only part of its calving grounds, perhaps a part that is relatively unimportant due to poor drainage conditions. Second, suitable alternative high-quality habitat appears to be available for those caribou displaced from Prudhoe Bay. Overall density of CAH caribou on their calving grounds is much lower than the other Arctic caribou herds in Alaska. The CAH and PH calving grounds are roughly equal in area (ca 6,400 km^2), and the WAH calving ground is only about 50% larger, yet these other herds are about 15 and 18 times larger, respectively, than the CAH (based on 1982 population estimates). However, the CAH spends most of the summer on its calving grounds, and some CAH caribou remain on the calving grounds all year. In contrast, the WAH and PH usually remain on their calving grounds for only about 1 month. Thus, individual CAH caribou may exert relatively more pressure on their calving habitat than caribou from the WAH or PH. Nevertheless, the smaller size of the CAH yields much lower effective density on its calving grounds, even when adjusted for time spent there (Table 2).

CONCLUSIONS

Experience with the CAH so far does not answer the question of what happens when caribou are displaced from their calving grounds. Only a small part of the herd has been displaced from a portion of the calving grounds to uncrowded areas already used for calving. CAH calving density remains low compared to other herds, despite a recent population increase. Overcrowding and consequent habitat stress that might result in reduced productivity have not occurred. Nor have caribou been displaced to areas where they might be exposed to increased predation. The CAH must increase substantially, and/or industrial development must expand (and displacement continue) before any serious consequences can reasonably be expected. Both events are in progress.

Concerns over the effect of a development similar to Prudhoe Bay on the calving grounds of the WAH, PH, or other herd are still valid. Although dire consequences are not a foregone conclusion, neither can they be dismissed simply because productivity of the CAH has not declined in response to the development at Prudhoe Bay.

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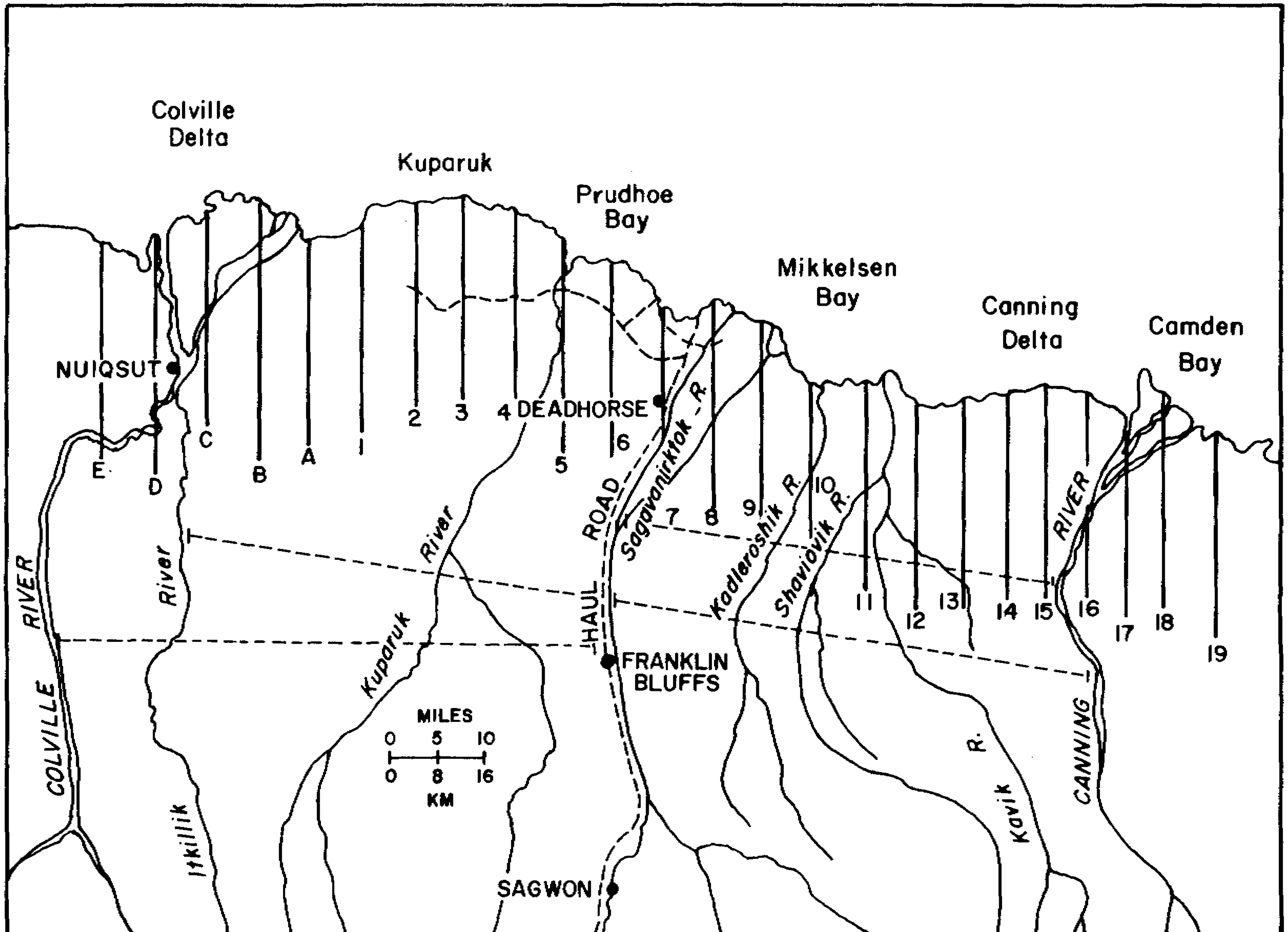

Figure 1. Aerial survey coverage of the Central Arctic Herd calving grounds.
——— helicopter transects, 1978-81; ---- fixed-wing transects, 1981.

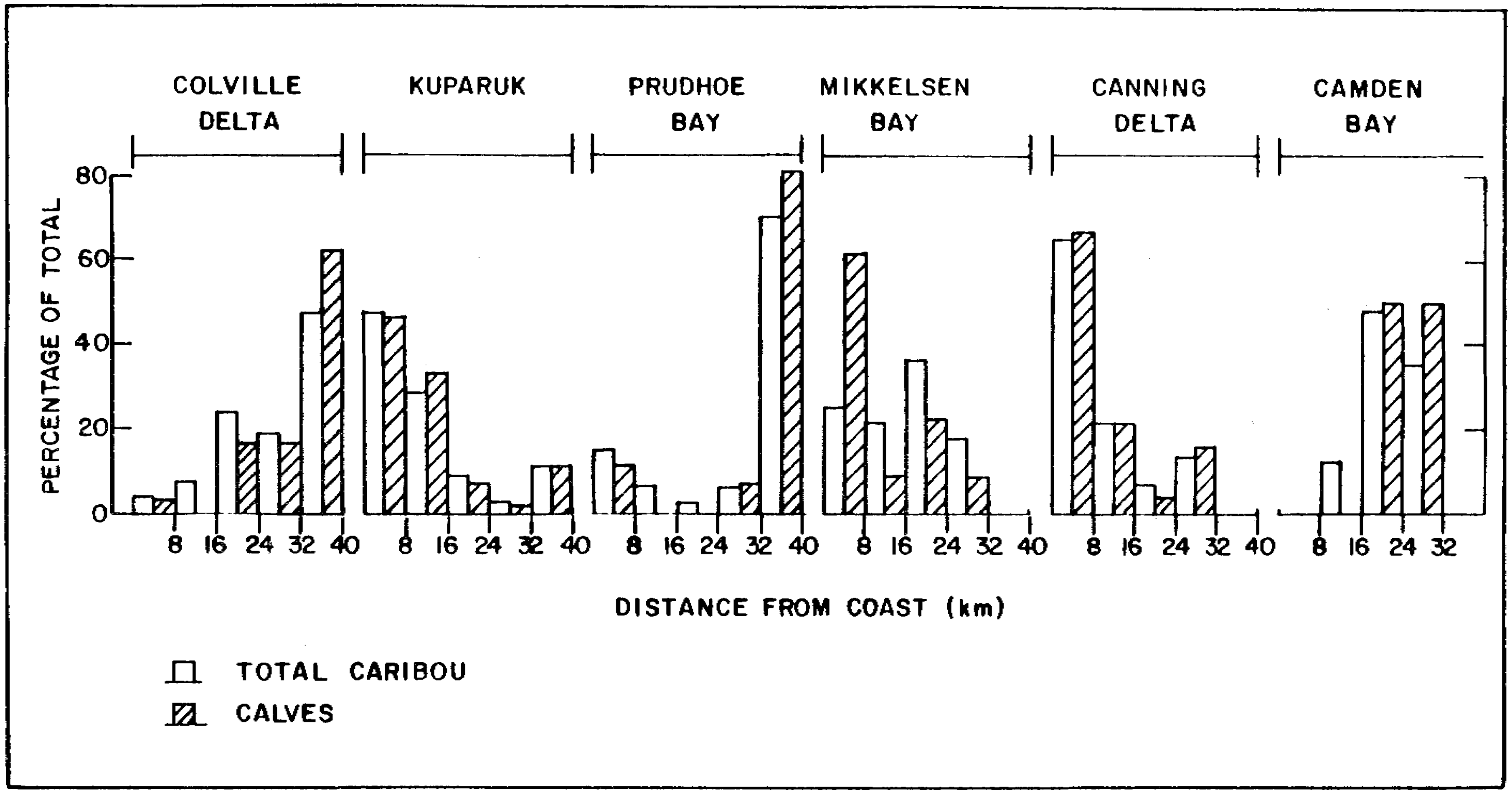

Figure 2. Distribution of caribou in relation to the Arctic Coast on the Central Arctic Herd calving grounds, 1981.

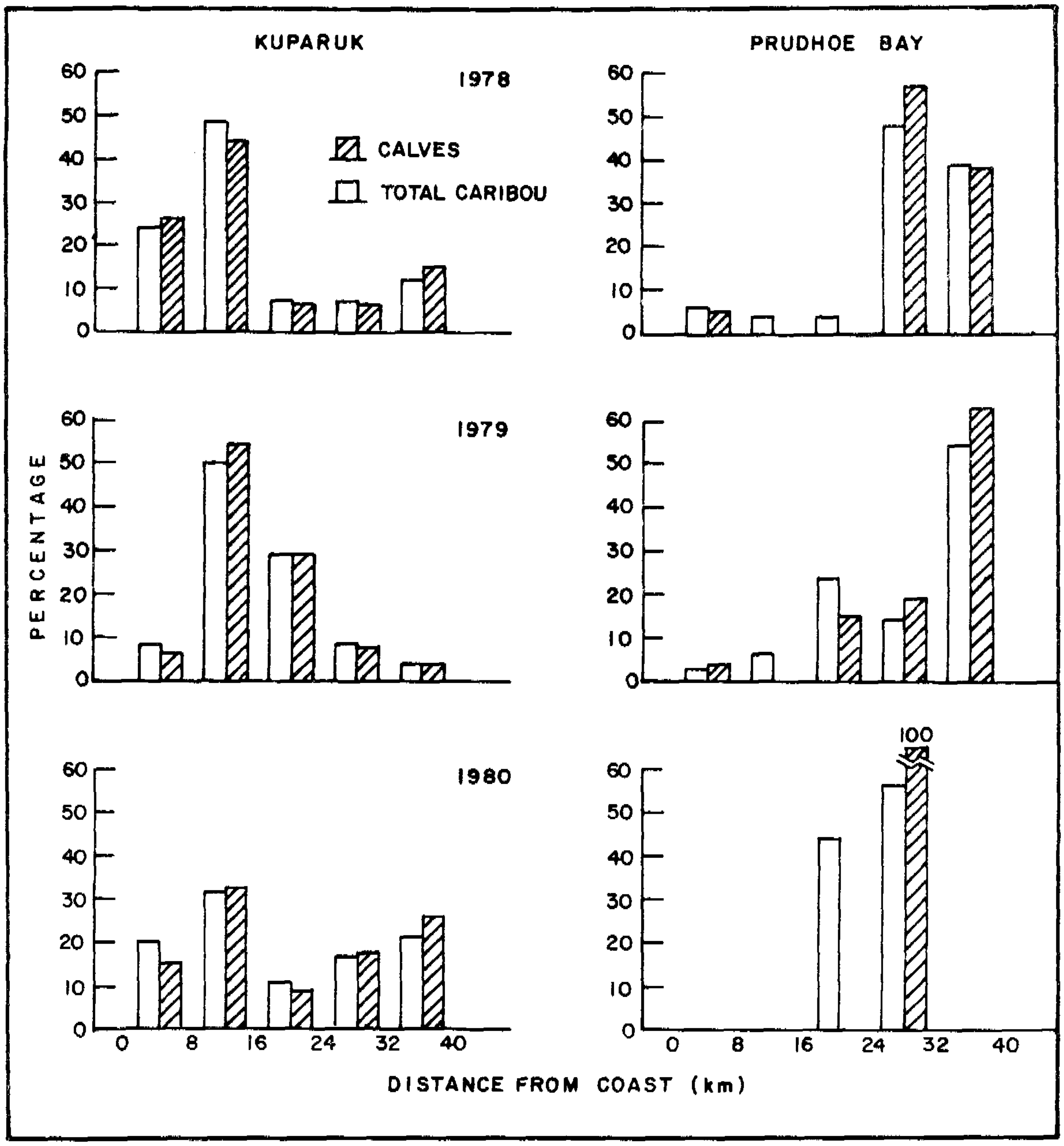

Figure 3. Distribution of calving caribou in relation to the Arctic Coast in the Kuparuk and Prudhoe Bay Regions, 1978-81.

Table 1. Distribution of Central Arctic Herd calving within 24 km of the arctic coast, 1978-81.

Region	Transect	Years surveyed	Mean no. caribou per survey	Mean % calves	Regional density (caribou/km^2)
Colville Delta	E	1	10.0	10	
	D	1	0.0	0	
	C	2	2.5	20	0.13
	B	2	12.0	4	
	A	2	19.5	13	
Kuparuk	1	3	24.6	34	
	2	4	81.5	40	0.90
	3	4	137.5	40	
	4	4	22.5	29	
Prudhoe Bay	5	4	6.8	4	
	6	4	3.0	0	0.06
	7	4	3.5	36	
Mikkelsen Bay	8	4	7.5	47	
	9	4	5.8	17	
	10	4	20.8	30	0.13
	11	4	9.5	3	
	12	4	6.3	28	
Canning Delta	13	4	50.0	39	
	14	2	28.5	40	
	15	2	63.0	42	1.05
	16	2	82.5	45	
	17	1	336.0	46	
Camden Bay	18	1	23.0	30	0.22
	19	1	11.0	9	

Table 2. Densities of caribou on calving grounds of the Central Arctic, Porcupine, and Western Arctic Caribou Herds, based on 1982 populations and historical use patterns.

Herd	Absolute density[a] (caribou/km^2)	Effective density[b] (caribou-mo/km^2)
Central Arctic	1.2	4.7
Porcupine	14.1	23.7
Western Arctic	15.0	15.0

[a] Number of caribou on calving grounds (including calves) divided by area of calving grounds.

[b] Number of caribou using calving grounds in all seasons times months on calving grounds divided by area of calving grounds.

APPENDIX C

Factors Affecting Pipeline Crossing Success of Caribou

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Alaska Department of Fish and Game

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Abstract. Early simulation studies on the Arctic Slope of Alaska showed that caribou would not pass freely beneath elevated pipelines. Our recent observations during summer indicate that crossing success varies with pipeline design, caribou group structure, and a number of environmental stimuli. Effective barriers to caribou movement exist where surface-to-pipe clearance is inadequate for physical passage, or when drifting snow along road/pipeline complexes reduces the effective clearance. Where pipeline elevation is sufficient, the outcome of an encounter is influenced by group size/composition, topography, insect activity, traffic level, and the intensity of local construction, as well as road and/or pipeline configuration. Most crossing attempts of the Kuparuk Pipeline/West Sak Road complex in 1981 and 1982 occurred during moderate or severe insect harassment, and crossing success increased significantly during oestrid fly harassment as compared to mosquito harassment. Crossing success on an individual and a group basis decreased with increasing group size. Present studies are aimed at describing local movements and evaluating the effectiveness of special pipeline crossing structures, but comparing crossing success has been difficult because different criteria for crossing success have been used. Maintaining caribou passage through oil fields requires careful planning based on an assessment of both local and regional movements.

INTRODUCTION

Early studies of simulated pipelines on the Arctic Slope of Alaska indicated that caribou would not pass freely beneath elevated pipelines (Child 1973). Most of the caribou encountering the simulations reversed direction or diverted around the structures. With the increasing complexity of oil pipelines in the vicinity of Prudhoe Bay, many caribou must cross elevated pipelines to reach calving grounds and insect relief habitat, and crossing success has become an important issue.

Some pipelines within the original Prudhoe Bay oil field were placed in rows and elevated only 0.4-1.1 m above the surface, forming an effective barrier to caribou. As a result, permits for pipeline construction now stipulate a minimum surface-to-pipe clearance of 1.5 m, to allow clearance for caribou to pass beneath. Under some circumstances, however, even these pipelines preclude caribou movements. In late spring 1982, for example, drifting snow accumulated beneath the Kuparuk Pipeline (KP) for much of its length, creating an impassable barrier.

Factors influencing crossing success of caribou beneath elevated pipelines include group size/composition, topography, insect activity, traffic levels, and the intensity of local construction, as well as road and/or pipeline configuration (Child 1973, Curatolo and Murphy 1983, Fancy 1983). In this paper we discuss the relative importance of these variables based on observations in the Kuparuk Development Area (KDA).

STUDY AREA

The KDA is located approximately 50 km west of the main industrial complex near Prudhoe Bay. Access to the KDA is via the West Sak Road (WSR), a 32-km extension of the Spine Road (Fig. 1). The WSR was built in winter 1977-78, and within 3 years a construction camp, permanent office/living quarters, oil/gas processing facilities, and an airport were in place at a Central Processing Facilities (CPF-1) pad.

In 1980-81 the Kuparuk Pipeline was constructed between the CPF-1 and the origin of the Trans-Alaska Pipeline, approximately 40 km to the east. The KP is 45 cm in diameter and supported on vertical pilings at 20 m intervals. For more than half its length, the KP is routed along the WSR; one production "flow line" is colocated with the KP and a second parallels the WSR between a well pad and the CPF (Fig. 1). Surface-to-pipe clearance of all elevated pipelines is a minimum of 1.5 m, increasing to 2 m or more where rivers and creeks are traversed.

METHODS

The WSR (Fig. 1) was surveyed systematically twice-daily by pickup truck during late spring and summer 1981-82. This survey transect totaled 32 km, including 10 km of road-only and 22 km of a road/pipeline complex. For each caribou sighting, we recorded time, location along the WSR, distance from the WSR, movements, and local traffic and construction activity. Insect activity was determined using correlations based on temperature and wind velocity (White et al. 1975) and confirmed by subjective estimates of local insect levels. Group composition was generally recorded as the numbers of adults and calves.

Groups interacting with roads and/or pipelines were observed until the termination of the initial crossing episode; that is, until groups crossed, moved away from the road, bedded down, began a feeding bout, or otherwise indicated they were not soon likely to attempt another crossing. Group movements and activities were recorded, and the survey was continued. After completing the standard survey, we returned to reobserve groups that had not crossed and noted any further interactions with the road and/or pipeline. Most groups were observed until they crossed, moved away from the road/pipeline, or otherwise abandoned the crossing attempt.

RESULTS

In 1981, we observed 14,148 caribou in 1,120 groups along the WSR during 86 surveys, and in 1982, 9,523 caribou in 776 groups were seen during 95 surveys (Table 1). The between-year difference in numbers of caribou observed may be a result of sampling variability and/or differences in survey schedules, although a similar decrease was noted by Curatolo and Murphy (1983) at a study site adjacent to the WSR. Calf percentages for each group size category were similar to the corresponding annual means, except for groups with fewer than 11 individuals. However, in 1981, the mean calf percentage (17.6%) was substantially lower than that obtained during composition counts of postcalving aggregations conducted in conjunction with the 1981 census (27%) (Whitten and Cameron 1983). No corresponding regional data are available for 1982.

The majority of caribou were in large (>40 caribou) groups (Table 1). Less than 5% of the groups observed in 1981 composed 54% of all caribou seen. Similarly, in 1982 less than 8% of the groups accounted for more than 65% of the caribou seen. The percentages of groups and individuals within each group size category are similar for the 2 years.

The frequency distribution of crossing attempts by groups and individuals was also similar in both years (Table 2). In 1981 and 1982, 92 and 91%, respectively, of caribou attempting to cross the road or road/pipeline were in groups of >40 individuals. Because most of the large groups were seen during periods of expected movement (i.e., during or immediately after a bout of insect harassment), they contributed disproportionately to the number of attempted crossings observed. In general, large groups remained in the immediate vicinity of the pipeline longer than small groups and were, therefore, more likely to be seen.

In 1982, crossing success of individuals decreased with increasing group size (Table 2). Although a similar trend was not apparent in 1981, it should be noted that individuals contributing to the 20% success rate among groups >100 were part of a single group of 917 that crossed only after numerous unsuccessful attempts 5-6 hours following initial contact with the road/pipeline complex. Crossings delayed to this extent cannot be considered truly "successful." Retaining only data on the earlier observations of crossing attempts by this group yields a success rate that approaches zero. When considered in this manner, both 1981 and 1982 data sets are consistent with our impressions that large groups commonly experienced difficulty crossing the road/pipeline complex.

Fewer caribou were seen trying to cross the WSR where it is separated from the pipeline in 1982 (Table 3). The difference cannot be attributed to a specific change, such as increased local traffic or construction, and is probably related to variations in the chance observation of crossing events. The percentage of groups successfully crossing the road was similar in both years, but the percentage of successful individuals was considerably lower in 1981 than in 1982 (Table 3). This difference can be attributed to the reactions of a single group. On 27 July 1981 a large, insect-harassed group of 636 caribou moved northward in the Kuparuk River floodplain and encountered heavy local traffic and construction activity on the WSR. The group remained south of the road for 2 hours and, when insect activity subsequently abated, it dispersed inland. This observation alone decreased the calculated crossing success from 93.4 to 33.4%.

Patterns of attempted and successful crossings of the road/pipeline complex varied considerably within and between years (Table 4). In 1982, fewer total caribou were seen and fewer crossing attempts were recorded during the precalving and calving periods than during any other period in either year; parturient cows apparently moved into calving areas north of the WSR from the west and do not often cross the WSR itself (W. Smith and M. Robus, unpubl. data). In contrast, numerous crossing attempts were observed during the mosquito season in both years. Greater contact with the road/pipeline is presumably a result of frequent movements through the area, between insect relief habitat along the coast and inland feeding areas (Child 1973, White et al. 1975, Cameron and Whitten 1980, Curatolo and Murphy 1983).

The type of insect harassment is apparently related to crossing activities of caribou. Average group size and the number of caribou attempting to cross were an order of magnitude greater during the mosquito season than during the oestrid fly period (Table 4). In both years the percentage of groups successfully crossing the road/pipeline complex was significantly higher during the oestrid fly season than during the mosquito period ($P < 0.001$, Chi-square, 1df). This may be attributable to the smaller size of groups and/or different behavioral reactions to the insect vector. We could not detect any corresponding changes in abiotic factors such as weather patterns, local traffic, or construction activity.

During the oestrid fly season in 1982, both individuals and groups were significantly more successful ($P < 0.001$, Chi-square, 1 df) in crossing the road/pipeline than during the same period in 1981.

The relatively low crossing success of individuals during the oestrid fly season in 1981 can be attributed to the responses of a single group of 58, seen on 25 July. Although both mosquitoes and oestrid flies were present in substantial numbers, the large group size suggests that the dominant response was to mosquitoes. If this group is deleted, individual success increases to 65%.

The effects of insects on local caribou movements are evident if only the results of those surveys conducted during moderate or severe insect harassment are considered. In 1981, we saw 30.7% of the caribou during surveys when insect harassment was moderate or severe, but these groups made 93.2% of the crossing attempts. Similarly, in 1982, 52.3% of the caribou observed during moderate or severe insect levels accounted for 97.2% of attempted crossings recorded.

DISCUSSION

During warm, windless days, harassment by mosquitoes drives caribou from inland feeding areas to insect relief areas along the coast and on river deltas. Insect harassment ceases with the onset of high winds and/or lower temperatures, and caribou move inland to feed (White et al. 1975). These insect-induced movements bring caribou into periodic contact with roads and pipelines within the KDA.

Caribou respond differently to oestrid flies (Curatolo 1975, Roby 1978, Curatolo and Murphy 1983). Group size is smaller, movements are less directional, and inland insect relief areas, including roads and gravel pads, are used more frequently. Our results indicate that, when oestrid flies are present, fewer caribou use habitats adjacent to the WSR, but their ability to negotiate roads and pipelines increases markedly.

Comparing data on the interactions of caribou with linear structures has been difficult because of differences in experimental design and interpretation of data. Child (1973) and Fancy (1983) reported on reactions of caribou to short, isolated structures east of Prudhoe Bay (Table 5). Both authors used 100% crossing by individuals within a group as the criterion for success. However, Fancy's study area included an adjacent road, and he evaluated crossing success based only on the first structure of the road/pipeline encountered by caribou. Fancy's recalculations of crossing success based on number of individuals (Fancy, pers. commun.) are substantially lower than group success (Table 5).

Curatolo and Murphy (1983), in evaluating crossing success of caribou at sites adjacent to the Kuparuk Pipeline/WSR complex, used 50% of the individuals within a group as the criterion for crossing success. We adopted the same criterion for our evaluation of data from the 22-km Kuparuk Pipeline/WSR, coverage that includes their study site. Curatolo and Murphy recorded data continuously for groups within their study area, which could explain in part the higher crossing success of groups they reported (Table 5). By comparison, we completed our standard survey after the initial sighting and later returned to reobserve crossing groups. In addition, larger groups were easier to identify and relocate, and therefore, our evaluation of eventual crossing success may be biased toward large groups which have a lower success rate.

In comparing all 4 studies, the most obvious consistency is the inability of large groups of caribou to cross elevated pipelines or pipeline simulations (Table 5). Although the criteria for crossing success differed, only 1 of an aggregate of 27 groups >100 (>50 for Child 1973) was successful. Reported crossing success of individuals ranged from 23 to 49.9%. Our success rates are significantly lower ($\underline{P} \leq 0.001$, Chi-square, 1 df) because caribou observed during our survey included groups that had already crossed the complex, were using local habitats during bouts of feeding or lying, or were avoiding the pipeline and not trying to cross. For example, large southbound groups of caribou were seen paralleling the road/pipeline complex after weather changes that depressed mosquito activity. Instead of directly crossing the WSR road to the south, most of these caribou moved west, remaining 1-2 km north of the WSR until they had skirted the CPF-1 (Fig. 1).

The difference between evaluating crossing success on a group or individual basis is evident from data obtained during the mosquito season in 1981 (Table 4). Although crossing success of groups was zero, 17.8% of the individuals from these groups crossed the road/pipeline complex. In other instances, however, group crossing success was substantially higher than for individuals because large groups (i.e., >100) tend to be less successful.

Crossing success can be considered a social response or a functional response. Given the importance of social interactions during migrations and calving (Miller et al. 1972, Bergerud 1974), an evaluation on the basis of intact groups would be most logical. However, during the insect season social bonds are ephemeral; group size may change daily and drastically depending on weather and type of insect harassment. Therefore, a functional response, i.e., the number of caribou that successfully cross the barrier, might be more appropriate. Unfortunately, little is known of the survival value of social interactions during large mosquito-induced aggregations and during the subsequent dispersal into smaller groups in response to oestrid harassment. Consequently, the long-term effects of even minor disruptions of social bonds and group cohesion during crossing attempts are difficult to evaluate.

When one group was removed from calculations of road crossing success (see Results), the results indicated that >90% of individuals and groups successfully crossed the WSR in 1981 and 1982. Success rates were significantly greater for roads than for road/pipeline complexes (P < 0.001, Chi-square, 1df) (Tables 3, 4; Curatolo and Murphy 1983). The one group was deleted because unusually heavy local traffic deterred the group from crossing. Although it is apparent that traffic influences crossing success, the amount of traffic or local construction that affects local caribou movements is unknown.

All authors but Fancy (1983) had sections of buried pipe or ramp crossings as components of their study sites. The data of Child (1973) and Curatolo and Murphy (1983) indicate a definite preference for these structures as crossing sites. However, our limited observations suggest that buried sites on the WSR are not used preferentially by caribou. Unfortunately, buried sections of pipeline along the WSR were not constructed specifically to accommodate caribou; consequently, these buried sections are only 22 m long, are associated with road traffic, and, in 2 instances, the openings are partially obscured from view.

Curatolo and Murphy's (1983) results and our unpublished data also indicate that one particular buried section of pipeline separated from vehicular traffic is highly selected by caribou. However, this section is 50% wider than the next widest buried section and the conformation of the opening is different from other buried crossings. Consequently, it is impossible to identify either the absence of associated disturbing stimuli or differences in the construction design as the factor that enhances its selection and successful use.

Although buried sections of pipeline can be preferentially selected by caribou, little is known of the importance of design details. Width, steepness of approach slopes, funneling structures, and viewability of the opening may greatly affect the use of a particular buried section. More importantly, since most pipelines are associated with roads, the effect of different amounts of traffic must be investigated.

Increasing the effectiveness of single crossing sites and isolated sections of pipelines is but one step toward developing a strategy to maximize access of caribou to critical habitats. Although permits for pipeline construction stipulate minimum clearances and provide for some buried crossings, the placement of new roads, pipelines, and other oil-related facilities all affect the use of existing sites to some extent. To be most effective, specific crossing sites must be integrated into a regional plan to preserve intact movement corridors through single and multiple oil field complexes.

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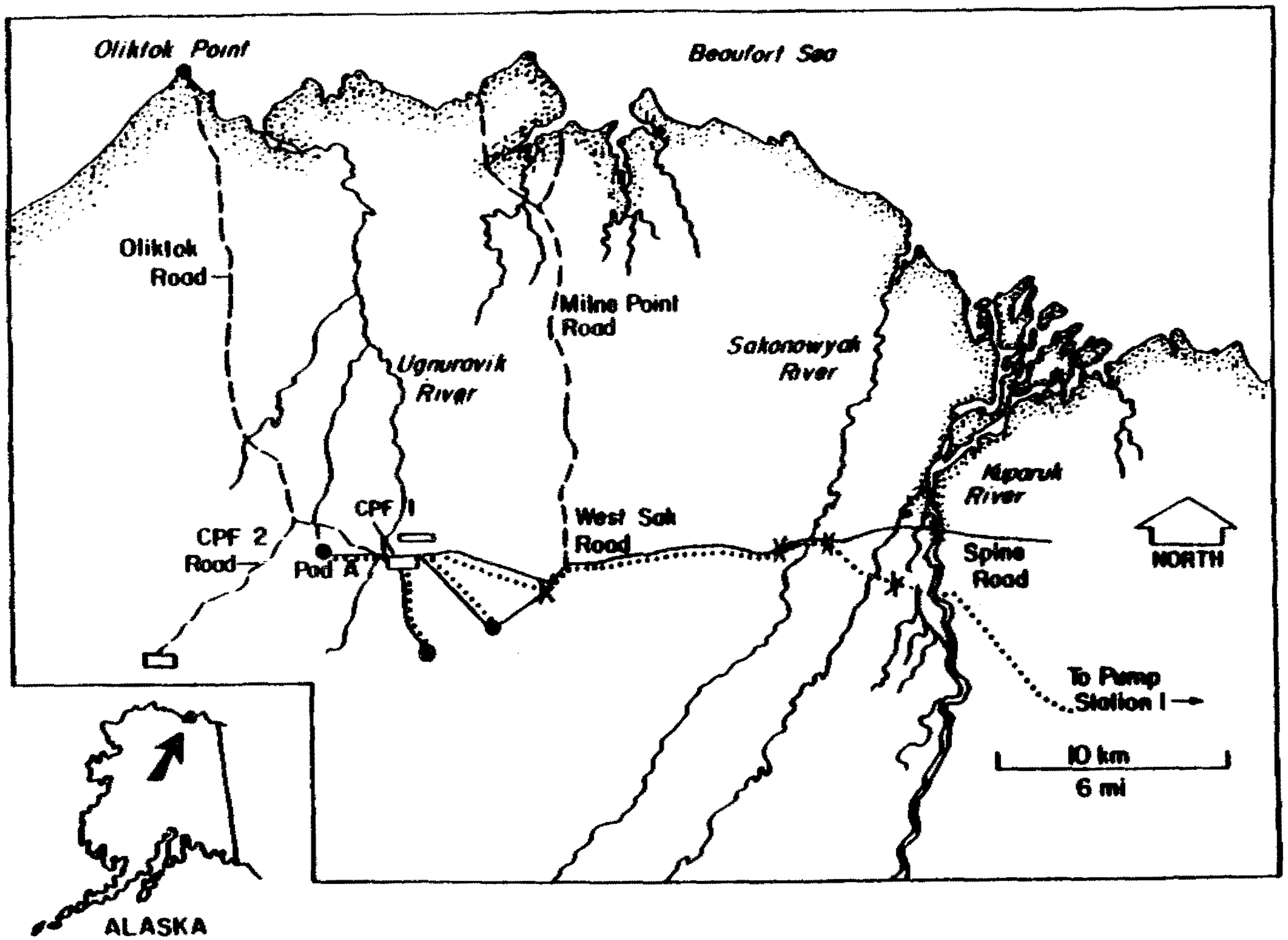

Fig. 1. Roads, pipelines, and facilities within the Kuparuk Development Area.

Key: _____ roads as of 1981; ----- roads added in 1982; ● drill pad; ..... above-ground pipeline; X buried pipeline.

Table 1. Group size and calf percentages among caribou observed along the West Sak Road, Kuparuk Development Area, Alaska, late spring and summer 1981-82. Numbers in parentheses are percentages of the total within each group size category.

Group size	1981 No. of groups		1981 No. of caribou		1981 % calves	1982 No. of groups		1982 No. of caribou		1982 % calves
1	260	(23.2)	260	(1.8)	1.2	196	(25.3)	196	(2.1)	1.5
2-10	629	(56.2)	2,701	(19.1)	10.4	451	(58.1)	1,622	(17.0)	11.1
11-40	176	(15.7)	3,543	(25.0)	19.0	70	(9.0)	1,490	(15.6)	16.6
41-100	38	(3.4)	2,357	(16.7)	19.6	38	(4.9)	2,294	(24.1)	19.3
>100	17	(1.5)	5,287	(37.4)	22.8	21	(2.7)	3,921	(41.2)	16.4
Totals	1,120	(100.0)	14,148	(100.0)	17.6	776	(100.0)	9,523	(100.0)	15.6

Table 2. Distribution of crossing attempts and successful crossings of the road/pipeline in relation to group size, Kuparuk Development Area, late spring-summer 1981-82.

Year	Group size	Crossing attempts[a] groups	Crossing attempts[a] individuals	Successful crossings[b] groups	Successful crossings[b] individuals
1981	1	21	<1	50	50
	2-10	57	5	25	16
	11-40	7	3	0	0
	41-100	11	16	0	9
	>100	4	76	0	20
		100	100		
1982	1	34	1	62	62
	2-10	45	5	72	67
	11-40	5	3	50	28
	41-100	8	18	0	7
	>100	8	73	0	3
		100	100		

[a] Expressed as percentages of total groups or individuals for each group size category.

[b] Expressed as a percentage of total groups or individuals that attempted to cross within each category.

Table 3. Attempted and successful crossing of the West Sak Road, late spring-summer, 1981-82.

	No. of crossing attempts		% Successful[a]	
	Groups	Individuals	Groups	Individuals
1981	22	989	90.9	33.4
1982	14	237	92.9	99.6

[a] Expressed as a percentage of total groups or individuals that attempted to cross.

Table 4. Comparative crossing success of caribou encountering road/pipe complexes along the West Sak Road.

	Total caribou observed			Crossing Attempts			% attempts successful	
	No. of groups	No. of caribou	% calves	No. of groups	No. of caribou	Avg. group size	groups[a]	indiv.
1981								
Postcalving (15 Jun-30 Jun)	459	2,497	11.8	3	15	5.0	0	0
Mosquito (1 Jul-19 Jul)	377	7,400	19.1	12	1,119	93.3	0	17.8
Oestrid[b] (20 Jul-7 Aug)	284	4,251	19.3	13	78	6.0	61.5	16.7
				28	1,212			
1982								
Precalving (10 May-26 May)	136	412	17.5[c]	0	0	--	--	--
Calving (1 Jun-20 Jun)	118	310	1.6	1	4	4.0	100.0	100.0
Mosquito (1 Jul-23 Jul)	310	7,595	15.4	23	1,045	45.4	34.8	5.4
Oestrid[b] (24 Jul-5 Aug)	212	1,206	19.6	14	36	2.6	85.7	86.1
				38	1,085			

[a] The group is considered to cross successfully if 50% of the group crossed the road or road/pipeline.
[b] Start of oestrid season from Curatolo and Murphy (1983).
[c] 1981 cohort.

Table 5. Summary of data on the reactions of caribou to lineal structures near Prudhoe Bay, Alaska.

Child (1973). Pipe simulation[a].

Years	# of groups	# of caribou	% of individual reactions to simulation: Crossing: Beneath	Crossing: Underpass	Crossing: Ramp	Detoured	Reversed	Groups >51 individuals
1971, 1972	110	5,599	0.7	4.7	17.7	42.4	34.4	0 of 15

Comment: Of 23% that successfully crossed simulation, 76% used 2 ramps that totaled 22% of total length.

Fancy (1983). Road/Pipe[b].

Year	# of groups	# of caribou	Reactions to road/pipe	Crossed first structure	Detoured	Reversed
1981	99	1,035	% groups (100% success)	70.7	19.2	10.1
			% individuals	49.9	46.3	5.8
			groups >100 individual caribou	0	3	0

Comment: Impossible to determine crossing success of the road/pipeline complex because only the first structure encountered was considered.

Curatolo[c] and Murphy (1983). Road/Pipe[c].

Year	# of groups	# of caribou	% of groups crossing (50% success)	% individuals crossing	Groups >100 individual (50% success)
1981	113	1,203	41	34	1 of 3
1982	36	769	53	31	0 of 2

Comment: 6% of individuals crossed buried sections totaling <1% of total length.

Table 5. (Continued)

Smith and Cameron[d]. Road/Pipe

Year	# of groups	# of caribou	% of groups crossing (50% success)	% individuals crossing	Groups >100 individual (50% success)
1981	707	8,777	1.1	2.4	0 of 1
1982	490	5,266	4.3	1.7	0 of 3

[a] Simulation, 3.1 km long, 1.3 m high, 5m above ground; 2 ramps, 22.9 and 30.5 m wide; 4 underpasses: 3@ 30.5 m wide x 2.3 m high, and 1 @ 45.7 wide x 1.2 m high.

[b] Road/pipe complex, L shaped and 4.8 km in length; no specialized underpasses or ramps; minimum surface-to-pipe clearance is 1.5 m, average clearance is ca. 2.1 m.

[c] Road/pipe complex, 2.4 km in length; two buried pipe sections, 21 m wide; minimum surface-to-pipe clearance is 1.5 m, average clearance is ca. 2.1 m.

[d] Road/pipe complex, ca. 21 km in length; 4 buried cx, 21-25 m wide; minimum surface-to-pipe clearance is 1.5 meters.