The Effects of Pipelines, Roads, and Traffic on the Movements of Caribou, *Rangifer tarandus*

JAMES A. CURATOLO and STEPHEN M. MURPHY

Alaska Biological Research, P.O. Box 81934, Fairbanks, Alaska 99708

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The frequency of Caribou, *Rangifer tarandus*, crossings of roads, pipelines, and pipelines along roads was studied in the Prudhoe Bay and Kuparuk oil fields on the Arctic Coastal Plain of Alaska. Caribou crossed an elevated pipeline or a road with a frequency similar to the control. It was only where a pipeline paralleled a road with traffic, that crossing frequencies were significantly less than expected (30% versus 66%). It is postulated that vehicles act in a synergistic fashion with a pipeline to produce a negative stimulus that results in decreased crossing frequency. Caribou crossing under elevated pipelines did not select for particular pipe heights within the range studied (152–432 cm). Caribou did select buried sections of pipeline as crossing sites more often than expected.

Key Words: Caribou, *Rangifer tarandus*, pipeline, road, oil development, Alaska.

The Central Arctic Caribou (*Rangifer tarandus*) Herd (CAH) ranges on the north slope of the Brooks Range between the Canning and Colville rivers (Cameron and Whitten 1979). The majority of the CAH remain on the Arctic Coastal Plain during summer, where they travel to the coast during periods of mosquito (*Aedes* spp.) harassment and move inland during mosquito-free periods (White et al. 1975). This movement pattern regularly brings the CAH into areas of oil development.

The most recent expansion of oil development on the North Slope of Alaska has been in the Kuparuk River Oilfield and western end of the Prudhoe Bay Oilfield, approximately 40 km west of Prudhoe Bay and within the summer range of the CAH. Development has been proceeding rapidly there since 1978 and has included construction of the Kuparuk Pipeline, a 40 km, east-west oriented, 40 cm diameter elevated pipeline. This pipeline and an expanding network of feeder pipelines intersect the summer movements of the CAH.

In 1980 the State of Alaska required that the minimum pipeline height be 1.5 m in the Kuparuk River Oilfield to allow for free passage of Caribou. At that time no quantitative data were available to substantiate the effectiveness of this stipulation. In 1981 studies were initiated by the oil industry to determine if this criterion was an effective mitigative measure and to gain insight into the reactions of Caribou to pipelines for future oilfield planning.

This report discusses the frequency that Caribou crossed pipelines and roads, whether pipeline height affected selection of crossing sites, and whether ramps (i.e. buried sections of pipeline) were preferentially used as crossing sites.

Study Area and Methods

This study was conducted near the Kuparuk and Ugnuravik rivers in Alaska, 10–20 km south of the Beaufort Sea coast (Figure 1). This region, dominated by wet sedge (*Carex* spp.) tundra and nearly flat except for pingos, river banks, and man-made structures, is typical of the Arctic Coastal Plain. Geobotanical aspects of the region are described by Walker et al. (1980).

Seven study sites ranging in size from 180 to 275 hectares (Figure 1) were used between 1981 and 1983, although not all study sites were used every year. Site 1 was used in 1981 and 1982; its northern border was an elevated pipeline (range 152–279 cm) adjacent to a road with traffic. Site 2 was used in 1983, and its northern border also consisted of an elevated pipeline (range 119–229 cm) adjacent to a road with traffic. Site 3 was used in 1981 through 1983; its northern border was an elevated pipeline (152–432 cm) adjacent to a construction pad with no traffic. Site 4 was used in 1983, and had as its northern border a high elevated pipeline (>650 cm) with no adjacent road. Site 5 was used in 1982 and was bounded on the north by a road with traffic. Sites 6 and 7 were used in 1981 and 1982; the northern borders of these sites were hypothetical pipelines consisting of a line of orange stakes placed at 50 m intervals. Three of the study sites (Sites 1–3) also had ramps (sections of buried pipe that were 50, 30, and 20 m wide, respectively).

Data were collected during the insect season: 2 July to 5 August 1981, 29 June to 1 August 1982, and 25 June to 29 July 1983. Variable-power spotting scopes and binoculars were used to observe Caribou from 3 m high towers. Observation times were not set; rather an effort was made to observe Caribou,

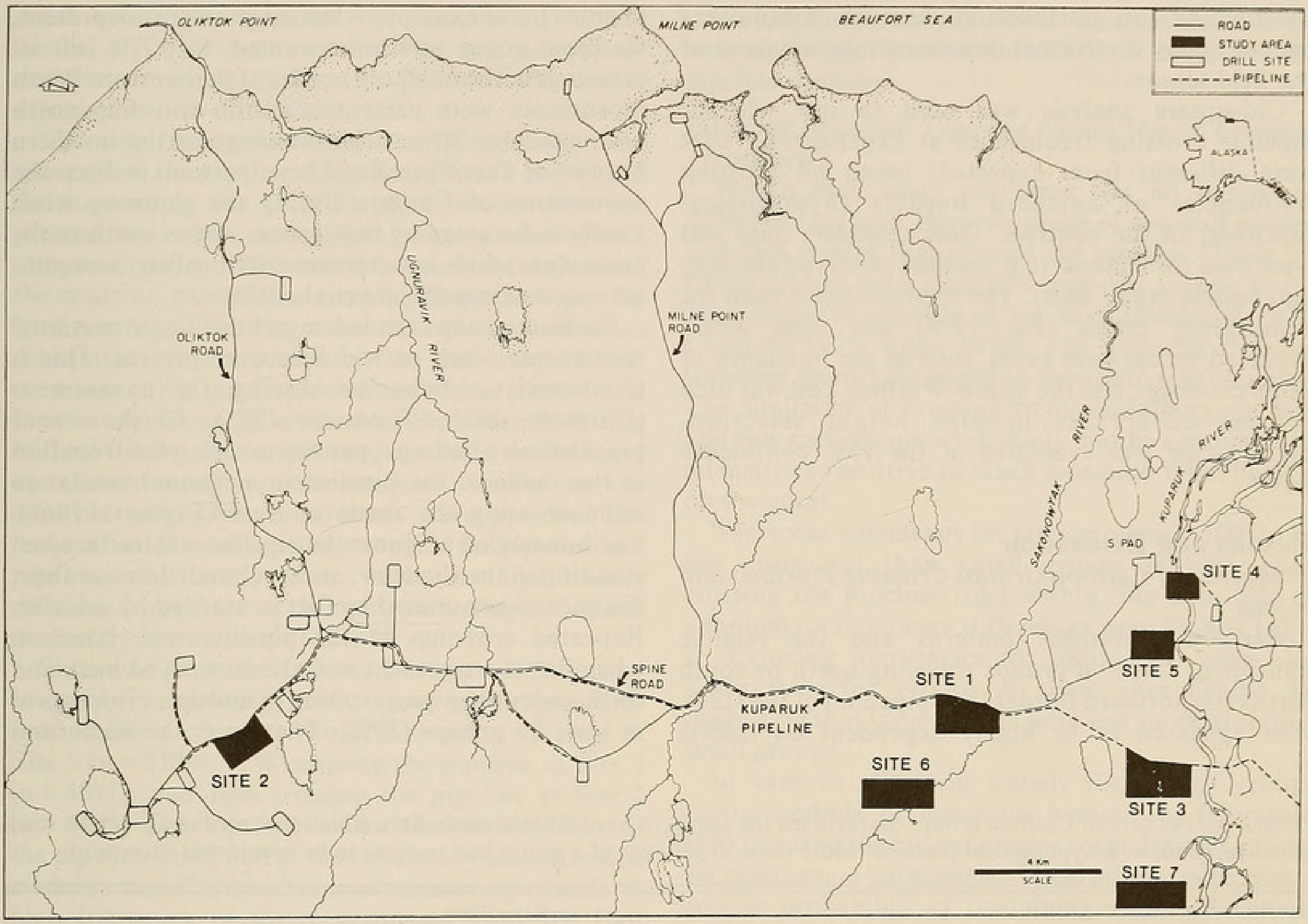

FIGURE 1. Location of study areas near the Kuparuk and Ugnuravik rivers in Alaska. Sites 1 and 2 are bounded by a pipeline adjacent to a haul road with traffic, site 3 is bounded by a pipeline adjacent to a construction pad with no traffic, site 4 is bounded by a pipeline, site 5 includes a haul road with traffic, and sites 6 and 7 are controls.

rather an effort was made to observe Caribou when they were in the vicinity and for as long as they were present. Data collected included group size, group composition (cow, calf, yearling, bull), route of travel through the study site, reactions of Caribou while crossing a road or pipeline, and number of vehicles in the study site. In addition, 10-minute point-in-time scans were taken of air temperature, wind speed, and insect presence. The presence (moderate/severe) or absence (none/light) of mosquitoes was determined using the relationship between mosquito activity and temperature and wind speed developed by White et al. (1975). The presence of oestrid flies was determined by observation of stereotyped behavioral responses to oestrids exhibited by Caribou, such as wild running (Curatolo 1975) and rigid standing (Espmark 1968) or by direct observations of flies. A severe reaction was recorded when caribou moved away from a disturbance at a trot or run. Severe reactions were distinguishable from ongoing activities, such as running induced by mosquitoes. Crossings of groups rather than individuals were selected for analyses because groups generally behaved as a cohesive unit. Crossing frequencies of individuals are also included for comparison.

Pipeline height was measured from the bottom of the pipe to the ground at each vertical support member (VSM). Caribou crossing between any two VSMs were recorded as having crossed under the pipeline at the mean height of those VSMs. All VSMs were numbered to locate crossing sites of Caribou. A Caribou group was arbitrarily considered to have crossed a pipeline successfully when >50% of the group crossed.

Observations of Caribou crossing pipelines and/or roads were classified according to the presence or absence of mosquitoes and oestrid flies to determine the effect these insects have on crossing frequency. Crossings by Caribou were also classified as either southbound or northbound because mosquitoes caused highly directional movements during most of the field season.

Chi-square analysis was used to test whether pipeline crossing frequencies at experimental sites were different from expected, based on crossing frequencies of northern borders (hypothetical pipelines) in the controls. Only complete data sets were used for analysis (e.g. caribou observed entering and exiting study sites). The log-likelihood ratio for contingency tables (Zar 1974) was used where expected values were small, such as the frequency of ramp crossings; and the Mann-Whitney Test was used to test differences in pipe height selection. Significance was evaluated at the 95% confidence level.

Results and Discussion

Frequency of Caribou Groups Crossing Pipelines and Roads

Caribou movement patterns and the relative number of Caribou groups traveling north or south across the northern border (e.g. pipeline) of the study sites appeared to be highly dependent on insects (Table 1). For example, when insects were not present, Caribou going south accounted for 77% of all crossings of the northern border of the controls. When mosquitoes were present, Caribou traveling north accounted for 80% of all crossings of the northern border of the controls. These patterns reflect the movements of Caribou during the summer, when Caribou, harassed by mosquitoes, travel north to the coast for relief and return south when mosquito activity declines (White et al. 1975).

Caribou groups tended to exhibit non-directional movements when oestrid flies were present. This is characteristic behavior during fly harassment (Curatolo 1975; Thomson 1971). Caribou near pipelines also had a propensity to seek relief from flies in the shade of the pipeline in a manner similar to reindeer using the shade of trees (Espmark 1968). Caribou tended to ignore the pipeline and traffic when standing in the shade or, at most, tended to run short distances when chased by flies or startled by vehicles. Repeated crossings of the pipeline were common when flies were present as Caribou weaved back and forth under the pipe, resulting in multiple crossings of at least 37 groups (39%). Therefore, the north and

TABLE 1. Per cent of Caribou groups that crossed the northern border of the study sites, which consisted of a pipeline, road, pipeline/road, or a hypothetical pipeline. More than 50 per cent of a group had to cross to be considered successful.

	Structure					
Insects Present	Pipeline/ Road Site 1	Pipeline/ Road Site 2	Pipeline Site 3	Pipeline Site 4	Road Site 5	Control Sites 6,7
None						
Total number groups	43	18	180	21	24	75
Southbound	16%*	11%*	61%	38%	42%	51%
Northbound	21%	22%	14%	14%	4%	16%
Total crossings	37%*	33%*	75%	52%	46%	66%
Mosquitoes						
Total number groups	45	9	118	23	27	61
Southbound	2%*	0	10%	0	0*	13%
Northbound	29%*	0*	58%	65%	100%*	51%
Total crossings	31%*	0*	68%	65%	100%*	64%
Oestrid Flies						
Total number groups	24	17	55	—	—	54
Southbound	54%	6%	9%	—	—	11%
Northbound	25%	35%	62%	—	—	56%
Total crossings	79%	41%	71%	—	—	67%
Overall						
Total number groups	112	44	353	44	51	190
Total crossings	44%*	30%*	72%	59%	75%	66%
Total number individuals	2014	1151	9846	2834	3325	2742
Total crossings	30%	5%	72%	57%	78%	61%
Traffic level (vehicles/hour)	moderate (15)	high (30)	very light (<0.1)	none (0)	moderate (15)	none (0)

*Indicates crossings significantly different from controls; only total crossings were tested for oestrid flies.

south crossing frequencies were not tested for the oestrid fly data because they did not adequately describe crossings during this period; most movements were non-directional.

Crossing frequencies similar to the controls were observed at the pipeline study sites (Sites 3 and 4) and the road study site (Site 5) when insects were not present and when mosquitoes were present. There were no significant differences between these sites and the controls, except that crossing frequency over the road was significantly greater than the control when mosquitoes were present. On the other hand, crossings at the pipeline/road study sites (Sites 1 and 2) were significantly lower than the controls during both of these periods, and the pattern of northbound and southbound movements were similar to the controls only when mosquitoes were present. The frequencies of total crossings at all of the pipeline and pipeline/road study sites were not significantly different from those of the controls during periods of oestrid fly harassment (Table 1).

Sixty-two per cent of the Caribou (n = 262) reacted severely (i.e. running) when crossing the pipeline/road at Site 1 compared to 47% crossing the road at Site 5 (n = 5106), 12% crossing the pipeline at Site 3 (n = 4371), and 10% crossing the pipeline at Site 4 (n = 4453). The high frequencies of severe reactions at the pipeline/road and at the road study areas provide evidence that Caribou respond to moving stimuli. A high frequency of severe responses to traffic (not associated with a pipeline) was also observed by Horesji (1981). However, because traffic usually is a transient stimulus, Caribou movements are not necessarily affected when no other structures are present.

We attribute the lower crossing frequency at the pipeline/road sites to the combination of vehicular traffic and a pipeline. Indeed, crossing frequency was lowest where traffic adjacent to an elevated pipeline was highest (1 vehicle every 1.9 minutes at Site 2 versus 1 vehicle every 3.9 minutes at Site 1). These observations may be best interpreted in terms of inherent behavioral traits of Caribou. Caribou evolved in open habitats with wolves as their major predator (Bergerud 1974). Thus, Caribou tend to avoid or be more alert in habitats that can conceal a predator (Curatolo 1975).

It seems that the frequency of traffic along a pipeline is important because Caribou must have sufficient time between vehicle encounters to successfully cross both the pipeline and the road. As Caribou approach an elevated pipeline, they usually hesitate up to 10 minutes before crossing, whether or not vehicles are present. A passing vehicle usually causes Caribou to retreat from the pipeline or, at least interrupts their attempt to cross. Thus, as traffic levels increase, opportunities for Caribou to cross the pipeline decrease.

Influence of Group Type and Group Size on Crossing Frequencies

Within each study site there was no significant difference between the percentage of cow-calf groups and bull groups that crossed the pipeline (Table 2). Other studies have identified cow-calf groups as the most sensitive segment of the herd (Bergerud 1974; Curatolo 1975; Roby 1978). The Kuparuk Pipeline traverses important routes to mosquito relief habitat. The similarity of crossing frequencies between bull and cow-calf groups in our study may be a result of the intensity of the drive to reach mosquito relief habitat on the coast.

There was a tendency for large groups (> 100) to be less successful than small groups (< 100) when crossing the pipeline/road within Site 1 or Site 2, although no significant differences were found (Table 2). Crossing frequencies for individuals were also lower than for groups at these sites (Table 1), suggesting that large groups were less successful than small groups.

In summer, Caribou usually form large groups during periods of mosquito harassment (Curatolo 1975); indeed the largest groups form during times of the most severe harassment. These large groups have a greater probability of containing some individuals that are more easily disturbed than others; this may, in turn, affect the behavior of the entire group. Large groups take more time to cross a pipeline than small groups, and this delay increases the potential for encounters with traffic. Thus, traffic along a pipeline may contribute to the lower crossing success of large groups that we observed.

There were no differences in crossing frequencies between large and small groups within sites with only a pipeline. In contrast, Child (1974) concluded that small groups crossed his simulated pipeline (no vehicular traffic) more often than large groups. It may be that Child's simulation was more disturbing to large groups (already under mosquito harassment) than the Kuparuk Pipeline or that sufficient habituation has occurred so that the pipeline we observed was no longer a disturbing factor.

Pipe Height Selection

Clearance of the elevated pipeline ranged from 152–432 cm at the three study areas where data on crossing site selection by Caribou groups were collected (Table 3). The mean pipeline height of crossing sites selected by Caribou at both pipeline/road study sites (Sites 1 and 2) did not differ significantly from the mean pipe height available. In

TABLE 2. Pipeline and pipeline/road crossing frequencies by group size and group type.

Study Area	Year	Group type[1]				Group size			
		cow-calf	n	bull	n	< 100	n	≥ 100	n
Pipeline/road (Site 1)	1981-1982	49%	58	38%	47	45%	107	20%	5
Pipeline/road (Site 2)	1983	24%	33	36%	11	30%	43	0%	1
Pipeline (Site 3)	1981-1983	71%	112	75%	202	72%	325	75%	28
Pipeline (Site 4)	1983	57%	21	67%	21	56%	36	75%	8
Control (Sites 6 and 7)	1981-1982	59%	81	71%	94	66%	185	60%	5

[1]More than 50 per cent of the Caribou in the group were either bulls or cows and calves; excludes individuals and cow-yearling groups.

1981, but not in 1982 or 1983, the mean pipeline height of crossing sites selected by Caribou at the pipeline study site (Site 3) was significantly higher than the mean pipe height available (Table 3).

There are no other quantitative studies for comparison with these data. The fact that Caribou selected for higher pipe heights only one year out of three suggests that pipe height is not an important factor in crossing site selection within the range of pipe heights we studied. Pipeline heights above 1.5 m are largely determined by topographic variations and it appears that normal movement patterns along certain topographic features (e.g., river drainages) probably account for the crossings observed under

TABLE 3. Mean heights of elevated pipeline available for crossing compared with mean heights of pipeline selected by Caribou for crossing.

Location	Type of Data	Year	Mean (cm)	SD	Range (cm)	n[1]
Pipeline/road (Site 1)	actual pipeline	—	186	27	152-279	168
	Caribou crossings	1981	188	29	152-279	92
	Caribou crossings	1982	183	23	152-279	78
Pipeline/road (Site 2)	actual pipeline	—	182	16	119-229	92
	Caribou crossings	1983	184	20	149-227	36
Pipeline (Site 3)	actual pipeline	—	261	65	152-432	139
	Caribou crossings	1981	301	70	152-432	138
	Caribou crossings	1982	274	66	152-432	345
	Caribou crossings	1983	278	68	152-432	184

[1]This number represents the number of VSMs in the actual pipeline in the study site or the number of crossings made by Caribou in the study site. A "crossing" consisted of one or more Caribou crossing under a pipeline between two adjacent VSMs in a more or less cohesive manner. Thus, one Caribou group can account for one or more crossings.

higher pipe heights. It is also possible that habituation may account for the lack of selection of high pipeline in the last two years of the study. A pipeline is a stationary structure, and is a relatively low level stimulus compared with a pipeline adjacent to a road with moving vehicles. Perhaps Caribou crossed under the high pipeline in 1981 (the first year the pipeline was in place) because it was less frightening than crossing under low pipeline sections. If this is so, it appears Caribou readily habituated, as there was no apparent selection for high pipeline in the following two years. On the other hand, the lack of selection of high pipeline in the pipeline/road site during any year (Table 3) may be explained by the additional disturbances caused by traffic at that site and by the lack of prominent topographic features for Caribou to follow.

Use of Ramps as Crossing Sites

Pipeline crossings were classified as either crossings under an elevated pipeline or crossings over a ramp (buried pipeline) to determine whether Caribou preferred specific pipeline configurations for crossing sites (Table 4). Six per cent, twelve per cent and nine per cent of the crossings at Sites 1, 2, and 3, respectively, were over ramps. These crossings were significantly more frequent than expected because the buried pipe constituted less than 2% of the pipeline at these sites. A preference for ramps was also observed in Prudhoe Bay in 1972 (Child 1974). Child found that 76% of the Caribou crossing a simulated pipeline crossed over ramps that represented 22% of the total length of the simulation.

The preference for ramps as crossing sites by Caribou appears to reflect the effect of elevated pipelines on Caribou behavior. Caribou tend to follow linear structures for some distance before crossing (LeResche and Linderman 1975). When Caribou encounter an elevated pipeline they may parallel it even though that may entail a change in the direction of travel. Upon reaching a ramp, the visual stimulus of the elevated pipeline is gone; this may provide a "path of least resistance" for Caribou to follow.

Summary and Conclusions

The frequency of crossings by Caribou of a pipeline adjacent to a road with traffic during both insect-free periods and periods of mosquito harassment was significantly less than expected. There was no significant difference when oestrid flies harassed Caribou. Our studies suggest that Caribou react to two types of stimuli in an oilfield: structures possibly resembling concealing habitat (e.g. raised pipeline) and moving objects possibly resembling predators (e.g. vehicles). It was only when Caribou observed these stimuli together (i.e. a pipeline adjacent to a road with traffic) that there was a significant decrease in the percentage of Caribou crossings.

Caribou readily crossed under an elevated pipeline or over a road. The ability of Caribou to cross a single structure (e.g. pipeline) compared to multiple structures (e.g pipeline and road) suggests that separation of roads and pipelines would facilitate Caribou movements in areas of oil development.

There did not appear to be selection for particular pipeline heights within the range we studied (152–432 cm), regardless of the traffic level. Therefore, it appears that the 150 cm minimum pipeline height that was required by the State of Alaska is adequate for Caribou passage.

There was a preference for ramps as crossing sites, although the crossing frequency was low. We doubt that any type of special crossing structure would be able to lessen the impact on Caribou when traffic levels are very high (i.e. one vehicle every two minutes). It may be that ramps do not function effectively under heavy traffic conditions during oilfield construction. Rather, ramps may be more applicable once the oilfield is in production and traffic levels decrease.

TABLE 4. A comparison between the number of ramp crossings[1] and the number of elevated pipeline crossings by Caribou groups, observed in three different locations along the Kuparuk Pipeline, Alaska.

		Ramp crossings		Elevated pipeline crossings	
Structure	Year	Observed	Expected	Observed	Expected
Pipeline/Road Site 1	1981-1982	10	1.07	170	178.93
Pipeline/Road Site 2	1983	5	0.85	36	40.15
Pipeline Site 3	1981-1983	65	5.27	667	726.73

[1]A "crossing" consisted of one or more Caribou crossing under a pipeline between two adjacent VSMs or over a ramp in a more or less cohesive manner. Thus, one Caribou group can account for one or more crossings.

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