THE REACTIONS OF BARREN-GROUND CARIBOU
(*Rangifer tarandus granti*)
TO SIMULATED PIPELINE AND PIPELINE CROSSING STRUCTURES AT PRUDHOE BAY, ALASKA

ALASKA COOPERATIVE WILDLIFE RESEARCH UNIT

University of Alaska
Fairbanks, Alaska

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INTRODUCTION

The announcement of the discovery of a major oilfield at Prudhoe Bay on the North Slope of Alaska in 1968 by Atlantic Richfield,and Humble Oil and Refining Companies (Exxon) focused world-wide attention on the potential impact of oil development in the Arctic. The increased presence of man and his activities in the Arctic were associated by many with far-reaching environmental and wildlife repercussions (Banfield 1972; Brooks et al. 1971; Brown 1971; Calef and Lortie 1971; Geist 1971; Klein 1972; Parker 1972; Sage 1970; Scott 1970; Weeden 1971). But nothing stirred as much controversy amongst industrial interests, conservationists and federal and state agencies as the proposed 800-mile, 48-inch diameter pipeline from Prudhoe Bay south to the ice-free port of Valdez on Prince William Sound (Anonymous 1971; Coates 1971; Gillham 1970; Laycock 1970; Reed 1970; Sage 1972; Weeden and Klein 1971).

In 1969, Undersecretary, Russell Train, of the U.S. Department of the Interior, presented to the industrial consortium, Trans-Alaska Pipeline System, since renamed Alyeska Pipeline Service Company (ALPS), a list of 79 questions that emphasized both environmental and social safeguards to be considered in the planning for pipeline construction. As a result, a comprehensive list of stipulations governing pipeline construction was developed. The U.S. Bureau of Land Management (BLM) was delegated to enforce these stipulations during pipeline construction.

Since little knowledge was available on the reactions of wildlife or other components of the environment to problems imposed by oil developments or pipeline construction and operation, BLM cautioned the consortium that not only would they police construction of the pipeline, but they would formulate new regulations to minimize environmental losses. For example, ALPS had originally suggested certain prototypes for big game crossings (ALPS 1971). However, the effectiveness of the crossings was unproven as BLM pointed out: "...those sections (of the pipeline) constructed above ground could be an effective barrier to migratory wildlife," and further cautioned that, "...there was no evidence available to support the supposition that caribou will pass under an elevated pipe or for that matter, over a ramp " (Brown, 1971; pg 83). Also, concomitant with oil developments, the landscape will be altered with the construction of road systems, oil drill rigs and pads, airstrips, construction camps and pipelines. It was conceivable to expect then that the combined effects of these features would exert considerable influence on the free movements of caribou across their summer range.

The literature is replete with studies describing the reactions of non-Arctic ungulates to range alterations (G. Child 1972; McCullough 1969; Rouse 1954; Russell 1964; Spillett et al. 1967; Shultz and Menzel 1969; Sundstrom 1966; Woodley 1965, 1972; Zobell 1968). Definitive studies of the reactions of wildlife to man-made obstructions and disturbances in the Arctic are scarce except for descriptions of aboriginal capture methods for caribou by Banfield (1954), Brower (1960), Kelsall (1968), Murie (1935), Sonneveld (1957), and Symington (1965). Recent works of Bergerud (1971), K.Child (1971c), Espmark (1970, 1972), Freddy and Erickson (1972), Geist (1970), Klein (1971), Lent (1966), Lentfer (1965), Leopold and Darling (1953), LeResche (1966), Miller et al. (1972), Pitzman (1970), Scotter (1964), Skoog (1968), Thomson (1972a), and Zhigunov (1968) give valuable insights on the reaction of Rangifer and other cervids to various types of obstructions and disturbances.

With a paucity of information available dealing specifically with caribou-pipeline interactions, it was imperative that a study of the behavioral responses of caribou to such man-made structures be initiated. Co-sponsored by the U.S. Bureau of Sport Fisheries and Wildlife, Alyeska Pipeline Service Company and BP Alaska, Inc., two pipeline simulations with experimental crossings for caribou were constructed at Prudhoe Bay in 1971. Field work was performed by Kenneth N. Child of the Alaska Cooperative Wildlife Research Unit, University of Alaska, under the direction of Drs. David R. Klein and Peter C. Lent. The 1971 studies were assisted by John Wright. Christian A. Smith assisted the principal investigator at Prudhoe Bay in 1972.

In addition to the current study, which focused on the reaction of caribou to simulated pipelines, other research into the impact of pipelines, road systems, and other developments and disturbances on caribou and reindeer have been undertaken through the Wildlife Research Unit. These include studies on the North Slope, funded by the U.S. Bureau of Sport Fisheries and Wildlife and investigations with reindeer and a simulated pipeline on the Seward Peninsula, supported by the U.S. Bureau of Land Management, Alaska Department of Fish and Game and the U.S. Bureau of Sport Fisheries and Wildlife. The results of these studies will be reported in a comprehensive analysis as part of a doctoral dissertation by the author.

HISTORICAL AND CONTEMPORARY IMPORTANCE OF THE PRUDHOE BAY AREA TO ARCTIC CARIBOU POPULATIONS

Very little is known of the historical importance of the Central Arctic area, between the Colville and Canning Rivers, to caribou as calving, summering, and wintering range. Anthropological works of Gubser (1965) and Sonneveld (1957) on the hunting practices of inland

and coastal Eskimos respectively located the calving grounds east of Teshekpuk Lake to Camden Bay. Stefansson (1971) reported that the largest post-calving concentrations he usually encountered during his travels were located east of the Kuparuk delta. Skoog (1968), summarizing the movements of caribou in Arctic Alaska, suggested the Central Arctic to be a center of habitation for a "Central Brooks Range Herd," characterized by its own calving, summer, and winter ranges. The herd, however, is believed to have lost its separate identity after the early 1950's when these animals apparently merged with the larger Arctic herd to the northwest. Gavin (1971; 1972) provides evidence to suggest the "Central" herd continues to exist and utilize this area of the North Slope, moving coastally from the central Brooks Range, east to the Canning River, then westwards along the coastal plains to the Kuparuk, Sagavanirktok and Colville Rivers, thence southwards. Hemming (1971), in a comprehensive review of the distributions and movements of caribou herds in Alaska, argues that the Central Arctic serves mainly as an overlap zone at the peripheries of the ranges of the Arctic and Porcupine herds, to the west and east respectively. The former herd has been estimated to contain at least 200,000 animals (Pegau and Hemming 1972) and the latter herd to contain about 101,000 animals (LeResche 1972).

Over-wintering use of the coastal plains is not an uncommon occurrence (Lent and Lønø 1962; Hemming 1971; Skoog 1968). Caribou have been known to over-winter at Prudhoe Bay on the oilfield, although numbers have varied between years (D.S. Braden 1972, pers. comm.). In some winters, however, larger groups have occasionally remained on the tundra. For example, Collins in 1937 (cited in Skoog 1968) described a larger wintering concentration of several thousand near the Kuparuk

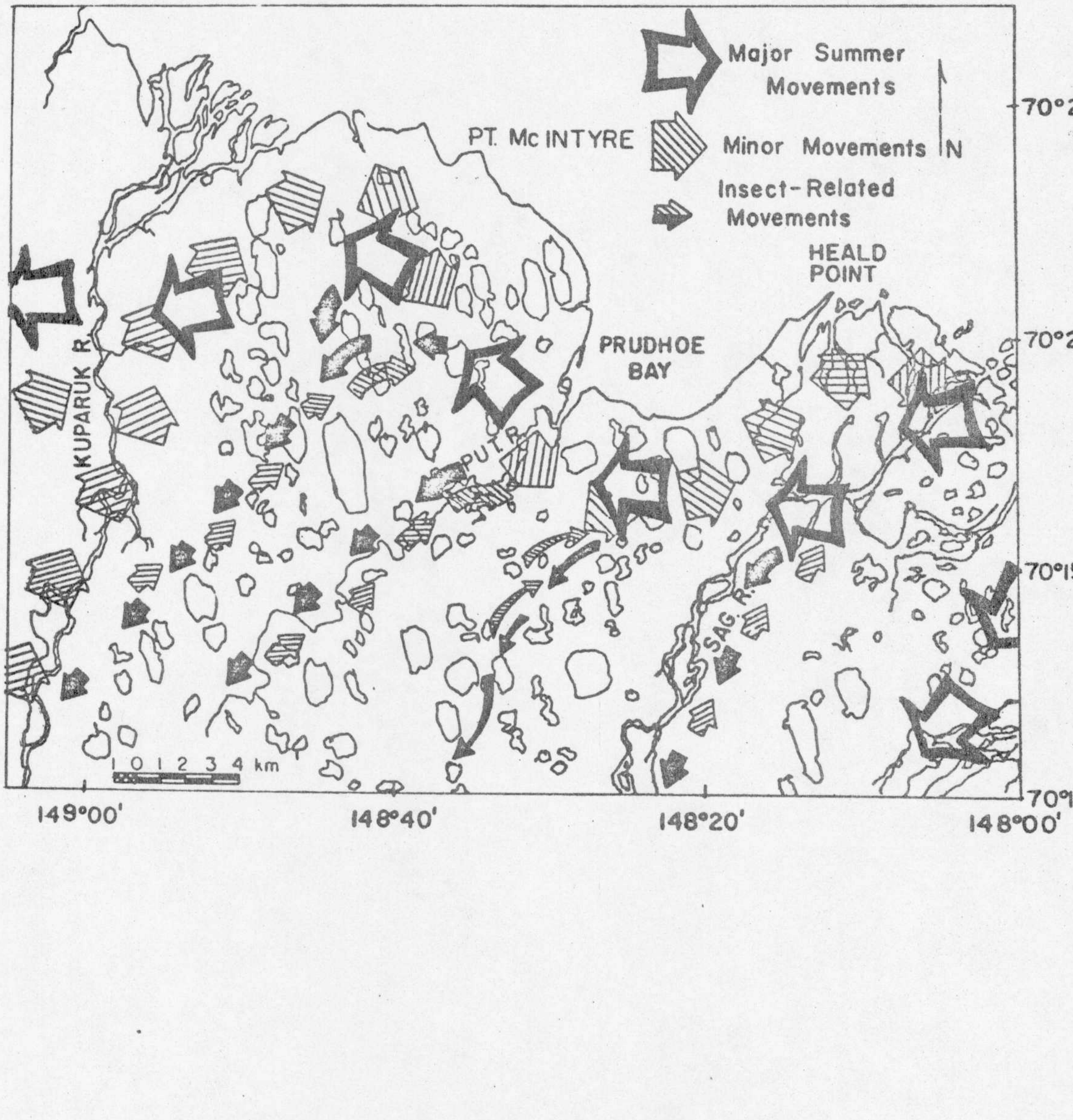
River. Olson (1959) reported a concentration of about 150,000 animals present within the Central Arctic during the winter of 1958. Thirty percent of these caribou were located coastally near the Sagavanirktok River.

The coastal plains of the North Slope are also described to be potential calving habitat (Skoog 1968). The use of the Central Arctic for calving is not well documented; however, Hemming (1972, pers. comm.) reported a large calving concentration of animals (ca. 1,000 to 1,500) present northeast of the Kuparuk River at one time during the last decade. Child (1971a; 1972a) reported the incidence of calving within the oilfield in 1971 and 1972. Gavin (1971; 1972, pers. comm.) confirmed the earlier observations by aerial reconnaissance and reported considerable calving activity to occur in the White Hills, approximately 85 miles south of Deadhorse.

The coastal area at Prudhoe Bay is an important summer range for a small population of approximately 3,000 animals (Child 1972c). The coastal flats, beaches, channels and deltas of the Sagavanirktok, Kuparuk, and Putuligayuk Rivers become important insect-relief habitats during the fly season. The summer influx of these animals into the Prudhoe Bay area usually coincides with the onset of the fly season (Child 1971, 1972, pers. observ.). Caribou enter the oilfield from the east and west, primarily at the delta of the Sagavanirktok River and down the Kuparuk and Putuligayuk Rivers (Child 1971b) respectively. The latter influx of animals is of a much smaller magnitude than the former movements which are characterized by herds varying in size from several hundred to several thousand (Child 1971, 1972, pers. observ.; Gavin 1971, 1972). Superimposed on these movements is an oscillation of animals that repeatedly moves across the oilfield from the southwest, heading northeast to Heald Point and the Sagavanirktok delta, then inland when conditions are favorable. This oscillation is apparently dependent on changes in the velocity and direction of the prevalent winds, temperature, and insect densities (Child 1971b; Thomson 1972b). Generally as the wind speed decreased below 12 mph at temperatures above 42 F (cf. Hopla 1964), caribou groups would coalesce within the oilfield and move en masse upwind to the northeast. Conversely when temperatures dropped and winds increased, insect densities declined, and as a result, the caribou would return inland from the coast. While such movements are neither migratory in the conventional sense nor random wanderings, they are predictable and directional on the basis of local environmental conditions (Child 1972c; Thomson 1972b). Because of this oscillatory pattern of summer movements (Fig. 1), caribou residing within the Prudhoe Bay area of the Arctic experience numerous confrontations with man-made obstacles.

Periodically, the Central Arctic is invaded by unusually large concentrations of caribou in early fall (Hemming 1971). The Prudhoe Bay area is not immune from these intermittent movements. Recently Thayer (1969; pers. comm.), Gavin (1971) and LeResche (1972) reported the appearance and passage of groups of several thousands through the oilfield. Skoog (1968) summarized major population shifts that occurred between the two Arctic caribou herds since the late 1800's. Most of the interchanges that he describes occurred through the central region of the North Slope. These large-scale movements are mostly unpredictable and infrequent in occurrence, but typify most of Alaska's caribou herds (Hemming 1971; Skoog 1968).

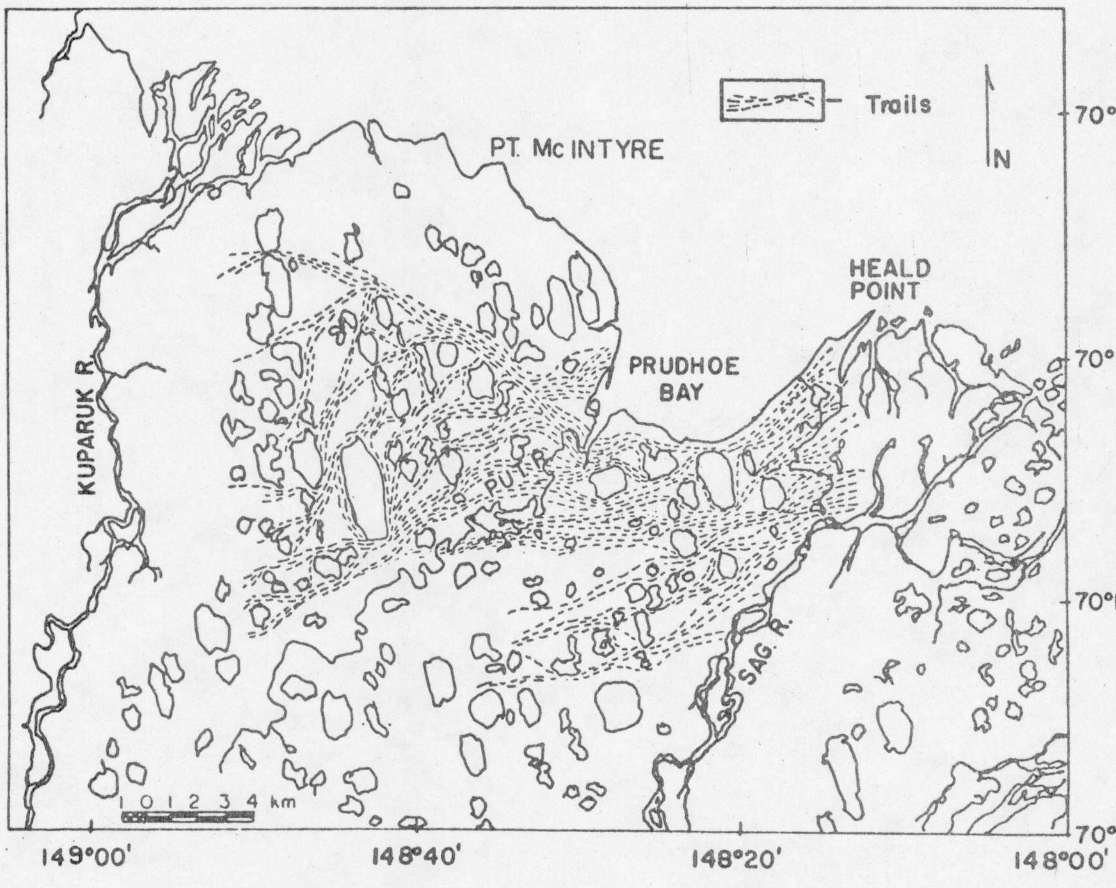
Figure 1. Map of the Prudhoe Bay Area on the North Slope of Alaska showing a) Unidirectional Pattern of Summer Movements of Caribou and b) the Insect-related Oscillatory Movements of Animals (Smaller Arrows) across the Oilfield.



The Prudhoe Bay oilfield is situated within a historic range of caribou as indexed by traditional trail systems (Figs. 2a, 2b). Although movements of animals through the area occur annually, they are presently on a smaller scale than summer movements reported elsewhere in the Arctic (LeResche 1972). However, the Central Arctic is characterized by intermittent migrations of animals numbering in the tens of thousands. Recent reports suggest that similar migrations have traversed the coastal plains at Prudhoe Bay. It is reasonable to expect that these occasional movements will continue to occur through the area, especially when either of the two major herds undergoes another shift in its range.

The oilfield is therefore important range to both Arctic caribou populations. It serves as summer range and insect-relief habitats for a small population of animals presently frequenting the area. Lately the Prudhoe Bay range has become increasingly important as a calving ground for a small segment of the resident herd that over-winters in the area. In time, the Prudhoe Bay range may increase in its importance to the Arctic caribou herds, especially if a major population shift moves into the Central Arctic from the west or east. Present and future oilfield developments at Prudhoe Bay will, to a greater or lesser extent, impede the free movements of caribou through the oilfield and to the coastal areas during the summer, and may also restrict the progress of the more infrequent and larger scale population shifts that are historically characteristic of the area.

Figure 2a. Map of the Prudhoe Bay Area of Alaska Delineating Traditional Trail Systems of Caribou from Aerial Photographs. Note the Obvious Alignment of Trails along Perimeters of Natural Terrain Features and Their Orientation in a Southwest-Northeast Direction.



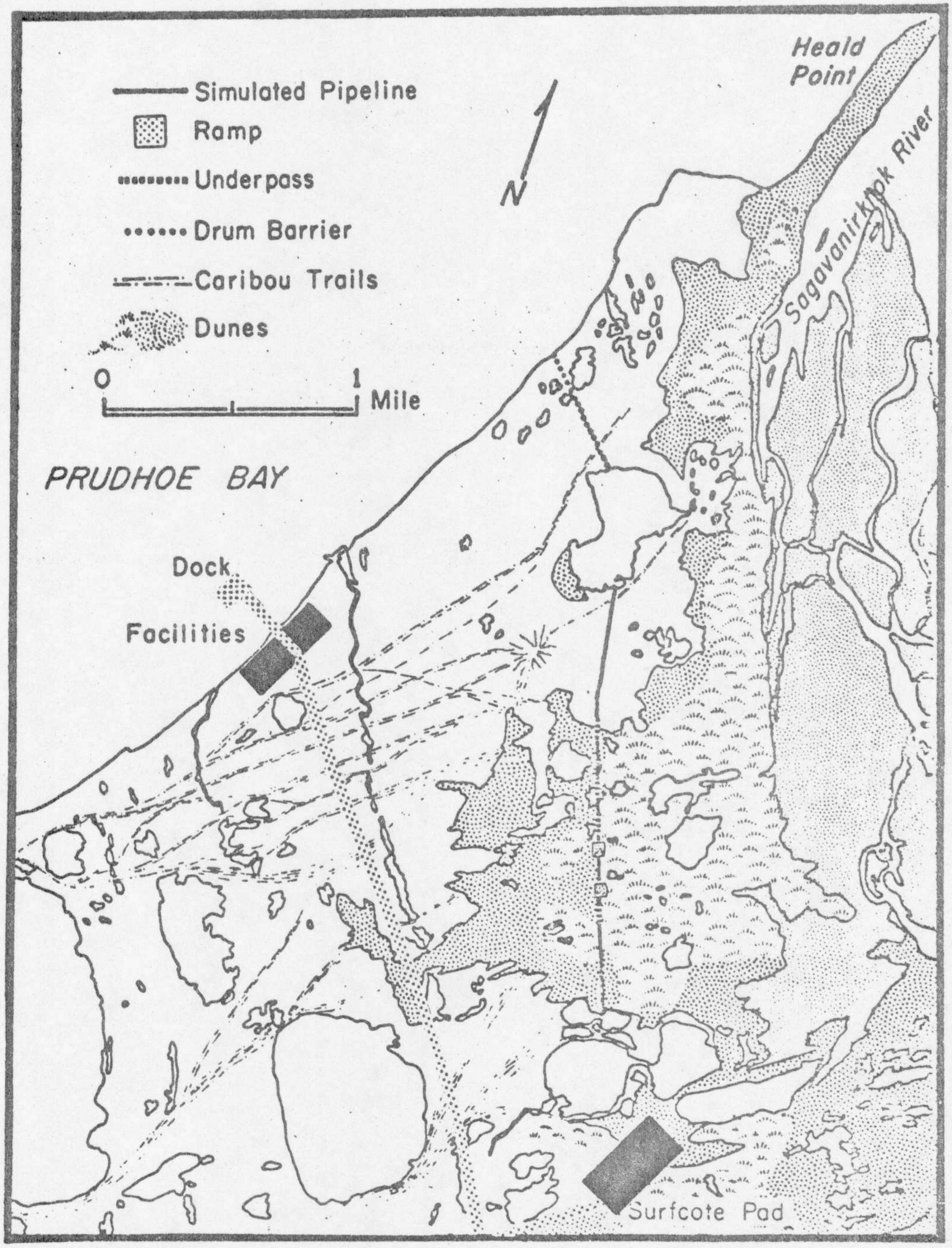


Figure 2b. Map of Heald Point and Prudhoe Bay showing the location and orientation of Alyeska's simulated 48-inch pipeline to the traditional trails of caribou mapped for the area. Because of the active sand dunes, trails could not be mapped further eastwards to the Sagavanirktok River.

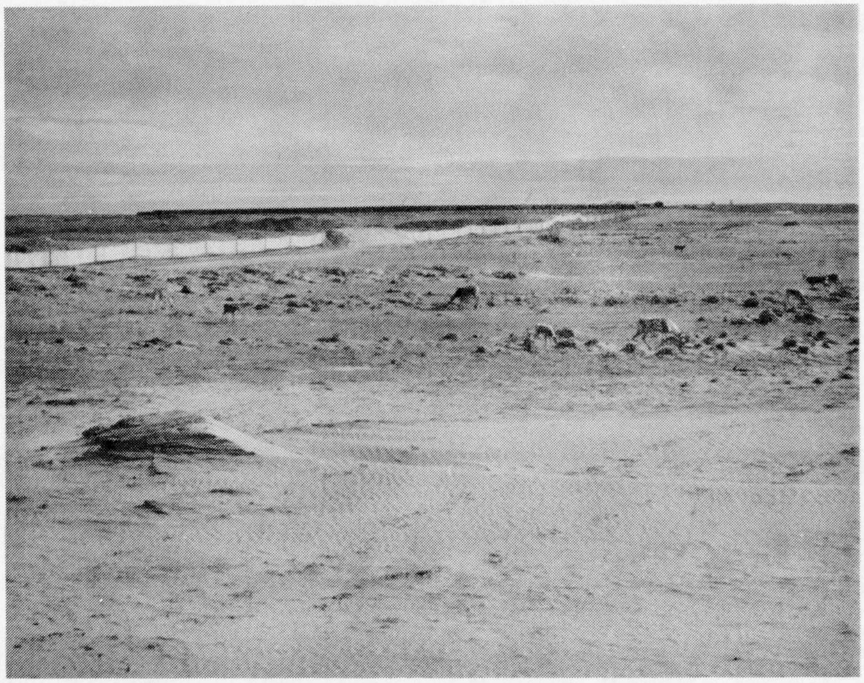
STUDY FACILITIES

With four-foot snowfencing, ALPS constructed a two-dimensional barrier to simulate the proposed 48-inch diameter Trans-Alaska pipeline. Approximately 10,200 feet in length, the snowfencing was elevated 20 inches above ground for most of its length on 10-foot spruce poles spaced at 25-foot centers. Burlap sacking was stapled on the east side of the fence to: a) minimize movements of the burlap and sounds from the fence due to prevalent winds, and b) to make the fence an optical barrier similar to the proposed pipeline. Two gravel ramps and four underpasses, as passage provisions for caribou movements, were included in the design. The ramps were 75 and 100 feet in length, linear in shape with 2:1 side slopes and aligned with the axis of the fence. To simulate expected differences in height and length of clearance beneath the 48-inch pipeline, three of the underpasses were 100 feet long and provided ground clearances of approximately 7 feet 8 inches; the fourth, although 150 feet in length, provided a 4-foot clearance above ground. To give a three-dimensional illusion at the underpasses, two spans of snowfencing were used (Fig. 3). Observations were made from a 14-foot tower approximately 50 feet from the fence and positioned equidistantly from the ramps.

In 1972, the designs of the crossing facilities were changed. Both ramps were modified. They were re-constructed equal in length with 5:1 slopes fanning out 360 degrees from the fence. Three of the four underpasses were increased in length to 200 feet, but all heights beneath the invert profiles of the elevated sections remained the same. At two of the underpasses, the snowfencing and sacking

Figure 3. A small nursery band of caribou feeds on Artemisia arctica in the sand dunes adjacent to Alyeska's snowfence and burlap 'pipeline'. A gravel ramp and underpass structure constructed to facilitate caribou crossings are shown.

Figure 4. A group of bull caribou feed on Artemisia arctica west of the snowfence and burlap barrier. Modified ramp and underpass structures are shown.



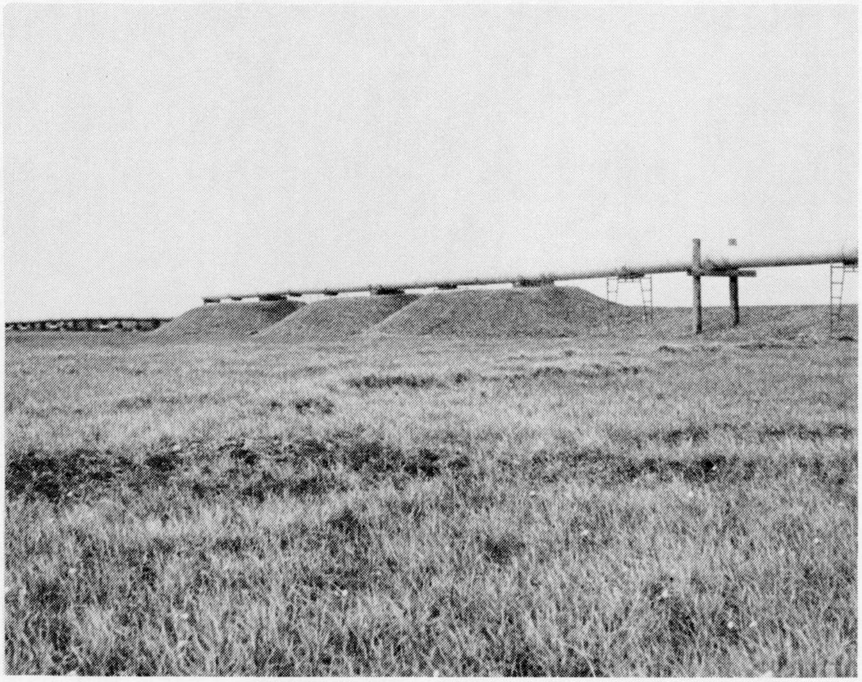
were replaced by 32-inch galvanized culverting to remove possible bias in the results due to movement of the burlap by wind. All supports were cut level with the top of the culvert and the snowfencing to standardize the optical properties at the passage provisions (Fig 4).

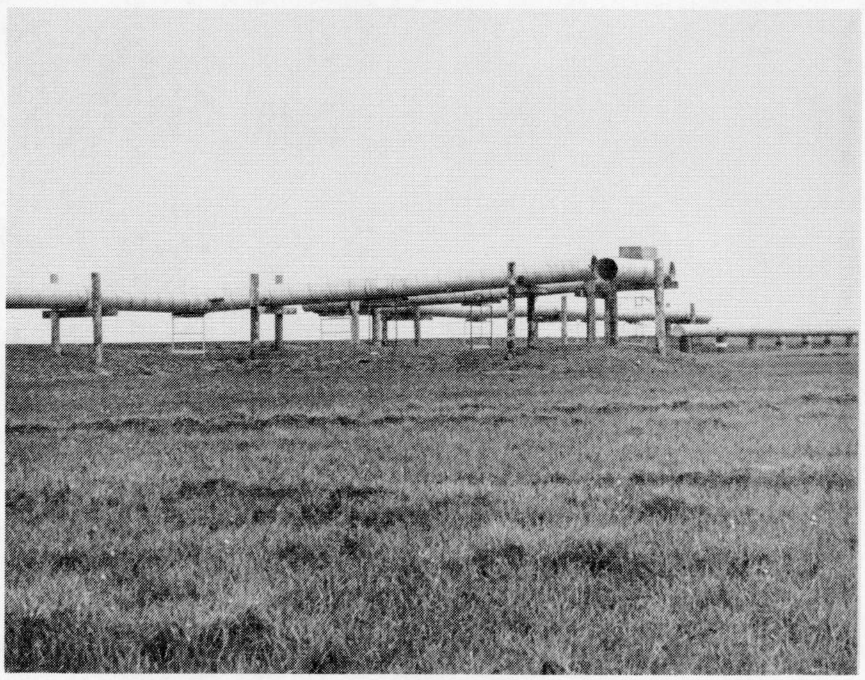
At the north end of the simulation, a diversional lead was constructed using oil drums, a 1/2-inch twisted steel cable, and florescent "day-glo" flagging. Ninety-three water-filled barrels were set at frequent intervals for a total distance of 2,800 feet to the Arctic Ocean. The cable was suspended and anchored on top of the drums and strips of flagging were attached regularly along the cable. By intercepting caribou, the barrier served to limit the likelihood of animals escaping around the northern end of the pipeline and deflected them toward it, increasing the likelihood of caribou confronting or re-encountering the structure and the crossing facilities.

BP Alaska, Inc., primarily concerned with the impact of feeder pipelines on caribou movements through Prudhoe Bay oilfields, constructed a pipeline simulation in 1971 for this study as well as for snow-drift investigations. A 3,600-foot pipeline of 24-inch culverting was suspended and anchored for 3,000 feet on water-filled oil drums. The remaining 600 feet were raised on various types of pilings and supports to provide a variation of ground clearances from 4 to 8 feet (Fig. 5). Also an expansion loop (20 x 40 feet) was simulated within this section of the pipeline. The eastward inclination of the loop allowed clearances of 6 and 8 feet above road and tundra surfaces respectively, which was believed to be adequate for caribou passage (Fig. 6). To intercept and channel movements of animals toward the

Figure 5. An oblique view of BP Alaska's simulated feeder pipeline. Ground clearances beneath the culverting on wooden pilings and gravel berms varied from 5 to 7 feet. These heights were believed adequate to permit easy passage of caribou beneath the over head obstacle.

Figure 6. An oblique view of the expansion loop constructed within the simulation. The inclination of the loop provided ground clearances of 8 and 6 feet above tundra and surface of the road respectively. The loop was initially intended to serve as the main crossing facility for caribou.





structure from the north, a cable with florescent flagging was strung from the north end of the pipeline eastward 900 yards on oil drums (Fig. 7). A 14-foot observational tower was constructed adjacent to the simulation on the gravel service road.

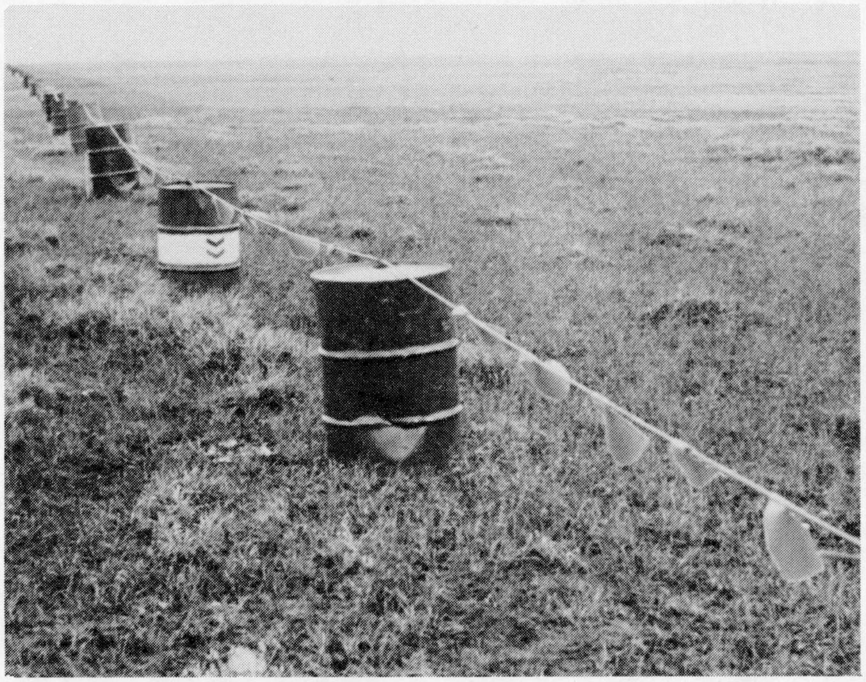
In 1972, to purposely test the efficiency of low-profile ramps, BP Alaska, Inc., modified the mock-up by lengthening the structure another 3,500 feet using spruce logs (10 inches DBH) rather than culverting set on oil drums. Two radial ramps (10:1) were constructed 2,000 feet apart within the extended length of the simulation. Four experimental 100-foot cable offsets, or leads, each positioned at 45 degrees to the axis of the roadbed, were included as an attempt to intercept and lead caribou over the ramps (Fig. 8).

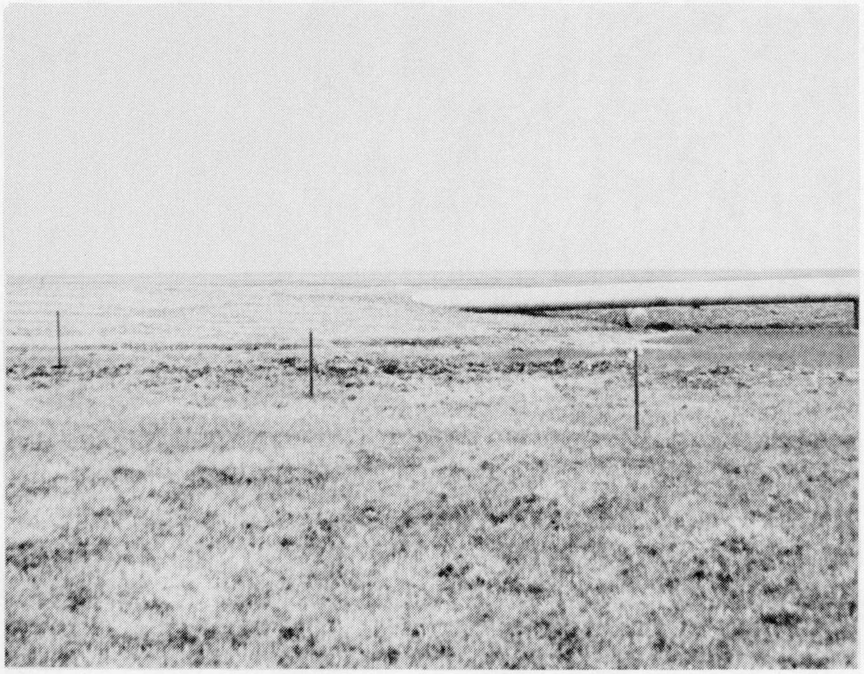
RESEARCH OBJECTIVES

Field data and observational records emphasized three themes for research: a) behavior of individual animals (by sex and age) and groups of caribou (by size and composition) in the vicinity of man-made obstructions, b) reactions of caribou presented with deflection or choice situations, that is, when in proximity to an alternate method of passage over or under the pipelines, and c) reaction of maternal cows and calves when confronting similar structures. The responses of animals on subsequent encounters with the pipelines were studied for insights on the learning ability of caribou to pass beneath or over obstacles.

Figure 7. The cable-oil drum barrier at the north end of BP Alaska's feeder pipeline constructed purposely to channel caribou against the simulation.

Figure 8. A low profile gravel ramp constructed to facilitate caribou crossings over the feeder pipeline. An experimental cable lead is shown.





FIELD PROCEDURES

Needless to say, recognizing individual animals or groups of caribou is a difficult, if not an impossible task, considering the mobility of the species and the instability of the herds. Nevertheless, field recognition of individuals and groups of caribou is invaluable for important insights on a) response differences of individuals and groups of animals encountering man-made structures, b) how previous experiences of caribou may influence their responses when re-encountering the structures, c) whether or not caribou, after initial failures to cross, return to make "another try" at crossing, d) the persistence of caribou attempting to cross man-made features, and e) whether or not the integrity of the social unit changed as caribou herds encountered the simulations. As a consequence, a field marking program was conducted in 1972 during the week of June 21 to 30. Caribou nursery bands and a few bull groups were marked with three non-toxic commercial fabric dyes (Calcomine Green, Calcocid Scarlet, and Yellow Calcomine Direct Chinoline) within a 35-mile (56.4-km) radius of Deadhorse airstrip using an aerial spray technique similar to that described by Simmons (1971). A minimum of 159 caribou were marked, using a Piper Super Cub equipped with a modified 90-gallon Sorensen tank (Table 1). The water-diluted dyes were applied to caribou bands on a color-coded scheme according to geographic location. To the west, southwest and northwest of Deadhorse in the Kuparuk and Putuligayuk drainages, caribou were sprayed with red dye; those animals within the area bounded to the west by the Putuligayuk River and the Sagavanirktok River to the east, and Franklin Bluffs south, were sprayed with yellow;

Table 1. Total Numbers and Composition of Caribou Marked by Aircraft Application of Commerical Fabric Dyes at Prudhoe Bay.

Color	Total Number of Animals Attempted	Composition of Animals Marked: Bulls	Cows	Calves	Yearlings	Number Marked
Red	101	11	29	20	8	68
Yellow	172	2	20	13	1	36
Green	205	2	31	19	3	55
Total in Sample	478	15	80	52	12	159

and southeast of the Sagavanirktok River, the animals were marked with green dye (Fig. 9). The presence of colored animals within the Prudhoe Bay area facilitated behavioral observations by permitting a) recognition of groups, b) mapping of movement patterns throughout the oilfield, and c) field identification of individual animals on a short-term basis. Throughout the duration of the summer, 48 dyed animals (27 red; 8 yellow; 13 green) were identified in groups residing within the Prudhoe Bay area and at the simulations.

Continuous sequences of individuals and groups encountering and reacting to both pipelines were recorded with the aid of 8 x 40 mm binoculars, spotting scopes, tape recordings and 16 mm cinematography.

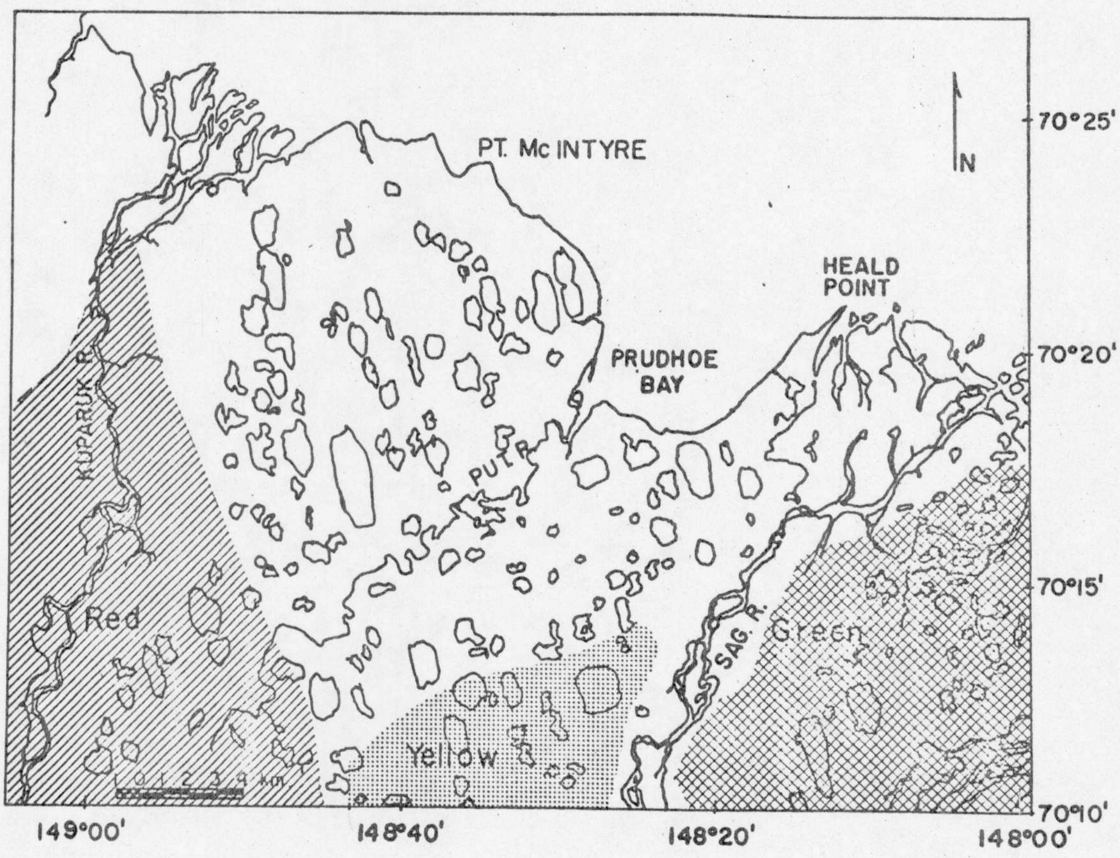
To supplement the behavioral observations, information on ambient weather conditions (air temperature, wind speed and direction) and changes in insect density (sampled by landing index methods similar to Hopla 1964) was collected. Also, leadership (by sex) of the group, direction of travel of animals as they approached the simulation and spatial orientation of individual animals within groups and between different groups if separated by the pipelines were recorded. In order to calculate the distance between the simulations and approaching animals, a series of florescent stakes were placed perpendicular to the pipeline at 50 m intervals adjacent to the crossings.

Statistical procedures used for analysis are described in Sokal and Rolf (1969a; 1969b).

RESULTS AND DISCUSSIONS

For purposes of the discussions, crossing success and successful crossings are synonymous terms and are defined within contexts of individuals and groups of caribou encountering the simulations. An individual animal is said to have successfully crossed the "pipelines" only if it negotiated the structures at a ramp, an underpass or crawled

Figure 9. Map of the Coastal Plains at Prudhoe Bay Showing the General Areas Searched and the Color-code Scheme Used in the Aerial Spray Marking Program for Caribou.



beneath the structure to the other side. Unlike individuals, groups of caribou as social units, must have negotiated the "pipelines" at the crossing facilities in their entirety (100 percent of their membership) in order to be considered a successful crossing. If a group separated into smaller subgroups when encountering the pipeline, however, and only a smaller portion of the group crossed the pipeline at either facility, then the number of animals crossing are considered successful by the former definition and recorded as the total number of animals crossing. By the latter definition, the encounter of the group is unsuccessful, since the group did not negotiate the structure as a complete social unit.

Most caribou observed encountering the pipelines in 1971 and 1972 as individuals or as members of groups showed a tendency to parallel the structures at an average distance of 50 meters (Figs. 10, 11, 12, 13). Many times these animals bypassed all crossing facilities and moved to the terminals. Reversed movements or end-runs to both terminals usually resulted when the caribou did not successfully negotiate the pipelines at the ramps or underpasses (Figs. 14 and 15). Generally, as the size of the group increased in number, the crossing success decreased significantly. Of 110 groups, 27 (24.5 percent) found access over the ALP's simulation as complete groups by the ramps and underpasses, whereas 83 of the groups (75.5 percent) did not use either facility to cross the pipeline. Groups of smaller sizes (2 to 10) tended to show greater interest in the obstruction, and as a consequence were more inclined to investigate and successfully use the ramps (12.9 percent) than was the case for the larger groups (7.5 percent). The larger groups, on the otherhand, as complete entities did not successfully negotiate the

Figure 10. Movements of 1,102 Caribou observed at Alyeska's Simulated 48-inch Pipeline in 1971.

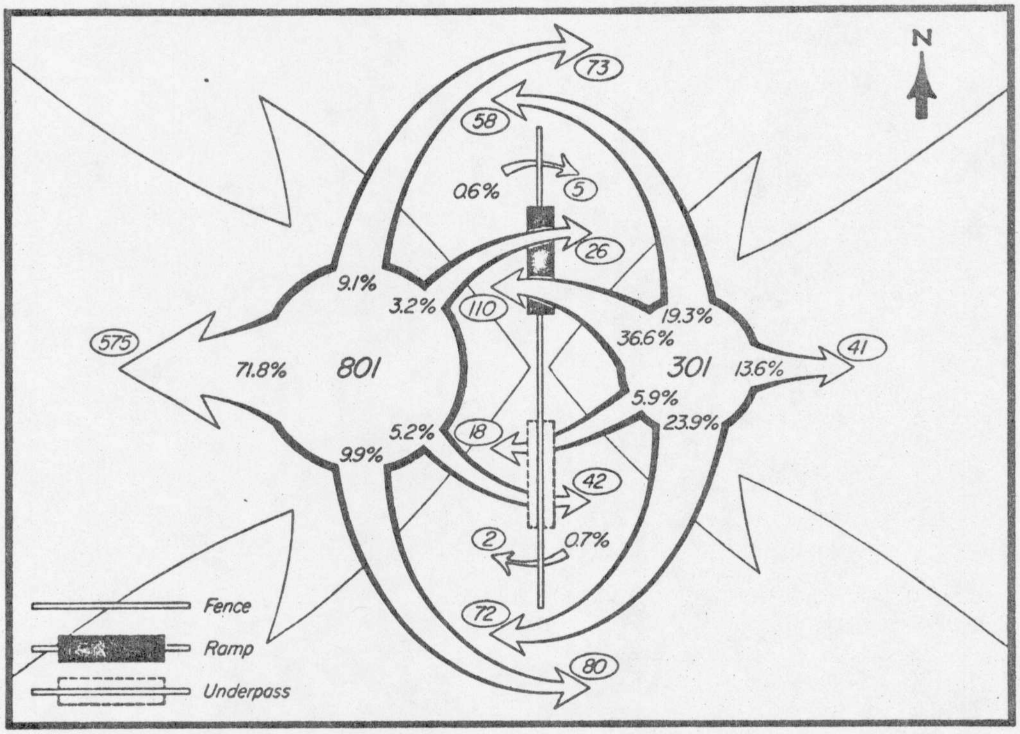


Figure 11. Movements of 4,497 Caribou observed at Alyeska's Simulated 48-inch Pipeline in 1972.

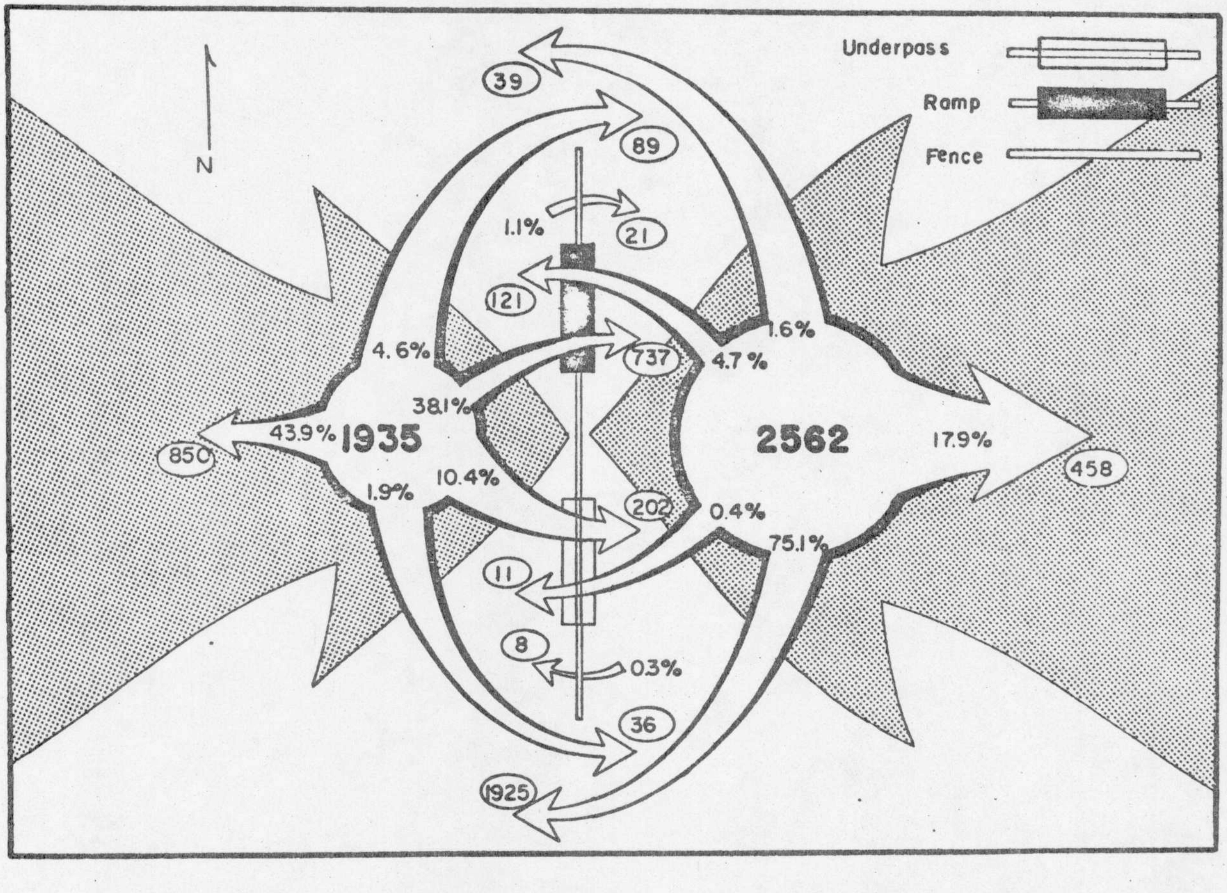


Figure 12. Movements of 605 Caribou observed confronting BP Alaska's Simulated Feeder pipeline in 1971.

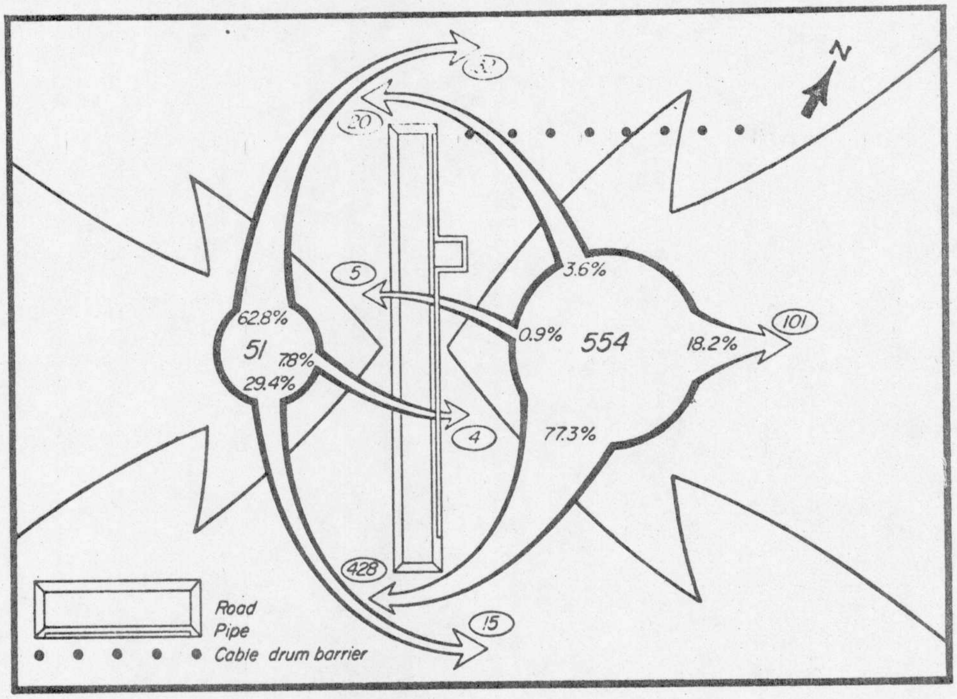


Figure 13. Movements of 757 Caribou observed confronting BP Alaska's Simulated Feeder pipeline in 1972.

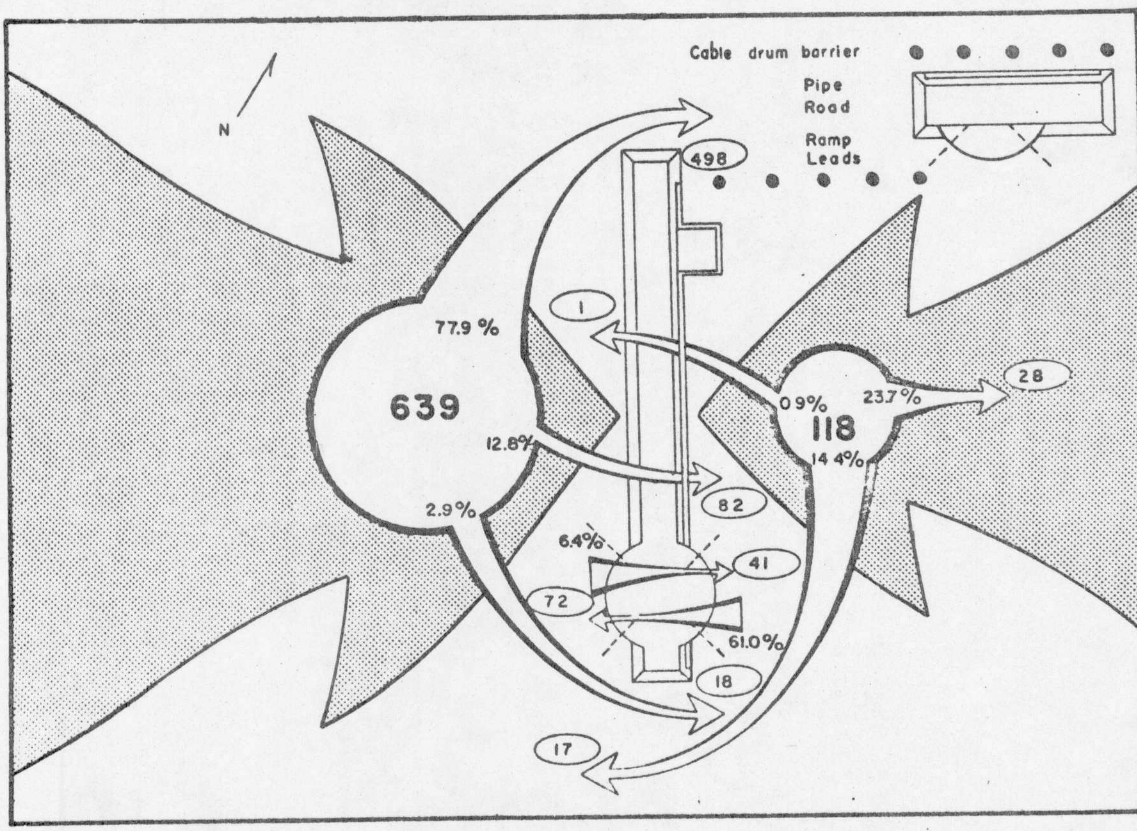


Figure 14. Summary of the movements of 5,599 caribou observed at Alyeska's Simulated Pipeline in 1971 and 1972.

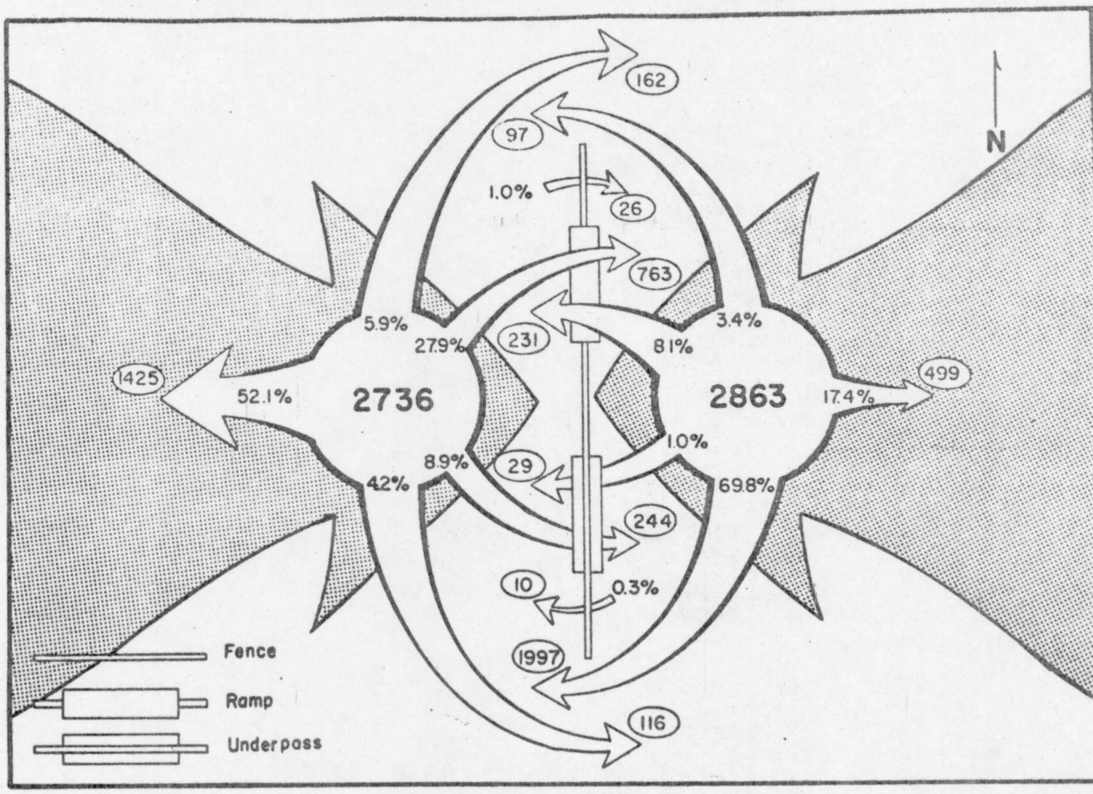
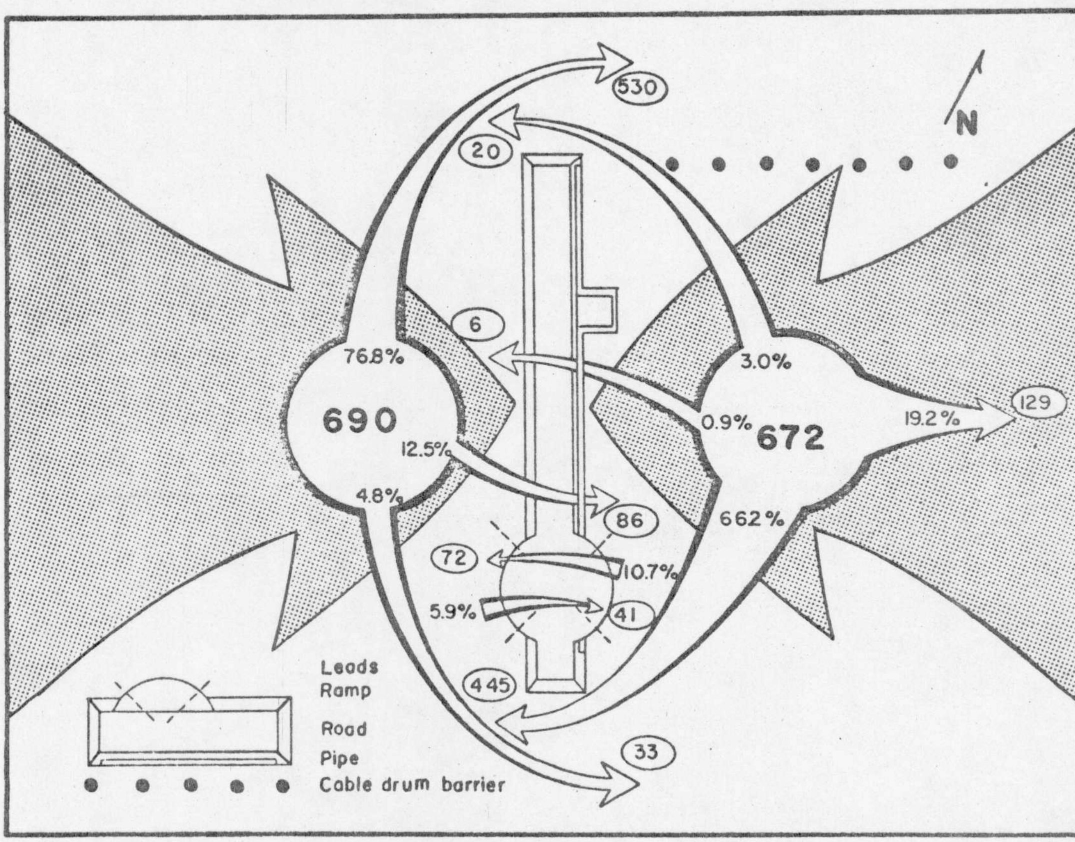


Figure 15. Summary of the movements of 1,362 caribou observed at BP Alaska's Simulated Feeder-pipeline in 1971 and 1972.



the pipeline at the ramps or underpasses, but instead either coursed the structure to its terminals, reversed their direction and returned from whence they came, or else separated into smaller subgroups before crossing at various locations (Table 2). When considered as individuals, however, caribou were more successful using the crossings to negotiate the pipeline. Of a total of 34 individual animals observed encountering the fence, 21 (69.0 percent) successfully used ramps and underpasses to cross the structure and 13 (31.0 percent) animals did not use either facility provided (Table 3).

Besides size differences of groups, there is also an apparent response difference between caribou groups of different age and sex compositions to the pipeline structures. For instance, groups of adult bulls or mixed herds with a large proportion of adult bulls, regardless of their size, frequently paralleled the elevated obstructions to the terminals, bypassing all crossing sites in their travels. Nursery bands, on the other hand, depending upon their size, would remain for longer periods of time against the barriers, investigating and using the crossing facilities more frequently than the former groups. Their movements, however, were greatly influenced by the pipelines. Original courses were mostly diverted along the structures and their direction usually reversed, especially for the larger group sizes.

Since crossing success of groups is significantly correlated with the size of the group, it was important to further investigate the social aspects of the group encounters that may have influenced the crossings. The study may also disclose whether or not selection for particular group size(s) results when either a) a group encounters and successfully negotiates the pipelines, b) groups after being separated at the fence, reunite successfully, or c) when two groups simultaneously encountering the fence from opposite sides unite at the

Table 2. Comparison of the Crossing Success of 110 Groups of Caribou of Different Sizes and Individual Animals Observed at Alyeska's Simulated Pipeline in 1971 and 1972.

Size of Group	Number of Groups	No. Groups Ramps	Successfully Underpasses	Crossing at Total	No. Groups Unsuccessful
Individuals	34	8	13	21	13
(2 - 5)	52	6	13	19	33
(6 - 10)	18	3	2	5	13
(11 - 15)	6	0	0	0	6
(16 - 20)	4	1	0	1	3
(21 - 25)	4	0	0	0	4
(26 - 30)	4	1	0	1	3
(31 - 35)	3	0	0	0	3
(36 - 40)	2	0	0	0	2
(41 - 45)	0	0	0	0	0
(46 - 50)	2	1	0	1	1
(51 - 400)	11	0	0	0	11
(401 - 1,500)	4	0	0	0	4
Totals	110	12	15	27	83

Table 3. Comparison of the Crossing Success of Individual Animals and Groups of Caribou at Alyeska's Simulated Pipeline in 1971 and 1972.

Size of Group	Number of Groups	Number Successfully Crossing the Pipeline	Number Not Crossing Pipeline
Individuals	34	21	13
(2 - 1,500)	110	27	83

crossing facilities. Twenty-nine of the 110 encounters were reclassified into two categories for study of the social factors that facilitate inter- and intra-group cohesion at the crossings. The categories used were a) interactions between members of the same groups which had been separated by the pipeline, and b) interactions between separate and distinct groups that simultaneously encountered the structure from opposite directions. In the former category, 8 (35 percent) of the 23 groups observed successfully reunited after initial separation. In the latter category, 3 of the groups coalesced; the others, unable to unite due to the presence of the fence, departed their separate ways. Lent (1966) discussed the importance of such social factors as inter-group activity, size differences between groups, and visual contact between groups, that can stimulate groups of caribou to a) coalesce, b) synchronize inter-group activities, and c) cross natural terrain features, which are important to the formation of large aggregations at the end of the calving season and in the establishment of well-defined pathways of movement after calving. On the contrary, both groups would run parallel to the structure equidistantly and in unison to the terminals, suggesting that the groups are reacting simultaneously to each other's escape behaviors (cf. Lent 1966). During these encounters, vocal contacts were frequently maintained by both groups across the barrier. Occasionally, visual contact was established as well, especially where topographic irregularities permitted the animals to see over or under the fencing. Bergerud (1971) and Lent (1966) have also argued that social facilitation and the following response operate strongly between members of the same and different groups of caribou when crossing and coalescing at natural terrain features. In the remaining 81 groups, 16 groups (20 percent) in response to the precedent of leadership, successfully negotiated the pipelines at the ramps and underpasses. The other 65 groups of caribou, however, did not cross the pipeline at any facility. Interestingly, in these latter encounters, 18 of the groups did not follow similar precedents set at the crossing facilities, and as a result, did not cross the pipelines.

Caribou generally seemed reluctant to overcome these features set in their pathway. Their unfamiliarity and resultant confusion upon initial confrontation with the obstructions may have taken precendence over their otherwise normal responses to natural terrain features to discourage any attempts to cross. Nevertheless, it should be pointed out that although inter-group social facilitation was not strong enough to stimulate successful crossing of the obstructions and coalescence of the groups, it did maintain some synchrony of activities within those groups that moved parallel to the structures and between those groups that although separated, simultaneously encountered and paralleled the simulation.

Crossing success of groups was also found to be significantly associated ($X^2 = 13.55 > X^2_{0.05(1)} = 3.84$) with the sex of group leadership. Groups under female leadership made greater use of the crossing facilities at the pipeline ($P < t \alpha [\infty]$) than groups led by bulls. Groups under male leadership, however, showed a greater tendency to avoid the structures and by wide detours, sought access to the other side around the terminals (Table 4).

Significant associations are described for crossing success of animals with a) increasing densities of biting insects, b) progression of the summer season, and c) number of occasions that caribou were present at the obstruction in 1972 (Appendix B).

Insect data collected at the tower sites were not applicable in the statistical analysis, since the observers were considerably above the level of the caribou and under different microclimatic conditions. However, biologists with the International Biological Tundra-Biome

Program sampled insect populations throughout the summer at Prudhoe Bay. Densities of biting insects (mosquitos and tabanid flies) were described subjectively by landing index methods (Hopla 1964) on a daily basis for the duration of the insect season, late June to late August. Initial density ratings were subsequently transposed to a linear scale from zero to ten for use in the computer analysis. The number of occasions that caribou experienced the pipeline was determined a) by identifying animals present within groups at the simulations according to recognizable dye patterns or diagnostic features (antler characteristics) of individuals, and b) by following the coalescence and movements of caribou groups within the oilfields when insect densities were intolerable, and observing their dissociation, and then relocating them on their return inland through road and aerial surveys. Reports from several biologists with the Tundra-Biome Program also confirmed observations that animals present at the pipeline had repeatedly traversed the oilfields in an oscillating fashion for the duration of the summer; their movements being mostly predictable on the basis of wind, temperature and insect conditions (Thomson 1972b). Time was also considered to be an important variable for study. It can be argued that caribou experience a greater motivation to move with the progression of summer and the onset of migrational stimuli. As a consequence, it may be argued that caribou beset with these drives may begin to cross obstacles more freely. Therefore, the complete time period recorded was from initial confrontation of caribou at the fence (Day 1) to the final confrontation (Day 24).

The data were fitted by computer analysis to multiple linear regression models and an analysis of variance performed to describe the best combination of parameters that could explain the most variation about the regression line. From the computer output (Appendix B), neither time, nor the number of occasions that caribou had experienced the fence could account for as great a deviation in the regression sum of squared term as did insect attack. The results therefore support the hypothesis that successful use of the crossing facilities by caribou on their summer range is primarily related to insect harassment. The duress experienced by the animals during the insect season motivates their coastal movements. As a result of this discomfort, the caribou herds were being driven against the simulation. As a consequence, caribou began to make greater use of the ramps and underpasses in order to gain access eastward to the coastal areas. On their return from Heald Point or the delta of the western channel of the Sagavanirktok River, the caribou herds generally paralleled the length of the simulation to its south end. At these re-encounters, insect harassment was minimal and at most times, negligible. The frequency of crossing success for these movements was much less than for the western encounters (Figs. 13,14,16). However, there is evidence in the data (Fig. 16) that suggests caribou began to make increasingly greater use of the crossings, especially the ramps, in order to negotiate the pipeline and return west. This may suggest that caribou were beginning to recognize the crossing facilities as avenues of access to the other side or that they were learning to use these alternate methods rather than the terminals for crossing. Also, because of the lateness in the summer season and the approach of migration to wintering areas, the animals may have been experiencing a greater motivation to move westwards, and as a result to cross the pipeline with increasing frequency. However, the majority of the animals that did not negotiate the pipeline successfully on these confrontations from the east paralleled the simulation and rounded its south end to return to the west (Figs. 14,15).

At BP Alaska's feeder pipeline, this same differential response of caribou to the structures as a result of insect densities was also manifested. Consequently, the same wind-insect relationship can partially explain the movement patterns and behavior of caribou witnessed at the pipeline (Figs. 13, 15); but these animals had previously experienced both Alyeska's and BP Alaska's pipelines prior to their return to the latter site. Observed responses may therefore be reflective of these former experiences and of experiences with various intervening terrain features. Most noteworthy of these confrontations with the pipeline is the increased use of the low profile ramp structures and the one incident of a caribou "crawling" beneath the pipeline (Fig. 13). With insects mostly absent during the eastern confrontations, the animals approached, investigated and began to cross the pipeline at the ramp crossings. Such behavior again suggests that animals may be learning to associate the discontinuities in the skyline profiles of the pipeline at the ramps as sites for access to the other side of the structure.

Animals that successfully crossed Alyeska's pipeline used ramp structures more frequently than passing beneath the simulation at the underpasses in both years (Table 5). Also, the use of the ramps by caribou for crossings increased significantly between both years ($P = 0.16 < t\alpha[\infty]$). Elevated sections of pipeline were usually

Table 4. Comparison of the Crossing Success of Caribou Groups at Alyeska's Simulated 48-inch Pipeline in 1971 and 1972 Considering Sex of Group Leadership.

Sex of Lead Animal	No. of Groups	No. and Percent of Groups Crossing	No. and Percent of Groups not Crossing
Male	50	4 (8.0)	46 (92.0)
Female	60	23 (38.3)	37 (61.7)
Totals	110	27 (24.5)	83 (75.5)

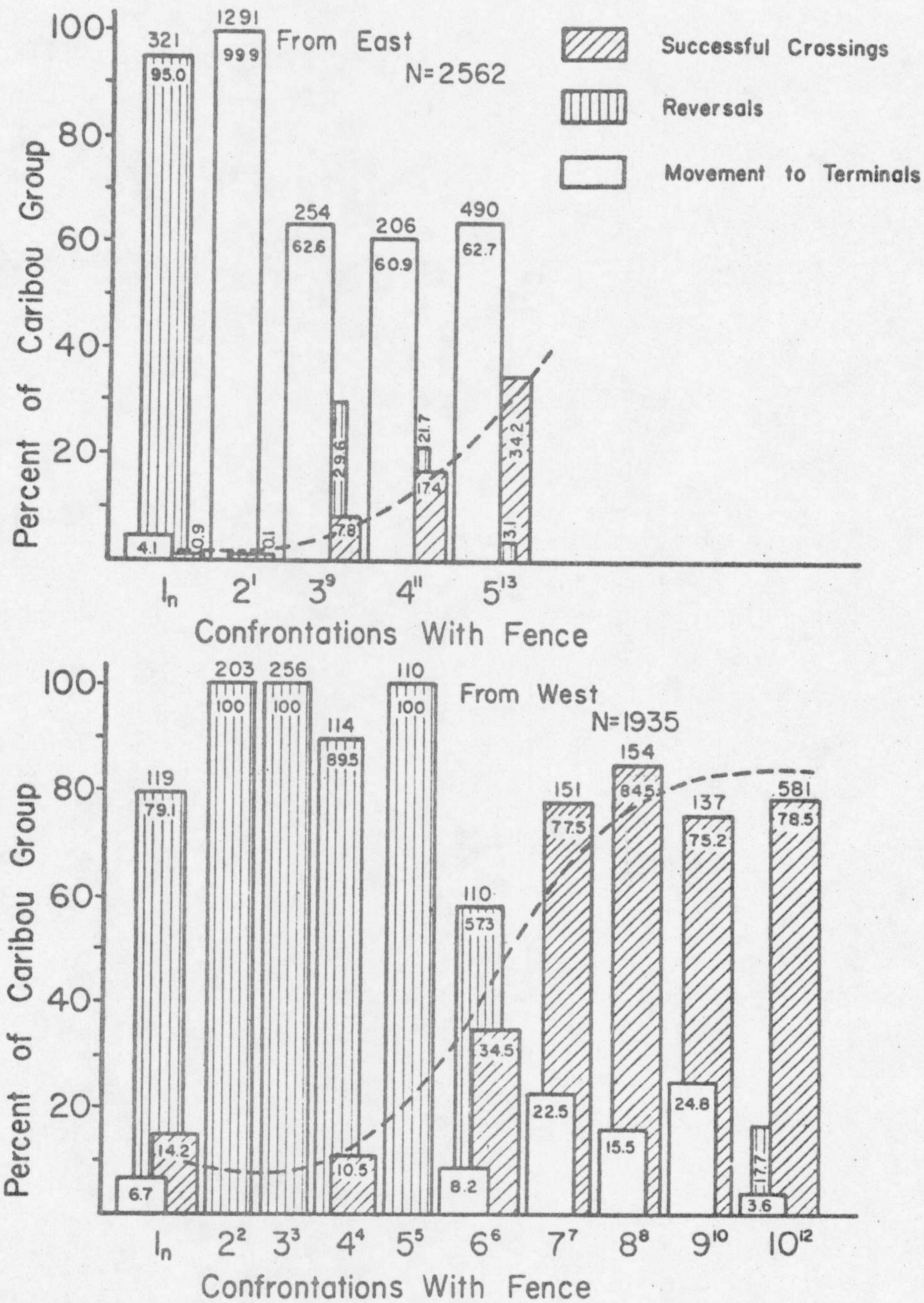


Figure 16. Change in the crossing success of caribou at Alyeska's simulated pipeline in 1972 related to a) direction of travel of approaching animals and b) number of occasions caribou were present at the pipeline. Superscripts denote the consecutive order of confrontations of caribou at the pipeline during the summer of 1972. 1_n represents the "initial" confrontations of caribou with the fence from both directions. Movements of caribou from the west were under insect harassment.

Table 5. Comparison of the Frequencies of Use of the Crossing Facilities by Caribou to Cross Alyeska's Simulated 48-inch Pipeline in 1971 and 1972.

Year	Total No. Animals at Pipeline	No. Animals Crossing Successfully	No. of Animals Crossing Pipeline at Ramps	Underpasses*	No. Animals Reversing Movements	No. Animals Moving to Terminals
1971	1102	196(17.8)	136(69.4)	60(30.6)	616(55.9)	283(25.7)
1972	4497	1071(23.8)	858(80.1)	213(19.9)	1308(29.1)	2089(46.5)
Totals	5599	1267(22.6)	994(78.5)	273(21.5)	1924(34.4)	2372(42.4)

* In 1971, 7(0.6) caribou crawled beneath the fence. In 1972, 29(0.6) animals crawled under the fence.

avoided by most animals, and as a consequence, they were used infrequently to cross the pipelines. Ramps apparently serve as the better method to facilitate caribou crossing pipelines. At the feeder pipeline (BP) simulation, both ramps might have received greater use by caribou if the cable leads had been replaced by more stationary materials in order to minimize wind movements in the structures, thus reducing the disturbing effect this had on the caribou (C.A. Smith 1972; pers. comm.). Nevertheless, caribou apparently must experience some motivational drive to overcome their reluctance to approach the obstructions before using the provisions to cross the pipelines.

One of the most important aspects of the study concerned the responses of maternal cows and their calves to the simulated pipelines and their crossing structures. For purposes of this investigation, the responses of parous cows and their calves on initial confrontations with the simulations and, the fate of the cow and calf when and if either member of the pair became separated at the pipelines were emphasized.

During the course of the study, 42 separate cow-calf pairs were observed confronting the pipelines. Twenty-three cows with their calves successfully negotiated the simulations at the crossings, the calves usually "heeling" to the cows as they crossed. The remaining 19 pairs were separated while attempting to negotiate the simulations but successfully reunited at a later time. The period of separation varied considerably from a minimum of several minutes to a maximum of 2 hours and 13 minutes. Responses observed were highly variable. Generally, the calves although highly exploratory in their behaviors (cf Lent 1966), would seldom divorce themselves from their dams and negotiate the obstructions in lieu of the cow's leadership. When separated from their calves, however, the cow would intensely search the site of the simulations. Since visual contacts were mostly limited by the obstructions, cows usually located their calves vocally. Reunions of cows and calves occurred most frequently beneath the fence (20-inch clearance) rather than at the crossing facilities. Of the 19 separated pairs, 13 cows took the initiative to crawl beneath the simulation to join their calves, and rather than return to the original side of the obstruction, they moved away from the pipeline. Because cows on occasion passed beneath the obstructions, it did not necessarily mean that the calf would follow the lead of the cow and cross the structure also. For example, in six of the observed separations, the cows had successfully moved beneath the obstructions at the underpasses, but the calves would not follow. After repeated attempts of the cows to attract their calves beneath the overhead obstacle failed (cf. Lent 1966), the cows returned, retrieved their calves, and rather than attempting to lead the calves beneath the pipeline again, moved to the terminals of the structure.

This study was conducted during the summer months when the caribou were present on their traditional summer range on the North Slope at Prudhoe Bay. Behavioral responses observed and reported are therefore essentially characteristic of this time period in the annual cycle of caribou. Rangifer, however, shows definite sexual and seasonal response differences to environmental stimuli (Harper 1955; Lent 1966 ; Kelsall 1968; Thomson 1972a). Consequently, in light of the species' seasonal variation of response thresholds, the validity of extrapolations of these results to caribou-pipeline confrontations at other seasons of the year is questionable, and the results largely speculative. Therefore, because of the seasonal limitation on this study, an investigation of the reactions of semi-domesticated reindeer to a large-diameter pipeline on the Seward Peninsula, Alaska was initiated. That study is co-sponsored by the U.S. Bureau of Land Management, U.S. Bureau of Indian Affairs, U.S. Bureau of Sport Fisheries and Wildlife, and the Alaska Department of Fish and Game. The investigation is currently being conducted by personnel of the Alaska Cooperative Wildlife Research Unit, University of Alaska, Fairbanks. Results of these experiments will be reported in a separate completion report to the above agencies at a later date.

SUMMARY

1. The Prudhoe Bay oilfield is situated on historic range of caribou. The area is important summer range, insect-relief habitat and lately, calving grounds for a small population of approximately 3,000 animals that utilizes the area.
2. The oilfield is characterized by occasional large scale and intermittent movements of thousands of caribou. These movements usually coincide with major population shifts between the Arctic and Porcupine caribou herds, to the west and east respectively. These large-scale movements are mostly unpredictable in nature and infrequent in occurrence but typify most of Alaska's major caribou herds and are historically characteristic to the Prudhoe Bay area of the Central Arctic.
3. Two pipeline simulations were constructed at Prudhoe Bay with various experimental methods of passage for caribou movements on their summer range. Studies of the behavioral responses of caribou to the structures were conducted during 1971 and 1972 to appraise pipeline designs necessary to permit unimpeded movements of caribou.
4. Caribou groups were aerially sprayed with three commercial fabric dyes within a 35-mile (56.4 km) radius of Deadhorse to facilitate behavioral oberservations and permit mapping of summer movements of caribou through the Prudhoe Bay oilfield in 1972.
5. A minimum of 159 animals of a total of 478 attempted, were marked and color-coded geographically. Throughout the study period, 48 dyed animals were sighted within the oilfield.

6. The majority of caribou approaching the pipelines in 1971 and 1972 showed a tendency to avoid the structures. At Alyeska's simulated 48-inch pipeline, of a total of 5,599 animals observed approaching the structure in 1971 and 1972, 994 (17.6%) used the ramps; 273 (4.9%) used the underpasses; and 36 (0.7%) passed beneath the fence in order to gain access to the opposite side of the simulation whereas 1924 (34.4%) reversed their original direction of movements at the pipeline and 2372 (42.4%) moved to the terminals of the structure. At BP Alaska's feeder pipeline mock-up, of 1,362 animals observed at the simulation, 92 (6.8%) passed beneath the pipe; 113 (8.3%) used the low-profile ramps to cross the pipeline; 129 (9.5%) caribou reversed their movements whereas 1,028 (75.4%) animals moved around the ends of the pipeline to the other side.
7. Crossing success of caribou groups over the pipelines is significantly correlated with size and composition of the group, and sex of group leadership.
8. Individual animals successfully crossed the pipelines more frequently than groups of caribou at the crossing facilities.
9. Inter- and intra-group social facilitation was not strong enough to stimulate successful crossing of the obstructions and coalescence of separate and distinct groups that were separated by the pipeline. Nevertheless, it did maintain some synchrony of activities between separate and distinct groups that simultaneously encountered and paralleled the simulations to the terminals.

10. Crossing success of caribou that repeatedly encountered the pipeline throughout the summer is significantly correlated with increasing densities of biting insects, number of occasions when animals were present at the simulations, and time of the season.
11. From a computer analysis of multiple linear regression models and by an analysis of variance, the best combination of the three parameters was described to explain the most variation about the regression line. Density of biting insects was found to be the one environmental parameter that could greatly influence the crossing success of animals over the simulation.
12. Time of the season and the number of occasions animals experience the pipelines were found to be less important influences on crossing success although the data suggest that caribou begin to make increasingly greater use of the crossing facilities at periods of low insect densities. It can be hypothesized that the animals a) may be learning to associate the passage provisions as crossing sites over pipelines because of their earlier experiences with the structures, and b) as the season advances toward the approach of migration, the animals may experience greater motivation to move, and consequently use the crossings more frequently.
13. Ramps appear to be the better method to facilitate crossings of caribou over the pipelines. Underpasses are generally avoided and infrequently used by caribou to negotiate the obstructions on their summer range.

14. Increasing use of the ramps between both years may be attributed in part to the improvement in the designs of the structures themselves.

15. Responses of cows and their calves to pipelines are variable. Calves, however, generally do not cross the pipelines without the company of their dams. Cows and their calves often were separated by the obstructions, but after a relatively short period of separation, they reunited successfully.

16. The behavioral data collected in this study specifically concern responses of caribou on their summer range and at post-calving time to pipeline structures. Rangifer, however, shows definite sexual and seasonal response variations to environmental stimuli. Consequently, the validity of any extrapolations of these results to caribou-pipeline encounters at other seasons is questionable and the results largely speculative.

17. A related study of the reactions of semi-domesticated reindeer to simulated pipelines on the Seward Peninsula, Alaska, is currently being conducted by personnel of the Alaska Cooperative Wildlife Research Unit. Results of these studies will be included in a separate completion report to the sponsoring agencies.

RECOMMENDATIONS

1. Traditional trail systems of caribou should be mapped along all proposed pipeline and roadbed rights-of-way by study of aerial photographs. Conflict sites between proposed construction and caribou traditions should then be determined by study of a series of map overlays prepared for the caribou migrations, gas and oil pipeline routes, and electric powerlines.

2. If a planned pipeline route will intercept traditional migrations perpendicularly, then several crossings (not less than three) should be constructed equidistantly from each other within the right-of-way to serve the traditional movements.

3. Where feasible, crossing structures within the feederlines should be constructed of maximum breadth to provide the greatest possible opportunity for caribou to successfully negotiate the pipelines and to allow for the simultaneous passage of large groups of animals.

4. Above-ground pipelines should be elevated at minimum possible ground clearances in order to a) minimize the optical barrier that the pipe presents for caribou, and b) to facilitate the approach and use of the crossing structures by caribou.

5. At Prudhoe Bay, caribou traverse the tundra by following leads of natural terrain features such as river channels, the edges of lakes and thaw ponds, and the ridges of low center ice polygons. Consequently caribou crossings may be strategically located along pipelines where the right-of-way may promise to intercept, encompass, or follow these natural terrain features. If, however, it is not possible to build a crossing at some of these locations, then the pipeline should be constructed not less than 50 yards from a body

of water to reduce the likelihood of topographic confinement of caribou between the confluence of the pipeline and the terrain feature.

6. The frequency of crossings along any pipeline depends on the traditional use of the area by caribou as indexed by the density of trails traversing the area, and on the environmental setting of the pipeline itself. In areas of more uniform landscapes, crossings should be located as frequently as possible along the pipeline. The resulting discontinuous profile of the pipelines may facilitate the animals to approach and cross the structures more freely.

7. Gravel ramps constructed over large diameter pipelines should be of maximum width, with slopes not exceeding 6:1 as a minimum. Diversional leads could be used at all ramps to facilitate animal crossings. More experimental work should be conducted on the use and design of the leads either on present pipeline simulations or on the actual crossings once the operational pipelines are built. The leads should be constructed of stationary materials to reduce wind movements. Also, if leads are incorporated into the design of the crossings, several alternative types are worthy of consideration; all should be of relatively low profiles to minimize the optical properties at the crossings, however. Designs for experimental consideration should include: a) simulation of trail systems over the gravel ramps, b) during winters, dark materials, such as black powder, can be spread over the ramps to simulate trail systems or else, with snow machines, trails can be made in the snowcover to lead animals across the pipelines at the ramps, and c) planks or timber can be placed on the tundra adjacent to the ramps in order to lead approaching animals to the crossings.

8. Vegetated ramps are feasible, but because of their artificial and temporary nature and need for continuous maintenance and reseeding, they are economically and biologically impractical. Unwanted concentrations of animals could occur against the pipeline or on the ramp, and as a result of trampling, increase the possibility for erosion and consequently endanger the integrity of both structures.

9. Gathering centers as the focal points of the feeder and transit pipelines should be "fenced-off" from caribou. A series of diversional leads could be placed around each center to divert migrations to nearby crossing sites. Also, the center should be made totally inaccessible to caribou to prevent migrating animals from becoming trapped between the confluences of the feeder and transit pipelines.

10. Further research is needed for insights into a) snow phenomena about pipeline structures and their influence on caribou movements, and b) seasonal response differences of barren-ground caribou to pipelines.

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APPENDIX A

Statistical Computations and Procedures Used for Tests of Hypothesis

I. Test of Independence of Two Properties Using the G-test

II. Testing for the Equality of Two Percentages and Independence of Two Properties

1. Test of independence of two properties using the G-test.

In Table 2, we examine as the null hypothesis whether the crossing success of the 110 groups of caribou observed at Alyeska's pipeline in 1971 and 1972 is independent of the increasing sizes of of the groups. Since there are more than two rows and columns, the computation of the test of independence by the ordinary chi-square test becomes rather tedious. The value of the test statistic X^2 can best be computed by using the preferred G-test (Sokal and Rolf 1969a, pp 582 - 601).

$$G = 2 \left[\left(\sum f \ln f \text{ for the cell frequencies}\right) - \left(\sum f \ln f \text{ for the row and column totals}\right) + n \ln n \right]$$

that is, G-value = 2[sum of transforms of observed frequencies - sum of transforms of column sums of frequencies - sum of transforms of row sums of frequencies + transforms of total number of items in the set]. The transformations of all cell frequencies are found in Sokal and Rolf (1969b; pp 69 - 109; Table G).

Computational Procedures to calculate the G-value:

Quantity (a). Sum of transforms for cell frequencies:

$$= 33\ln 33 + 19\ln 19 + 13\ln 13 + 6\ln 6 + 5\ln 5 + 2(4\ln 4) + 2(3\ln 3) + 2\ln 2 + 4(1 \ln 1) + 11 \ln 11$$

$$= 115.385 + 55.944 + 33.344 + 10.751 + 8.047 + 2(5.545) + 2(3.296) + 1.386 + 26.377$$

$$= 268.916$$

Quantity (b). Sum of transforms for row totals:

$$= 52\ln 52 + 18\ln 18 + 11 \ln 11 + 6\ln 6 + 4(4\ln 4) + 3\ln 3 + 2(2\ln 2)$$

$$= 200.523 + 52.027 + 26.377 + 10.751 + 4(5.545) + 3.296 + 2(1.386)$$

$$= 317.926$$

Quantity (c). Sums of transforms for column totals:

$= 27\ln 27 + 83\ln 83$

$= 88.988 + 366.764$

$= 455.752$

Quantity (d). Transform of total number of items in the set:

$= 110\ln 110$

$= 517.053$

G-value = 2[Quantity (a) - Quantity (b) - Quantity (c) + Quantity (d)]

= 2[268.916 - 317.926 - 455.752 + 517.053]

= 2[12.291]

= 24.582

This value of the G statistic is to be compared with a X^2-distribution with (a-1)(b-1) degrees of freedon, where (a) is the number of columns and (b) the number of rows in Table 2. In this case, the degrees of freedom, df = (2-1)(11-1) = 10.

At the 5 percent level of significance, chi-square (X^2) with 10 degrees of freedom is 18.307 (Sokal and Rolf 1969b; pp 163 - 167). Since the calculated G-value is greater than $X^2_{0.05(10)}$ then G is significant at $\alpha = 0.05$, and we therefore reject the null hypothesis that crossing success of caribou groups is independent of the group size. Consequently, we can accept the alternative hypothesis that the observed crossings of the caribou groups is related to the size of the particular group.

II. Testing for the equality of two percentages and independence of two properties. Considering Table 3 as our example, we examine the data to determine: 1) if successful crossing of the pipeline at ramps or underpasses is independent of the size of the group. Here we compare successful use of the crossing facilities between individual animals and groups of caribou; 2) if the observed frequency of crossing performed by individual animals is significantly different from the observed frequency of crossings by the larger groups.

A. Computational Considerations and Procedures.

1. Unlike the calculations performed for the analysis of the data in Table 2, a conventional chi-square, 2 x 2 contingency test of independence is used to examine the association between crossing success and size of the caribou group (Sokal and Rolf 1969b; pp 585-591). The value of the test statistic X^2 can be calculated by the formula:

$$X^2 = \frac{(ad - bc)^2 n}{(a + b)\ (c + d)\ (a + c)\ (b + d)}$$

where a, b, c and d are cell frequencies in rows and columns, (a + c), (b + d) and (a + b), (c + d) are row and column totals, respectively and n is the grand total (Sokal and Rolf 1969b; pp 587).

Table 3. Comparison of Crossing Success of Individual Animals and Groups of Caribou at Alyeska's Simulated Pipeline.

Size of Group	Number	Successful Crossings	Unsuccessful Crossings
Individuals	34	21	13
(2 - 1,500)	110	27	83
	144	48	96

Substituting observed frequencies from Table 2 in the formula, calculated chi-square is 16.19. Comparing this value of observed chi-square with the critical value of X^2 with one degree of freedom at the 5 percent level of significance (3.84), we find that chi-square is significant. Since the observed X^2 is much greater than $X^2_{.05(1)} = 3.84$, we reject the null hypothesis that crossing success is independent of group size where a significant relationship for crossing frequencies observed between individual caribou and groups is described.

2. In order to test for the equality of observed frequencies of successful crossings between individual animals and groups of caribou, we test for a significant difference between the percentages of successful crossings calculated for each category. Statistical procedures are discussed in Sokal and Rolf (1969a; pp 607-608).

Calculations: The test statistic used is:

$$t_s = \frac{\arcsin\sqrt{p1} - \arcsin\sqrt{p2}}{\left[820.8\left(\frac{1}{n_1} + \frac{1}{n_2}\right)\right]^{1/2}}$$

where p1 and p2 are the proportions of the characteristic in the two samples, n_1 and n_2 are respective sample sizes, and 820.8 is a constant representing the parametric variance of a distribution of arcsin transformations of percentages.

Table 3 Comparison of Crossing Success of Individual Animals and Groups of Caribou at Alyeska's Simulated Pipeline.

Size of Group	Number	Successful Crossings	Unsuccessful Crossings	p (Successful Crossings)
Individuals	34	21	13	0.6176
(2 - 1,500)	110	27	83	0.2454

From Table K, (Sokal and Rolf 1969b; pp 129-136):

$$\arcsin\sqrt{0.6176} = 51.81; \quad \arcsin\sqrt{0.2454} = 29.69$$

By above formula,

$$t_s = \frac{51.80 - 29.69}{[820.8\ (1/34 + 1/110)]^{1/2}}$$

We compare t_s with the normal deviate in the table of areas of the normal curve (Table P, Sokal and Rolf 1969b; pp 157-158). If we use a two-tailed test, however, then after doubling the probability, we could also look up $t\alpha[\infty]$ for the Student's-t-distribution (Table Q, Sokal and Rolf 1969b; pp 159-162). At infinity, and critical value at 3.29 for Student's-t, alpha is 0.001. From Table P (Sokal and Rolf 1969b; pp 157-158), we obtain a value of P = 0.0001. Since the calculated P is less than alpha, we can conclude that the sample for individual caribou has a significantly higher percentage (frequency) of successful crossings at ramps and underpasses than the sample for groups.

APPENDIX B

Regression analysis used for statistical inferences on the relationship between the crossing success of caribou over the pipeline, and a) insect density, b) time period elapsed during the summer, and c) number of times animals were present at the simulation.

Table 1. Data collected in 1972 at Alyeska's Simulated pipeline for use in the computer analysis of multiple regression models to study the relationships between successful crossings of the simulation by caribou with a) progression of the summer season (time), b) number of occasions that animals present on the oilfield visited the site of the simulation, c) insect harassment, and d) direction of travel of animals when approaching the pipeline.

Date of Caribou Visitation at Pipeline	Number of Occasions Caribou Present at the Pipeline**	Total Number of Days Since the Initial Visit	Index to Insect Density	Total No. Animals at Pipeline	No. and Percent of Animals Crossing	Direction of Travel Towards Pipeline
July 8	Initial	1	0	119	17(14.2)	W to E
" 9	Initial	2	0	321	3(0.9)	E to W
" 10	1	3	0	1291	1(0.1)	E to W*
" 13	2	6	3.3	203	0	W to E
" 14	3	7	1.2	256	0	W to E
" 15	4	8	5.3	114	12(10.5)	W to E
" 17	5	10	1.8	110	0	W to E
" 21	6	14	6.5	110	38(34.5)	W to E
" 22	7	15	8.0	151	117(77.5)	W to E
" 23	8	16	9.3	154	130(84.5)	W to E
" 24	9	17	0	254	20(7.8)	E to W*
" 26	10	19	8.7	137	103(75.2)	W to E
" 27	11	20	3.5	206	36(17.4)	E to W*
" 30	12	23	10.0	581	455(78.5)	W to E
" 31	13	24	4.6	490	168(34.2)	E to W*

* Movements of caribou that once approaching the simulation from the west moved to the northeast and returning at a later time confronted the simulation on the east side.

** During the summer of 1972, caribou were observed to oscillate between the coastal plains and inland ranges depending on climatic conditions and insects. Animals would move northeast to Heald Point repeatedly during the summer under insect attack and as a result visit the simulation frequently. Based on these observations, presence of dyed animals amongst those caribou present at the fence and on reports from biologists with the IBP Tundra Program, it is assumed, for purposes of this analysis, that some animals of the total numbers counted at the fence, may have visited the sand dune area and the simulation a minimum of 13 times during the summer since July 10.

Table 2. Summary of the statistical procedures and calculated values from the regression analysis for the relationships between crossing success of caribou at Alyeska's simulated pipeline and the three parameters indicated.[a]

Order of Parameters in the Regression Analysis.[a]	Regressions Sums of Squares due to Each Parameter.	Calculated F-Value	Significance of the Regressions at $\alpha = 0.05$[b]
0 1 2 3	0: 11364.00	119.02	
	1: 6866.28	71.92	s.
	2: 491.55	5.10	n.s.
	3: 1.42	0.01	n.s.
0 1 3 2	0: 11364.00	119.02	
	1: 6866.28	71.92	s.
	3: 479.76	5.02	n.s.
	2: 13.21	0.14	n.s.
0 3 1 2	0: 11364.00	119.02	
	3: 3528.21	36.95	s.
	1: 3817.83	39.99	s.
	2: 13.20	0.14	n.s.
0 3 2 1	0: 11364.00	119.02	
	3: 3528.21	36.95	s.
	2: 1536.66	16.09	s.
	1: 2294.37	24.03	s.
0 2 3 1	0: 11364.00	119.02	
	2: 4033.06	42.24	s.
	3: 1031.90	10.81	s.
	1: 2294.29	24.03	s.
0 2 1 3	0: 11364.00	119.02	
	2: 4033.06	42.24	s.
	1: 3324.78	34.82	s.
	3: 1.42	0.01	n.s.

[a] Parameters considered in the computer analysis:

0: crossing success of caribou over the simulation,

1: increasing density of insects,

2: elapsed time during the summer season; recorded by number of days from the first visit of the simulation by caribou,

3: number of occasions that caribou within the Prudhoe Bay oilfield had visited the simulation.

[b] s. denotes a significant regression where the calculated F-value is greater than the F-statistic at (1,9) degrees of freedom and 5 percent level of significance = 5.12.

n.s. denotes a non-significant relationship.

The direction of travel from east to west as shown in Table 1 indicates that these animals had previously encountered the pipeline. Return confrontations were therefore considered as another experience. Consequently for the purposes of the computer analysis, the data for the east and west confrontations of animals with the simulation were not treated separately as indicated in Figure 16 in the text.

The computer program, "An abbreviated Doolittle Method For Calculation of the F-Statistic" by Dr. S. J. Harbo, Biometrician, Department of Wildlife and Fisheries, University of Alaska, was used for the multiple regression analysis. For further reference on the statistical procedures, the reader is directed to the text, Linear Computations by P. S. Dwyer, John Wiley and Sons, New York, 1951.

APPENDIX C

Descriptions of 19 Observed Cow-Calf Separations at Pipeline in 1971 and 1972

Descriptions of 19 Observed Cow-Calf Separations at Pipeline in 1971 and 1972.

July 10, 1971 -- Cow moves through underpass at 9:46 a.m.; calf follows 10 m behind cow and refuses to accompany dam. Cow moves out about 20 m from crossing and feeds, then turns to calf and grunts. Cow moves closer to underpass and attempts to attract calf through, but calf won't follow. Cow moves to calf (9:53 a.m.); both move west to sand dunes; calf at heels of cow.

July 11, 1971 -- At 12:09 p.m., cow moves over ramp to east side of fence. Calf about 15 m behind cow, fails to follow dam over ramp when cow moved out of sight below crest of the ramp. Calf moves along ramp and moves to fence. Cow approaches the position of the calf. Cow moves head beneath fencing, possibly in attempt to attract calf to follow. Calf makes no attempt to cross. At 12:19 p.m., cow crawls beneath obstruction (20-inch clearance) and reunites with calf. Pair move westwards to Spine road.

July 13, 1971 -- Cow and calf move northwards along the simulation south of first underpass. At 10:33 a.m., cow begins to feed in dunes about 30 m west of the fence; the calf moves towards structure and inspects the pipeline. At 10:38 a.m., the calf moves into wind trough between fence and sand dunes and moves beneath fencing to separate itself from its dam. Calf begins to run along fence repeatedly; attracts cow's attention. Cow breaks feeding activity, looks to fence, then moves to structure. Cow begins to trot southwards in response to calf. Animals run southwards along fence. Calf can be seen over top of fence, and because of sand dunes, both animals must see each other easily over the fence. At 10:47 a.m., cow and calf approach edge of lake approximately 1000 m south of the first underpass. Cow follows edge of lake and is led directly to the calf which was standing at the confluence of the lake and fence. At 10:53 a.m., cow puts head under the fence and pushing with hind legs, forces herself under the fence to her calf (clearance 21 inches). The pair run eastwards.

July 16, 1971 -- At 2:32 p.m., a calf moves beneath fencing about 200 m north of the fourth underpass. Cow feeding. Cow looks to fence and calf, possibly in response to latter's vocalizations and movement of calf's legs seen beneath the snowfence. Cow moves to fence, head up, head bobs, touches fence with muzzle, lowers head and looks to calf beneath the obstruction. Both begin to move northwards along the simulation. At 2:56 p.m., cow quickly lowers herself and pushes herself under the fence to join the calf. Both move eastwards.

July 18, 1971 -- A calf observed north of third underpass at 8:25 p.m. feeding. Cow on west side feeding. At 8:29 p.m., cow moves to fence, lowers its head and looks to calf, then begins to walk northwards along the fence, looking over the top of the fencing to calf. At 8:32 p.m., cow pushes itself beneath fencing and retrieves her calf.

July 23, 1971 -- Calf crawls beneath fence south of first underpass at 3:46 p.m. Moved to underpass, but would not pass through to join cow. Runs along east side of fence repeatedly. At 4:12 p.m., calf runs length of fence to south end of structure; cow follows calf southwards. At 4:25 p.m., cow moves beneath fencing, joins calf and both move south to end of structure.

July 28, 1971 -- Cow passes through second underpass at 4:45 p.m. and moves westwards amongst sand dunes; calf does not follow, but remains on the east side of the fence about 30.5 m north of the underpass. At 5:22 p.m., cow returns to pipeline about 400 m north of calf's position at the underpass. Cow moves along fence to calf. Calf would not pass beneath fence to join cow. Cow moves to underpass, faces calf, head bobs; calf refuses to join cow. At 6:58 p.m., cow moves through underpass; calf heels to cow and both move eastwards from fence.

July 29, 1971 -- Cow and calf separated at first underpass at 3:32 p.m. Calf refuses to follow cow. Cow moves to underpass, attempts to attract calf through, then moves to calf's position. Calf heels to cow and at 3:48 p.m., the pair depart from the structure.

July 14, 1972 -- At 1:35 p.m., three calves and four yearlings rest in the shade on the east side of the fence, approximately 600 m north of the fourth underpass. A group of 10 caribou are adjacent to these 7 animals, but on the west side of the fence. Two cows are immediately adjacent to the calves' position, one feeding, the other lying down. At 1:46 p.m., one cow (feeding) looks to fence, puts head beneath fencing and passes to the east side and her calf (34-inch clearance). Second cow at 2:06 p.m., rises, urinates, moves to fence and at the crossing site of first cow, moves under and joins the animals on the east side. The cows and calves feed; one calf nurses; then the four move eastwards from the fence. The yearlings remain in the shade of the fence. At 2:28 p.m., a third cow from the west passes beneath the fence. The third calf rises, runs to cow, and the pair move eastwards.

<u>July 14, 1972</u> -- At 3:48 p.m., threecalves lying against fencing at south end; two cows and yearlings feeding within 5 m of the fence on west side. On the east and immediately adjacent to the three calves, three other calves feed within the shade of the fence, and five cows feed within 10 m of the fence. At 4:08 p.m., one cow of the eastern group walks to the fence, lowers herself and pushes through and runs westward, followed by a calf. At 4:18 p.m., another 'western' calf passes beneath the fence. Cow from west group moves to fence, head bobs, moves north along fence, then lowering herself on "all fours," pushes through to the east side. Two cows with calves from east group move to end of fence and join the western group of animals. The third calf on the east, at 4:31 p.m., moves under the fence to the west, followed by the cow. Remaining two animals on east side of the fence move north to first underpass to gain access to the western animals.

<u>July 20, 1972</u> -- At 2:18 p.m., calf moves beneath snowfencing to east side of fence north of the first ramp. Cow is attracted to calf possibly a visual response to motion of calf's legs beneath fence. Cow moves to fence, vocalizes (grunts) repeatedly, head bobs, lowers head below bottom of the fence and looks to the calf (posture similar to attraction pose). Cow then (2:26 p.m.) lowers herself and in a quick motion, pushes herself beneath fence, joins calf and both run eastwards from the structure.

July 22, 1972 -- Of 151 animals, 107 caribou mostly cows, calves and yearlings were observed moving east beneath fourth underpass, under insect stress. The remaining animals crossed the simulation at the second ramp (7) and north end (37). All cows and calves, except for three cows and their calves crossed the simulation successfully as they moved eastwards through the underpass. The three cows, however, had moved beneath the underpass initially, but the calves refused to follow them. The cows returned and failing to atract their calves through, moved to the west side of the fence, and with their calves, moved southwards to cross to the east at the ramp, bypassing three underpasses in their travels.

July 30, 1972 -- During encounter of 490 animals on the east side of the fence, a calf was observed by C. Smith on west side of fence north of the second underpass. Apparently the calf had passed beneath the fence. The cow was reported on the east, moving diagonally towards the second underpass. The calf was about 3 m from the fence and feeding. The cow moved to the fence and with head uplifted, appeared to look over the fence to her calf. The calf moved to the fence and the pair moved southwards and reunited at the underpass, the cow moving through to the west side to unite with her calf.

Table 1. Summary of 23 interactions between caribou that were separated at Alyeska's pipeline in 1971 and 1972.

Date of Observation	Size of Group	No. Animals Separated from Group at Ramp	Underpass	Terminal	Site of Reunion*
July 6, 1971	3			1	---
July 8, 1971	12		1		Underpass
July 10, 1971	7	4			---
July 14, 1971	6		2		---
July 17, 1971	3		2		---
July 18, 1971	9		1		---
July 18, 1971	23		1		---
July 23, 1971	10		2		---
July 23, 1971	9			6	---
July 25, 1971	8			3	---
July 26, 1971	24		2		---
July 8, 1972	52		1		Underpass
July 8, 1972	79		3		Ramp
July 10, 1972	1295			4	Terminal
July 15, 1972	2	1	1		Ramp
July 21, 1972	110	21	9	8	---
July 22, 1972	151	10	107	34	Terminal
July 23, 1972	154	122	8	24	---
July 24, 1972	73		5		Terminal
July 24, 1972	68		3		Terminal
July 24, 1972	4		3		---
July 29, 1972	581	376	66	23	---
July 30, 1972	490	107	1	332	---

* Blanks indicate separated animals did not reunite with group.

Table 2. Summary of 6 Simultaneous Encounters between Separate and Distinct Groups of Caribou at Alyeska's Pipeline in 1971 and 1972.

Date of Observation	Size of Groups on: East Side of Pipeline	West Side of Pipeline	No. of Animals Crossing Pipeline to Join Either Group at Ramps, Underpasses, Terminals
July 4, 1971	12	5	2 to West
July 7, 1971	8	1	3 to West
July 10, 1971*	3	36	3 to West
July 23, 1971	7	30	0
July 14, 1972*	3	2	3 to West
July 17, 1972*	2	3	2 to East

*Denotes a successful union of both groups across pipeline. The others are not considered successful reunions by definition (Text, Page 13).