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SECOND INTERIM REPORT ON THE EFFECTS OF THE TRANS-ALASKA PIPELINE ON CARIBOU MOVEMENTS

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Raymond D. Cameron and Kenneth R. Whitten

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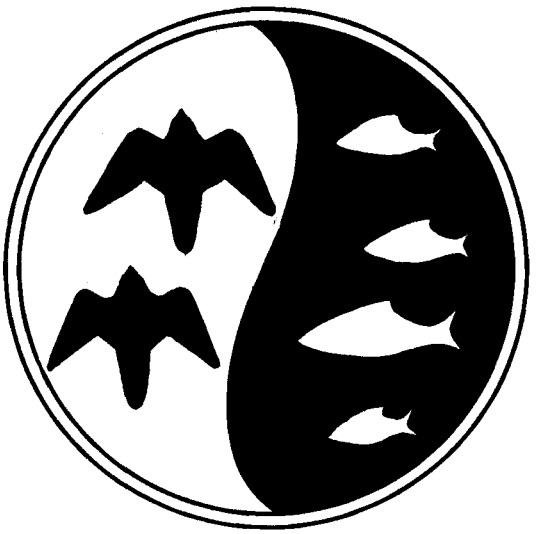

JOINT STATE/FEDERAL FISH & WILDLIFE ADVISORY TEAM

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SUMMARY

The north slope route of the Trans-Alaska Pipeline traverses the range of the Central Arctic caribou herd. Although movements of this subpopulation are basically north and south, they extend across the pipeline corridor during spring and fall migration and during post-calving movements in summer. In 1975 the seasonal movements of this subpopulation were determined using systematic aerial surveys. The results have been prepared for publication and appear as Appendix I of this report. This survey technique was again utilized in 1976 and, although weather-related differences in the onset and timing of movements were noted, no major changes in seasonal range occupancy were detected. Sexual segregation of the herd described in 1975 was also apparent in 1976.

In 1975 the mean percentage of calves observed in summer was approximately one-third lower than that obtained from concurrent aerial surveys of the adjacent region; fall means estimated from road and aerial surveys were similar. In both summer and early fall, mean latitudes calculated for groups with and without calves from the haul road were lower than for corresponding groups observed from the air, and an analysis of regional distribution of caribou determined from haul road surveys adjacent to the road and aerial surveys away from the road revealed differences in caribou occupancy and group composition. Few if any caribou were observed in northern sections of the haul road near Prudhoe Bay throughout the study, and calf percentages in summer were consistently lower for each of four arbitrarily established regions of the haul road than expected on the basis of aerial survey results; fall calf percentages did not differ appreciably. Mean caribou group size was generally lower along the haul road than in adjacent areas, suggesting corridor-related fragmentation of groups or interference with normal group formation. These results are presented in a separate manuscript, the text of which appears as Appendix II of this report.

Caribou avoidance of the pipeline corridor described for 1975 appeared to increase during 1976. Calf percentages determined from haul road surveys continued to be lower than those obtained from comparable aerial surveys, particularly during spring and summer. Sustained caribou avoidance of the Prudhoe Bay area was noted, and various abnormalities in group composition were observed in southern regions of the pipeline corridor. Caribou sighting frequency along the haul road and the observed rate of corridor crossings were generally lower in 1976 than in 1975. As in 1975, contact with and crossings of elevated pipe were infrequent. Results indicate that the herd is undergoing a separation into eastern and western components, each with largely independent north-south movements.

Data on sex and age composition of the Central Arctic herd show an unsually high proportion of bulls. Calf production is moderate, (ca: 44 calves/100 cows) and summer mortality is low. However, subsequent composition counts in July and October indicate a low winter survival of calves to yearling age.

CONTENTS

BACKGROUND

Studies of the effects of the Trans-Alaska Pipeline on caribou movements commenced in mid-1974 and, to date, major research efforts have been focused on that portion of the pipeline route between Prudhoe Bay and the crest of the Brooks Range. Initial surveys by air provided a general inventory of caribou numbers and, together with recent reports by other workers, furnished valuable clues on the patterns of seasonal movement. Ground surveys along the then-complete haul road began in September 1974 but were restricted to that portion of the proposed pipeline route between Pump Station 3 and Galbraith Lake. The pipeline was to be almost totally elevated in this region, and information on local caribou movements was required to finalize design and location of special big game crossings.

In 1975 aerial surveillance was more systematic than in the previous year, and six surveys were conducted between March and November. Each followed a specific route designed for representative sampling of caribou in the area, and coverage was duplicated to permit direct comparison of individual survey results over time. These and other concurrent observations strongly indicated the existence of a discrete caribou herd with a seasonal range roughly centered on the pipeline corridor. Information obtained on seasonal movements and group composition of this "Central Arctic herd" form a reference base for subsequent observations. These data were presented in preliminary form in a previous report (Cameron and Whitten 1976), and a manuscript was prepared which outlines the aerial survey technique employed and presents findings on seasonal movements and sexual segregation of caribou in this region of the central arctic slope (Appendix I).

Haul road surveys conducted in 1975 were also regular and systematic, covering the entire length of the corridor between Prudhoe Bay and Pump

Station 4. During summer the mean percentage of calves along the haul road was appreciably lower than that obtained during comparable aerial surveys, suggesting avoidance of the corridor by cow-calf pairs. However, no such differences in calf percentage were noted in fall. Throughout summer and fall few caribou were observed in northern sections of the haul road near Prudhoe Bay. These initial effects of the Trans-Alaska Pipeline on local distribution and group composition of caribou were described in a second paper which is given in Appendix II of this report.

Aerial surveys continued on a regular basis in 1976 to detect any major changes in seasonal movements and sex and age composition of the herd. Collaring of caribou, both with radio transmitters and visual identification, has continued and resightings have verified movement data obtained through aerial surveys. Haul road surveys were again conducted to identify any local differences in group composition and north-south distribution of caribou. In addition, sex and age composition of the herd was obtained in July and again in October, and represents our most reliable information in terms of initial calf production and early survival. This report summarizes recent progress in the above areas of investigation, including a brief analysis of the current trend in caribou avoidance of the pipeline corridor. Several other aspects of this investigation are in progress and will be dealt with only briefly, if at all. Graduate research on the daily and seasonal activity patterns of caribou is now complete and a master's thesis on this subject is in the final stages of preparation.

OBJECTIVES

In accordance with stipulations 2.5.4.1* and 2.5.3.1 of the Stipulations for the Agreement and Grant of Right of Way for the Trans-Alaska Pipeline, this project is designed to accomplish the following objectives:

To determine herd identity, general numbers, productivity, and seasonal movement patterns of caribou which range in the vicinity of the pipeline corridor.

To characterize movement behavior of caribou which encounter the haul road, pipeline, and construction-related activities.

To assess the effectiveness of special crossings in allowing for unrestricted movement.

PROCEDURES

Methods of aerial and haul road survey are given in Appendices I and II, respectively, of this report.

Aerial sex and age composition surveys were conducted with the aid of a helicopter. In July all groups classified were within 20 km of the

*"Leasees shall construct and maintain the pipeline, both buried and above ground sections, so as to assure free passage and movement of big game animals."

coast between the Kuparuk and Canning Rivers. In October all groups observed along the standard aerial survey route (Fig. 1 in Appendix I) were classified. Individuals within each group were identified on the basis of external genitalia, body size and/or antler development as bulls, cows, calves, or yearlings.

FINDINGS AND DISCUSSION

Herd composition and calf production/survival

On July 20-21 an estimated 4,000 caribou were observed in post-calving aggregation along the arctic coast between the Kuparuk and Canning Rivers, and a total of 1,386 were classified by helicopter. Calves constituted 18 percent of the herd, corresponding to a ratio of 43 calves/100 cows. Thirteen yearlings per 100 cows and 86 bulls per 100 cows were observed. Some error may have occurred in identifying all cows due to the imprecision of the total estimate, and because one particularly large group of 1,100 was not adequately classified.

Between October 12 and 15, 1,228 caribou were classified in the study area (Table 1). The standard aerial survey route (Fig. 1 in Appendix I) was chosen because of a pronounced north-south gradient in group composition; bull:cow ratios north and south of 70° latitude, respectively, were 59:100 and 268:100. Utilization of the pre-established route of coverage should, in theory, permit sampling of the herd in proportion to caribou density, thereby adjusting for any regional differences in composition (Appendix I). However, in the mountains and foothills where bulls predominated, caribou appeared to be concentrated in major river valleys and the survey probably yielded a disproportionately high number of caribou present in the area. Thus, reported figures may slightly overestimate bulls. However, it is clear that bulls are relatively numerous in this herd and we consider the July value of 86 bulls per 100 cows a minimum ratio. The true bull:cow ratio probably exceeds 1:1.

In October 1976 calf:cow ratios were consistent throughout the study area at 46 calves per 100 cows. This is slightly higher than the July figure (see above), indicating a slight error in one or both estimates. However, these data do indicate that calf mortality was very low between July and October 1976.

Numbers of yearlings per 100 cows observed in July and October, respectively, were 13 and 9. The July estimate indicates that winter survival of calves was low. A mean of 16 percent calves was calculated from total aerial survey observations during fall 1975 (Cameron and Whitten 1976). Assuming a constant proportion of other cohorts this corresponds to approximately 45 calves/100 cows, indicating an estimated over-winter calf mortality of 70 percent for 1975-76. In addition, a decrease in the yearling ratio between summer and fall 1976 indicates additional yearling mortality. Continued yearling mortality during a period of high calf survival is difficult to explain. However, during October composition surveys some large male yearlings may have been erroneously added to the bull cohort. Despite these inaccuracies, available data strongly indicate that winter mortality of calves is high

Table 1. Aerial surveys: caribou numbers and group composition, April-November 1976.

Survey Number	Incl. Dates	Total obs		Total Classified[1]					Groups with calves[2]					Groups without calves[3]			
		N	G	N	G	%B	%ca	%A	N	G	%B	%ca	%A	N	G	%B	%A
1	4/7-4/8	545	48	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	6/30-7/2	843	92	842	91	29	17	33	437	22	1	33	33	405	69	59	33
3	8/11-8/12	293	92	293	92	23	15	52	125	24	2	36	49	168	68	39	55
		Summer mean				27	17	36			1	33	36			54	39
4	10/12-10/15	1228[4]	186	1228	186	44	17	0	967	88	34	21	0	251	98	81	0
5	11/16-11/22	816[5]	101	-	-	-	-	-	509	55	-	-	-	158	25	-	-

[1] excludes "unknowns" (see Appendix I)
[2] total caribou in groups with one or more calves present
[3] total caribou in groups with no calves
[4] fall composition counts by helicopter
[5] only presence or absence of calves was noted

Note: N = number of caribou, G = number of groups, B = bulls, ca = calves, A = adults

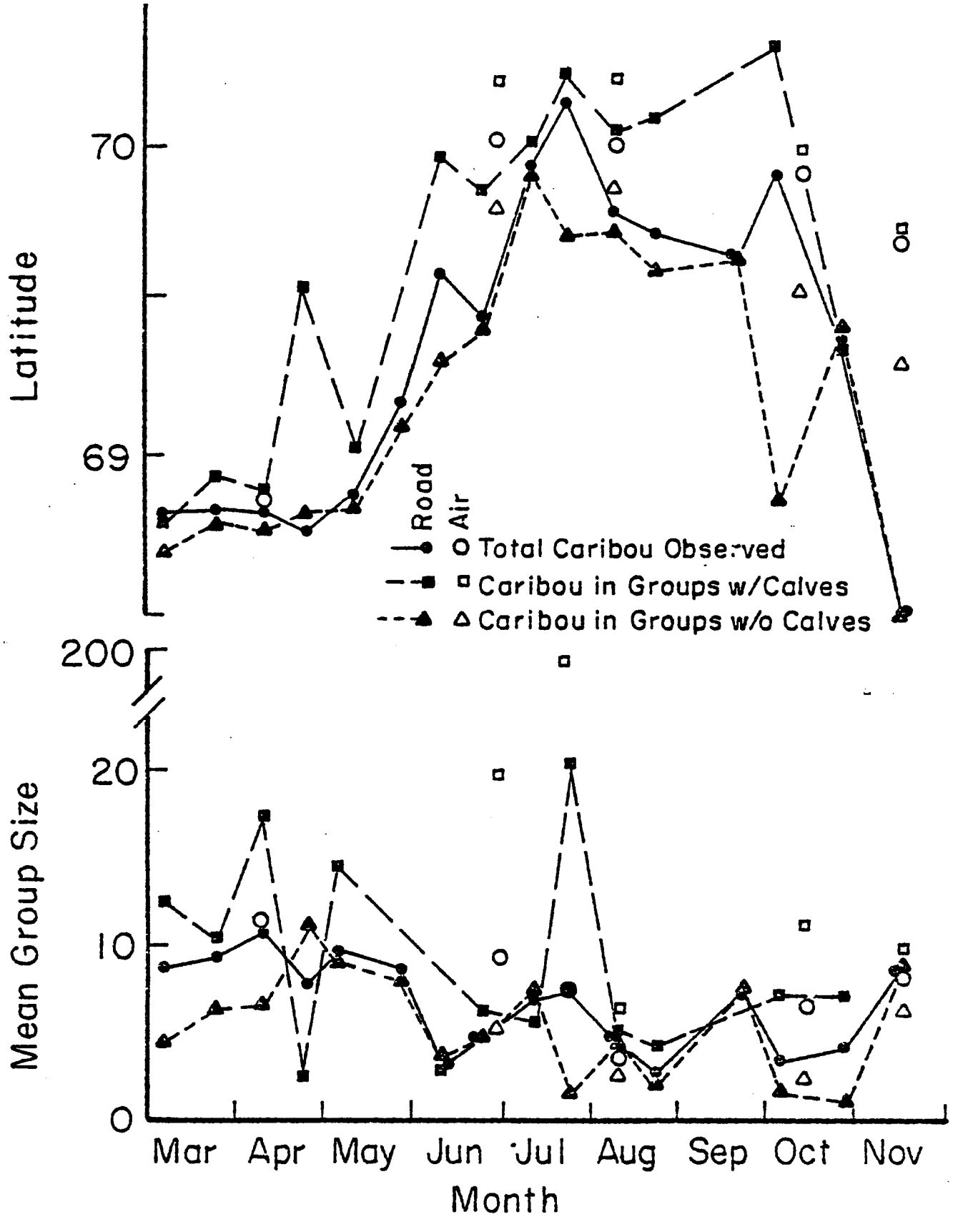

Fig. 2. Seasonal changes in mean latitudinal position of caribou along the haul road and a comparison with corresponding results from aerial surveys - 1976.

Table 2. Haul road surveys: caribou numbers and group composition, March - November 1976.

Survey dates	Total obs.		Total classified[1]							Groups with calves[2]							Groups without calves[3]					
	N	G	N	G	%B	%C	%Y	%ca	%A	N	G	%B	%C	%Y	%ca	%A	N	G	%B	%C	%Y	%A
3/3-3/5	105	12	56	7	5	38	4	14	39	38	3	3	47	5	21	24	18	4	11	17	0	72
3/24-3/25	179	19	79	10	28	17	0	10	45	41	4	15	20	0	30	35	38	6	34	16	0	50
4/5-4/10	218	20	135	12	54	13	5	9	19	88	5	32	19	7	15	26	47	7	85	4	2	9
4/25-4/26	123	16	80	8	44	1	3	3	50	2	1	0	0	0	100	0	78	7	45	1	3	51
5/10-5/14	213	23	208	21	90	3	1	3	3	44	3	68	16	0	14	2	164	18	95	0	1	4
5/24-5/28	362	43	305	38	86	8	5	0	1	0	0	–	–	–	–	–	305	38	86	8	5	1
		Spring mean			67	10	3	5	15			33	24	4	19	20			78	6	3	13
6/8-6/11	137	39	107	30	78	7	7	4	4	11	4	0	27	9	36	27	96	26	89	4	6	1
6/23-6/26	217	45	217	45	94	2	1	1	2	6	1	33	33	16	16	0	211	44	96	1	1	2
7/10-7/14	246	35	246	35	85	4	1	2	9	16	3	6	44	6	25	19	230	32	90	1	1	8
7/23-7/26	93	13	93	13	19	37	2	29	13	81	4	7	42	2	33	15	12	9	100	0	0	0
8/9-8/12	93	21	93	21	88	8	0	4	0	9	2	12	44	0	44	0	84	19	96	4	0	0
8/23-8/26	135	60	135	60	78	11	0	10	1	32	8	13	41	0	41	6	103	52	98	2	0	0
		Summer mean			79	9	1	6	5			10	41	3	34	12			94	2	1	3
9/21-9/22	15	2	15	2	73	0	0	0	27	0	0	–	–	–	–	–	15	2	73	0	0	27
10/7-10/8	10	3	10	3	40	30	10	20	0	7	1	14	43	14	29	0	3	2	100	0	0	0
10/28	8	2	8	2	38	38	0	26	0	7	1	29	42	0	29	0	1	1	100	0	0	0
11/19	9	1	9	1	100	0	0	0	0	0	0	–	–	–	–	–	9	1	100	0	0	0
		Fall mean			64	14	2	10	10			21	43	7	29	0			86	0	0	14

[1]excludes "unknowns" (see Appendix II)
[2]total caribou in groups with one or more calves present
[3]total caribou in groups with no calves

Note: N = number of caribou, G = number of groups, B = bulls, C = cows, Y = yearlings, ca = calves, A = adults

and yearling recruitment to the herd correspondingly low. Additional work on sex and age composition is scheduled for spring 1977.

Seasonal movements and group composition determined by aerial survey

Shifts in the center of caribou occupancy between spring and fall are shown in Fig. 1. In 1976 northern spring movements commenced later than in 1975 (see Fig. 2 in Appendix I), although by late June the majority of the herd was near the coast and corresponding centers of occupancy between the two years were not appreciably different. In both years a shift to the west was detectable between June and August, but displacement of the center of occupancy in 1976 was smaller, suggesting a decrease in the extent of western movements of the post-calving aggregation (see Appendix I). Past observations indicate that these movements previously extended through the Prudhoe Bay area in late July (Cameron and Whitten 1976), but during the past two years of study no large groups have been observed in the industrial complex north of Deadhorse (see Fig. 1).

In 1976 fall movements began later and were over a shorter distance than during the same period in 1975. The center of occupancy determined in November 1976 was located at the latitude of Franklin Bluffs (Fig. 1), whereas the corresponding center in 1975 was near Sagwon (Fig. 2 in Appendix I), a north-south separation of about 50 km. Differences in the timing and extent of seasonal movements probably reflect between-year variations in weather. During fall 1976 temperatures were unseasonally mild and snowfall was light until early November. Similarly, delayed northern movements in spring may be related to unusually late snowstorms and low temperatures. Despite the above differences in timing, patterns of caribou movement within the study area were similar during the two years of study, and centers of occupancy were within approximately the same range of distances from the corridor throughout spring, summer and fall.

Caribou numbers and group composition determined from aerial surveys are given in Table 1, and comparable data for 1975 are presented in Tables 1 and 2 of Appendix I. In August 1975 a larger proportion of calves was observed than in preceding or succeeding months. This may have been due to some egress of bulls, yearlings and nonparous cows which subsequently returned to the study area by September (Appendix I). In 1976 the proportion of calves remained constant at approximately 17 percent throughout summer and fall, and no partial egress was detectable.

The seasonal pattern of sexual segregation described in Appendix I for 1975 was also apparent in 1976 (Fig. 2). Groups of caribou with calves consistently occupied higher latitudes than those without calves. Also, as in 1975, increased mixing of the sexes was evident during the rut, with the proportion of caribou observed in groups with calves increasing from a summer mean of 50 percent to about 80 percent in October.

Distribution and group composition of caribou along the pipeline corridor

Caribou numbers and group composition observed during haul road surveys between March and November 1976 are shown in Table 2. Caribou

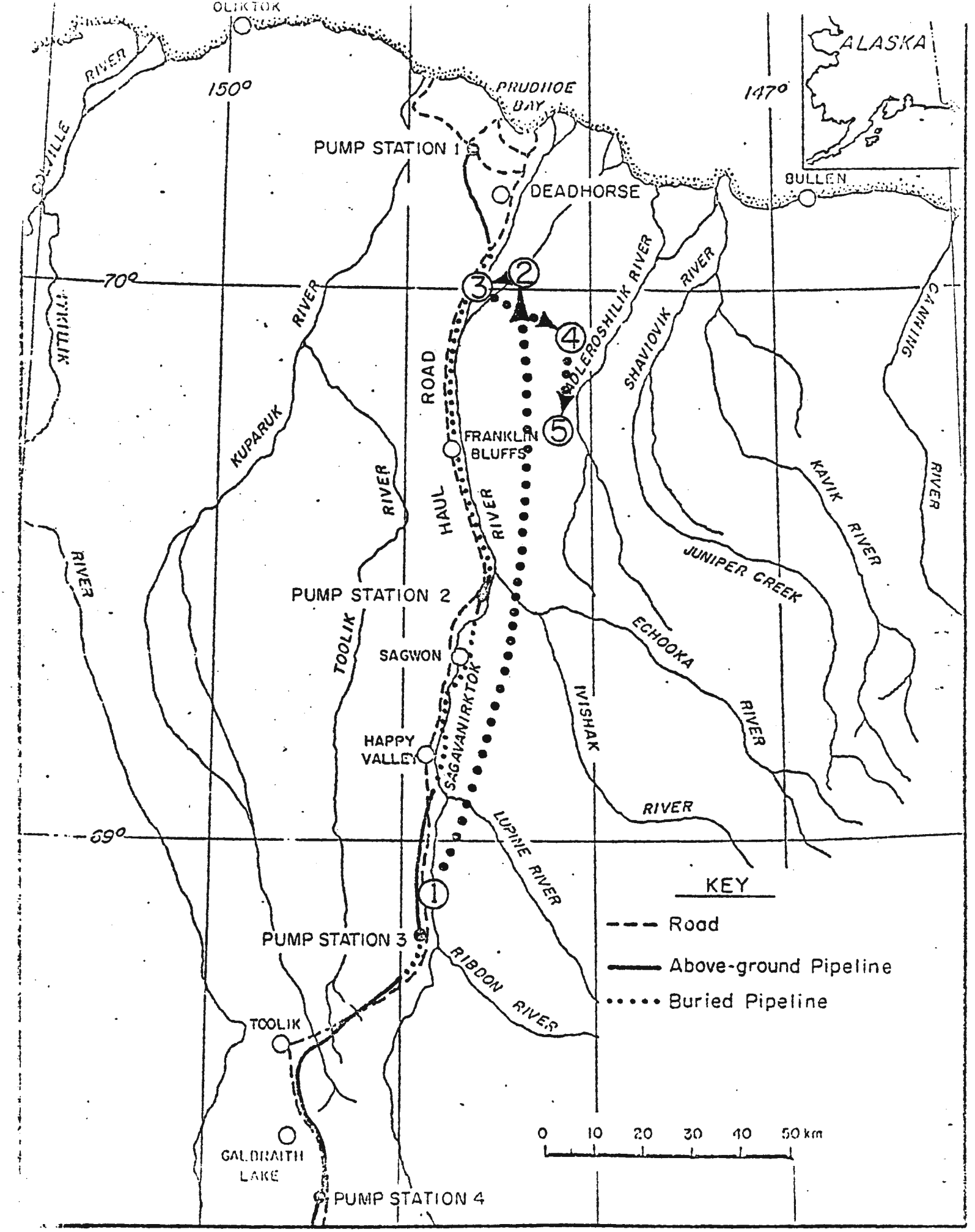

Fig. 1. Seasonal shifts in the center of caribou occupancy, April-November 1976. Survey dates are given in Table 1.

distribution and calf percentages determined from haul road surveys in 1975 were compared with corresponding data obtained by aerial survey (Appendix II). Major differences in composition for 1975 and 1976 are summarized in Table 3. In both years calves observed along the haul road during summer were present in substantially lower numbers than predicted from extensive aerial surveys. Lower overall calf percentages observed along the haul road are not due to a decrease in the relative number of calves in groups with calves (Table 3), but to fewer groups with calves being present (Appendix II). During spring 1976 the overall proportion of calves along the road was low (Tables 2 and 3) and, although no comparable data are available from aerial surveys, this partly reflects low over-winter calf survival. It is noteworthy, however, that the proportion of total caribou observed in groups with calves decreased steadily as spring progressed (Table 2), suggesting an increased sensitivity of cows to the pipeline corridor as parturition approached.

Fall calf percentages in 1975 were identical for road and aerial surveys, indicating a decrease in cow-calf avoidance of the corridor (Appendix II). In fall 1976 calf percentages were lower along the road than those determined from aerial surveys, but these values are questionable because of the small sample size (Table 2). Bulls predominated in groups without calves along the haul road in all seasons for both years (Table 1 in Appendix II; Table 2). Unfortunately, only mature bulls were identified during aerial surveys and results are not comparable.

Changes in mean latitude of caribou occupancy along the haul road were similar in 1975 and 1976 (Fig. 2). However, as discussed above, the onset of spring and fall movements was delayed in 1976. Within each year, mean latitudes determined for total caribou observations were generally higher for aerial survey observations than for haul road observations (Fig. 2 in Appendix II; Fig. 2). The more southerly distribution of caribou along the road is due both to differences in composition (i.e., groups with calves, normally located farther north, tend to avoid the haul road) and to a general avoidance of northern sections of the road. Although a similar analysis of comparative caribou distribution has not yet been made for 1976, the close agreement of movement patterns and changes in group composition suggests a similar avoidance response in 1976.

Changes in caribou occupancy and crossings of the pipeline corridor

By midsummer 1976 the number of caribou observed in the vicinity of the pipeline corridor was less than during the previous year. To demonstrate this change, the frequency of caribou sightings along the haul road was determined for each of three seasons in 1975 and 1976. Since bi-weekly road surveys were not always balanced with respect to north-south coverage, complete survey trips north from Happy Valley were paired with those to the south for each survey series (see Methods, Appendix II). A sighting frequency was calculated by dividing the number of caribou observations by the one-way distance covered. Values for each year were calculated on seasonal basis and are shown in Fig. 3. Relatively more caribou were observed in spring 1976 than during the same period in 1975. However, the sighting frequency declined sharply in summer 1976, whereas an increase is shown for summer 1975. Far fewer caribou were observed in

Table 3. Summary of major differences in group composition determined by haul road and aerial surveys, 1975 and 1976.

	1975					1976				
	Total Classified		Groups w/calves		Groups w/o calves	Total Classified		Groups w/calves		Groups w/o calves
	%ca	%B	%ca	%B	%B	%ca	%B	%ca	%B	%B
Spring										
Road	-	-	-	-	-	5	67	19	33	78
Summer										
Road	13	65	40	31	94	6	79	34	10	94
Air	21		35			17		33		
Fall										
Road	17	43	23	29	92	10[1]	64	29[1]	21	86
Air	17		21			17[1]		21[1]		

[1] = October composition counts only (no November figures available).

Note: ca = calves, B = bulls

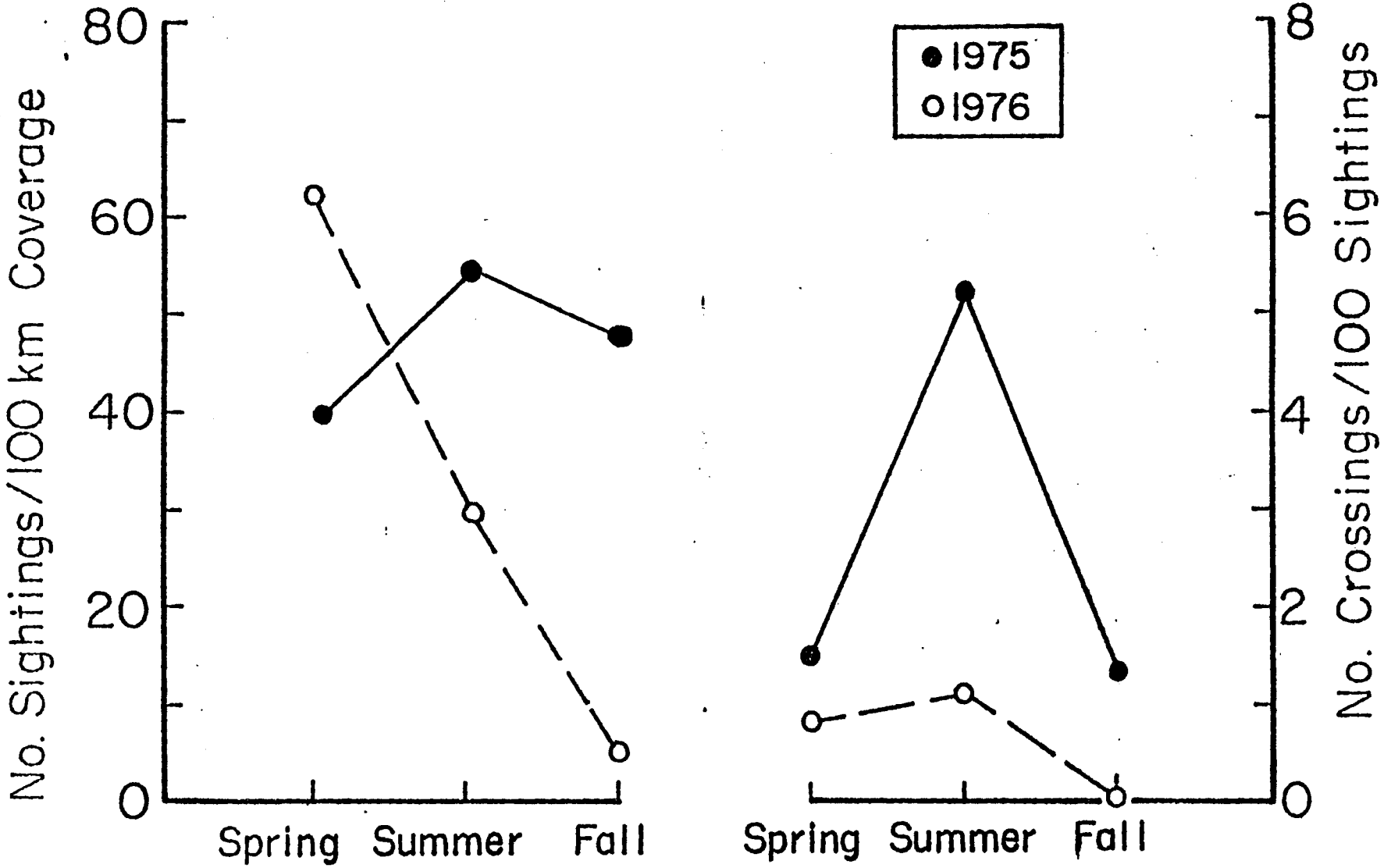

Fig. 3. Seasonal changes in caribou sighting frequency and corridor crossing rate, 1975-1976.

fall 1976 than during fall 1975. Thus, the results demonstrate an accelerated decline in caribou occupancy of the pipeline corridor during 1976.

The number of observed haul road crossings was also lower in 1976 than in 1975. A crossing rate (i.e., the ratio of observed crossings to total sightings) was calculated for each season (Fig. 3). Values followed the same trend in both years but were consistently lower in 1976. Hence, fewer caribou were seen along the corridor in 1976, and those present crossed the road less frequently. This was true even in spring 1976, when the sighting rate was relatively lower than in 1975.

As discussed above centers of caribou occupancy for 1975 and 1976 demonstrated similar seasonal trends of caribou movement and were located in similar positions with respect to the corridor (Fig. 2 in Appendix I, Fig. 1). Longitudinal distribution of caribou in the study area appears to be such that the herd overlapped the corridor to a similar degree in both years. Therefore, the lower number of caribou observed along the haul road probably did not result from a change in seasonal distribution of the herd, but rather reflects a general withdrawal of caribou from the corridor area itself. Associated with this local avoidance is an increasing reluctance to cross the corridor with its haul road and pipeline components.

Elevated pipe crossings

The paucity of observed caribou interactions with the corridor (Cameron and Whitten 1976, Fig. 3) continues to prevent formulation of specific conclusions regarding direct effects of the pipeline on movement behavior. Recorded contact of caribou with elevated pipe has varied with season, involving widely differing conditions of snow cover, habitat, insect conditions and construction-related activity. However, some generalizations can be made on behavior and between-year differences. In 1976, 16 group crossings of elevated pipe by 135 caribou were recorded; 5 individuals deflected (Appendix III). Eleven groups totaling 110 caribou were actually observed and the remainder were identified from tracks. Of the individual caribou crossings observed 80 were identified as adult bulls, 3 were cows, and 1 was a calf (a short yearling in this case). No crossings by cow-calf pairs were apparent from tracks.

Whereas the majority of observed crossings in 1975 occurred during intense oestrid fly harassment (Cameron and Whitten 1976), only one such incident was noted in 1976. In 1976 many adult bulls sought insect relief on gravel pads in Franklin Bluffs Camp and along the construction pad between Franklin Bluffs and Deadhorse, but very few caribou were seen near elevated pipe during the insect season. In 1976 the majority of crossings occurred during late spring, 16-22 km south of Happy Valley. Dust from the haul road accelerated the disappearance of snow in this area, exposing beds of *Equisetum* and triggering early growth of *Eriophorum vaginatum*. Caribou bedded on hillsides above the pipeline and periodically approached the pipeline or crossed under it to feed. No comparable observations were recorded in 1975. Many of the crossings in 1975 occurred during and immediately following rut (Cameron and Whitten 1976). In contrast, during fall 1976 a reduced occupancy of the

entire corridor was noted and only two crossings were recorded. Thus, caribou interactions with elevated pipe were markedly dissimilar in 1975 and 1976, but interpretation of the various changes is difficult due to between-year differences in the length of pipe erected and the intensity of construction activity.

The extent to which elevated pipe might restrict free movement of caribou was a major concern at the inception of this project. In reality, the question of crossing success has proven to be somewhat irrelevant due to general avoidance of the corridor. The majority of corridor crossings occur where the pipeline is buried, but local traffic and human activity may represent an equally serious or overriding impediment to caribou movements. When approaching and crossing either haul road or elevated pipe caribou frequently exhibit outward signs of stress. Given a choice for crossing location of elevated pipe caribou may select greater pipe heights (Cameron and Whitten 1976); however, along most of the route surface-to-pipe clearance does not vary appreciably over short distances. Of the special big game crossings in place on the arctic slope, only the special elevated pipe at the "ice cut" 16 km south of Happy Valley, has been utilized. To our knowledge, no "sag-bends" (i.e., short buried sections in otherwise continuous elevated pipe) were used during 1976, but one such crossing reportedly occurred during early 1977. Several crossings have occurred where short segments of elevated pipe were not yet in place or at points of transition to buried mode. The latter observations may be more indicative of the future value of sag-bend structures should a moderation or reversal of the avoidance phenomenon occur in subsequent years.

In the absence of human influence, areas of buried pipe do not appear to represent a serious barrier to caribou movement. Fortunately, the placement of buried pipe between Franklin Bluffs and Pump Station 2 and near the mouth of the Ribdon River coincides with two major areas of caribou movement, providing some optimism for future accommodation. Similarly, the various sag-bend crossings may become more functional if sensitivity of caribou to human activity decreases. At the present time, however, accommodation is not apparent, and the stipulation for free passage and movement of caribou is not being satisfied. The greatly reduced frequency of caribou sightings and a sharp decline in corridor crossings suggest that the herd is dividing into eastern and western portions, each with largely independent north-south movements.

RECOMMENDATIONS

Continued analysis of caribou movements, seasonal occupancy of the pipeline corridor, and herd status is essential if maximum benefit to industry and wildlife management is to be derived from this research project. The initial effects of the pipeline corridor on caribou distribution and group composition have been identified, but little is known of specific behavioral responses of caribou to the Trans-Alaska Pipeline; nor has an appropriate assessment of special big game crossings been possible to date. The crucial question is whether caribou will continue to avoid the area and if an associated shift in overall seasonal movements will occur. A subsequent decrease in herd productivity may accompany any herd displacement and/or perturbed seasonal movements. However, caribou may accommodate to the pipeline and the current avoidance trend

may be reversed with an eventual adjustment to pipeline structures and human activity.

The following is a summary of the status of major elements of this investigation. Some component studies have been completed, several are in progress, and others are scheduled for the future.

A. Completed studies

1. Herd identity

The Central Arctic herd (approximate size 5,000 head) appears to be the only caribou subpopulation on the arctic slope which is currently affected by the Trans-Alaska Pipeline.

2. "Baseline" data on seasonal movements.

A determination of normal preconstruction movements of caribou was not possible because inception of this project followed the commencement of construction activities. However, reliable reference data on the seasonal movements of this herd were obtained during the early stages of pipeline construction and represent our only means of assessing future changes.

3. Caribou distribution and group composition along the Trans-Alaska Pipeline corridor.

Initial abnormalities in latitudinal distribution and group composition have been described.

4. Herd status.

Our most complete data on sex and age composition of the Central Arctic herd were obtained in 1976. The relative size of various cohort classes has been determined and calf production/early survival has been quantified. Winter mortality of calves has not yet been adequately defined, but counts planned for this spring should provide a reliable estimate.

B. Studies in progress

1. Habitat selection.

A great deal of information has been obtained on seasonal changes in habitat preference in relation to nutritional requirements, insect disturbance, and snow conditions. Analysis of these and additional data will commence in the near future.

2. Movement behavior of caribou in relation to the pipeline and haul road.

These studies have been in progress for nearly three years and are to continue throughout the life of the project.

3. Assessment of the effectiveness of special big game crossings.

Use (or non-use) of these special structures by caribou will continue to be documented.

4. Changes in overall seasonal movements of the Central Arctic herd.

Monitoring of seasonal movements of caribou by aerial surveillance is to continue as required.

5. Changes in caribou distribution and group composition along the Trans-Alaska Pipeline corridor.

A determination of seasonal and annual trends in the distribution and sex and age composition of caribou along the corridor is critical to successful evaluation of chronological changes.

6. Movements of collared caribou.

To date, collared caribou have been used primarily to verify herd integrity and seasonal movements determined by other means. Additional caribou are to be collared this spring and studies of subsequent movements should provide additional information on pipeline crossing frequency.

7. Changes in herd status.

The Central Arctic herd will continue to be monitored for any changes in production and mortality.

C. Proposed studies

1. Avoidance distance of cow-calf pairs.

Further quantification of cow-calf avoidance of the pipeline corridor is required. We propose to determine annually the mean distance of calves from the pipeline corridor through grid surveys by air and to describe any changes which occur with season. This should assist in estimating the size of areas to which cows and calves have reduced access.

2. Caribou trail patterns.

A historical record of caribou movements on the arctic slope is available as a permanent trail system. We propose to map these patterns by air and compare the result to the current patterns of caribou movement. This will provide a means of identifying any major changes in seasonal movement which have occurred with recent development of the arctic slope.

In consideration of the above project demands, it is recommended that full funding be extended through June 1978 with partial support continued for a minimum of two years thereafter.

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APPENDIX I

SEASONAL MOVEMENTS AND SEXUAL SEGREGATION OF CARIBOU DETERMINED BY SYSTEMATIC AERIAL SURVEY

(Submitted to the Journal of Wildlife Management)

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ABSTRACT

An aerial survey technique is described for monitoring the seasonal movements of caribou. Six surveys were conducted between March and November 1975 over a specified route on Alaska's central arctic slope. A "center of caribou occupancy" was determined for each survey by calculating the latitudinal and longitudinal means of caribou distribution. The results demonstrate a gradual movement to the north beginning in March and continuing into August, thereafter progressing southward through November. Latitudinal means for caribou observed in groups with calves were compared with the corresponding means for caribou in groups without calves between June and November. Movement patterns were similar, but groups with calves remained at significantly higher latitudes than those without calves. The dynamics of sexual segregation are considered in relation to seasonal changes in group size and composition. Interpretation of survey results and the requirements and limitations of the technique are discussed.

Past studies have established the existence of two major caribou (*Rangifer tarandus granti*) subpopulations in northern Alaska, the Western Arctic and Porcupine herds. Traditional calving areas, respectively, are on the extreme western and eastern arctic slope, and seasonal movements of both herds have extended centrally to the Sagavanirktok River (Hemming 1971). More recently Child (1973) and Gavin (1973) noted calving on the coastal plain near Prudhoe Bay. Since fidelity to a distinct calving area is a criterion for herd status (Skoog 1968), these observations suggested that the central arctic supports a resident herd as well as caribou which appear periodically from adjacent regions.

The Trans-Alaska Pipeline, currently under construction between Prudhoe Bay and Valdez, is routed along the Sagavanirktok River through this central area of the arctic slope. Because little was known of the indigenous caribou a major study was commenced to determine general numbers, herd identity(ies), and seasonal movements. This report describes a technique for ascertaining seasonal movements of caribou and deals with data obtained between March and November 1975 in the vicinity of the pipeline corridor. This information, obtained during the early stages of construction, represents a baseline reference for future data to be collected as the pipeline nears completion and during the initial stages of operation.

This study was funded jointly by the Alaska Department of Fish and Game through the Joint State/Federal Fish and Wildlife Advisory Team and by Federal Aid in Wildlife Restoration Project W-17-8. Logistic support by Alyeska Pipeline Service Company is gratefully acknowledged. We are indebted to D. D. Roby and W. T. Smith for technical assistance and to L. M. Hunt, S. O. Harbo and D. F. Holleman for statistical advice.

STUDY AREA

Approximate boundaries of the study area are the Beaufort Sea to the north, the crest of the Brooks Range to the south, and the Canning and Itkillik Rivers to the east and west, respectively (Fig. 1). Three physiographic units are apparent (Spetzman 1959). The arctic coastal plain is characterized by poorly drained sedge meadows dominated by *Carex* spp. It rises gradually to an elevation of about 180 m at its southern border (approximate latitude 69°20'). The foothills continue inland as rolling plateaus and low linear mountains rising to more than 900 m; *Eriophorum* tussock tundra predominates but a number of herb, low shrub, and lichen communities are also present. Transition to the mountainous northern slopes of the Brooks Range begins near the southern extreme of the study area. Rugged, glaciated peaks extending from northeast to southwest rise to maximum elevations of 2500 m. Throughout the study area are numerous rivers and creeks which support stands of riparian willow (*Salix* spp.) as well as a variety of grasses, sedges and herbaceous vegetation.

From its origin a few kilometers west of Prudhoe Bay the Trans-Alaska Pipeline roughly parallels the associated haul road (Fig. 1) through the study area, traversing all three physiographic regions. Pipeline construction commenced in the spring of 1975, following completion of the haul road, and work efforts were near maximum during the major portion of this study.

METHODS

Aerial surveys were conducted over a specific portion of the study area. To permit duplication of coverage and to facilitate position identification, each survey (Table 1) followed the arctic coast and a number of major rivers (Fig. 1). Flight routes were distributed as uniformly as possible. A Cessna 180 or 185 with a pilot and one observer was employed in all survey flights. Airspeed ranged from 190 to 210 km/hr and altitude was adjusted between 60 and 120 m (above-ground), depending on terrain. While flying two parallel transects over an area 6 km wide along the coast, speed and altitude were varied to provide constant viewability for an estimated 3 km to either side of each drainage.

Following a sighting of caribou a low pass was made to obtain a total count and, in most cases, a sex and age composition. A "group" was defined as a single caribou, or two or more caribou separated by less than an estimated 300 m; groups were considered distinct if the distance between closest individuals exceeded 300 m. Cohort identification was limited to four categories: calf (less than one year old), adult (more than one year old, sex unknown), mature bull (obvious adult male, probably more than four years of age), and unknown (unclassified as to sex or age). Locations were noted on a 1:500,000 aeronautical chart and applicable information was entered on a portable voice recorder.

A geographic "center of caribou occupancy" was calculated for each set of survey observations. Consecutive single-digit numbers were

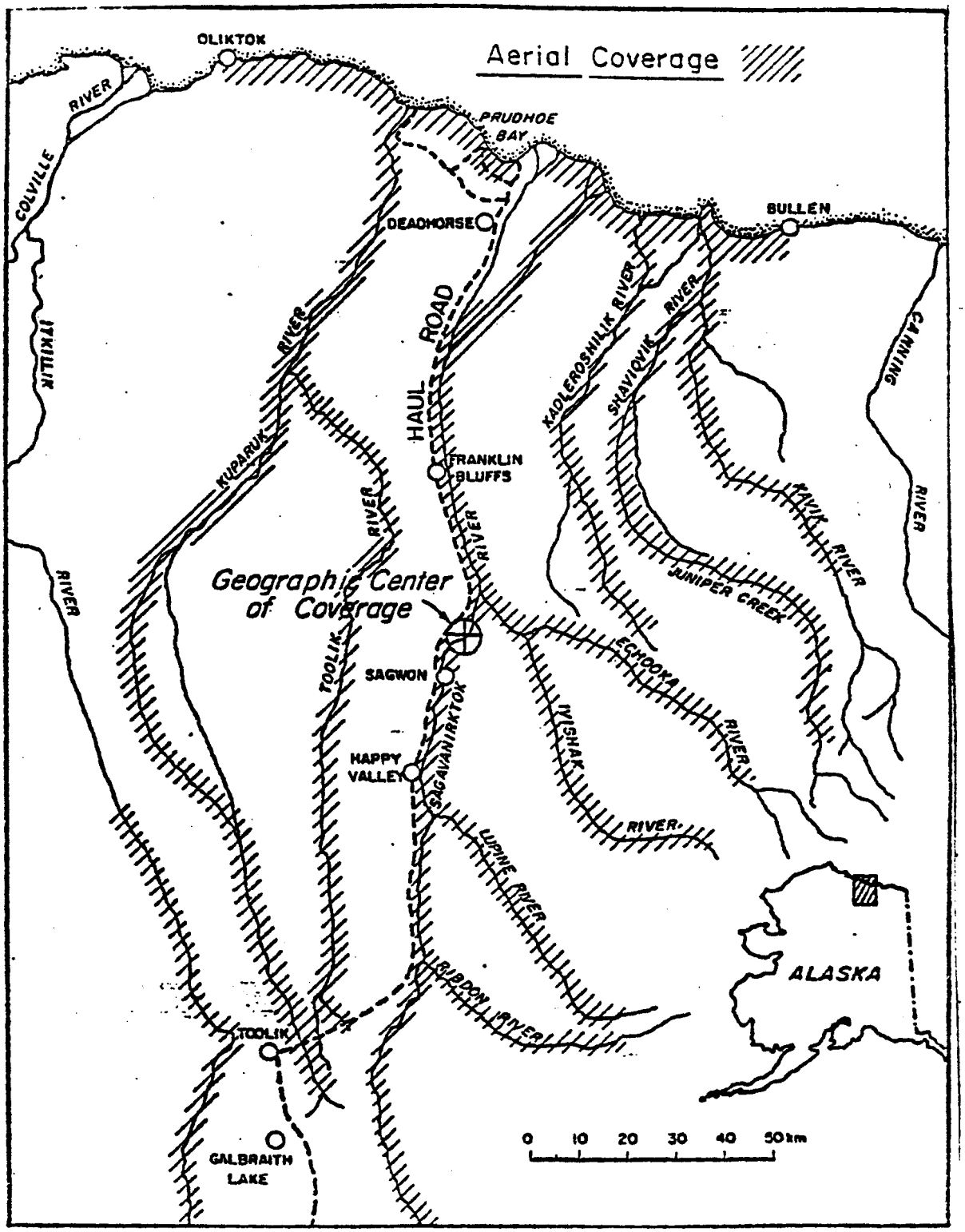

Fig. 1. Route of survey coverage within the study area.

Table 1. Latitudinal and longitudinal means of caribou distribution determined from aerial surveys, March-November 1975.

Survey Number	Inclusive Dates	No. of Caribou	No. of Groups	Latitude (mean ±SD)	Longitude (mean ±SD)
1	Mar 9-10	629	56	69°22'±28'	148°43'±13'
2	May 18-21	709	90	69°43'±29'	148°40'±25'
3	Jun 25-27	866	108	69°56'±22'	148°16'±13'
4	Aug 7-11	559	82	70°05'±22'	148°31'±12'
5	Sep 22-25	675	29	69°24'±30'	148°11'±10'
6	Nov 18-24	1021	133	69°19'±27'	148°29'±12'

assigned to each degree longitude between 147° and 151° and to each one-half degree latitude between 68° and 70°31'. The location of each group was described in terms of these geographic coordinates, estimated to the nearest tenth of a unit. Latitudinal/longitudinal means ($\bar{X}$) and standard deviations (SD) were calculated as follows:

$$\bar{X} = \frac{\Sigma\ G_i\ L_i}{\Sigma\ G_i} \qquad SD = \frac{\Sigma\ G_i\ (L_i - \bar{X})^2}{\Sigma\ G_i}$$

where for group i, G_i is number of caribou and L_i is the observed latitude or longitude expressed in arbitrary units. Final values are obtained by reconverting to the conventional base-sixty format. The result for each survey can be depicted geographically as a planar mean with a two-dimensional standard deviation.

An estimated "center of coverage" (Fig. 1) was determined by averaging the products of each 15' and 30' - spaced coordinates of latitude and longitude, respectively, and the number of intersections of each with the coverage route; final coordinates were obtained by dividing product means by the respective total number of intersections. The central location of this point demonstrates a balance of linear coverage, and the relative location of a given center of caribou occupancy reflects the degree of population symmetry within the study area.

Centers of caribou occupancy were compared using Students t-test (one-tailed distribution) with degrees of freedom based on the aggregate number of groups. Significance was evaluated at the 95% confidence level.

RESULTS

Latitudinal and longitudinal means (±SD) of caribou occupancy are listed in Table 1 and the geographic centers of occupancy are depicted in Fig. 2. Spring migration is shown as a northward shift between March and May, a trend which continued through the June calving period and into August. In contrast to the rather leisurely movement north during spring and summer, the subsequent reversal in fall was relatively rapid, occurring within a six-week period. Little additional movement was noted in November, suggesting considerable overlap of rutting areas and winter range.

Beginning with aerial surveys conducted in late June, calf numbers were recorded for the majority of observations, and it became evident that groups with calves were occupying higher latitudes than other groups. To verify this, separate centers of occupancy were calculated for total caribou observed in groups with calves and for those without calves. Directional trends of seasonal movement were similar for the two classes but all latitudinal means were significantly different, corresponding to a north-south separation of from 45 to 63 km (Fig. 3a); longitudinal differences were also significant in June and August (not shown), but

*At 69° latitude, linear distance associated with one degree of latitude is more than double than that associated with one degree of longitude.

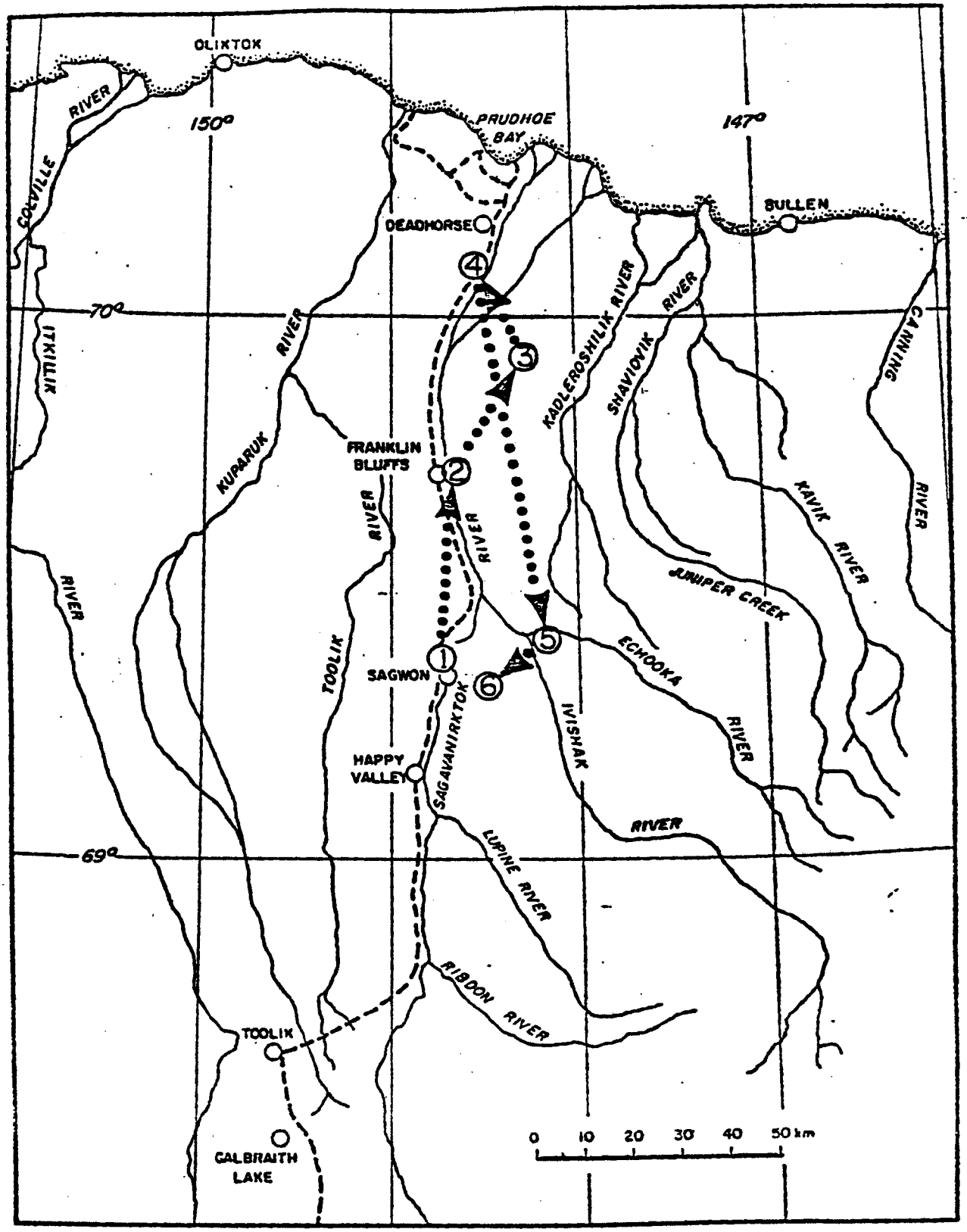

Fig. 2. Seasonal shifts in the center of caribou occupancy, March-November 1975. Survey dates are given in Table 1.

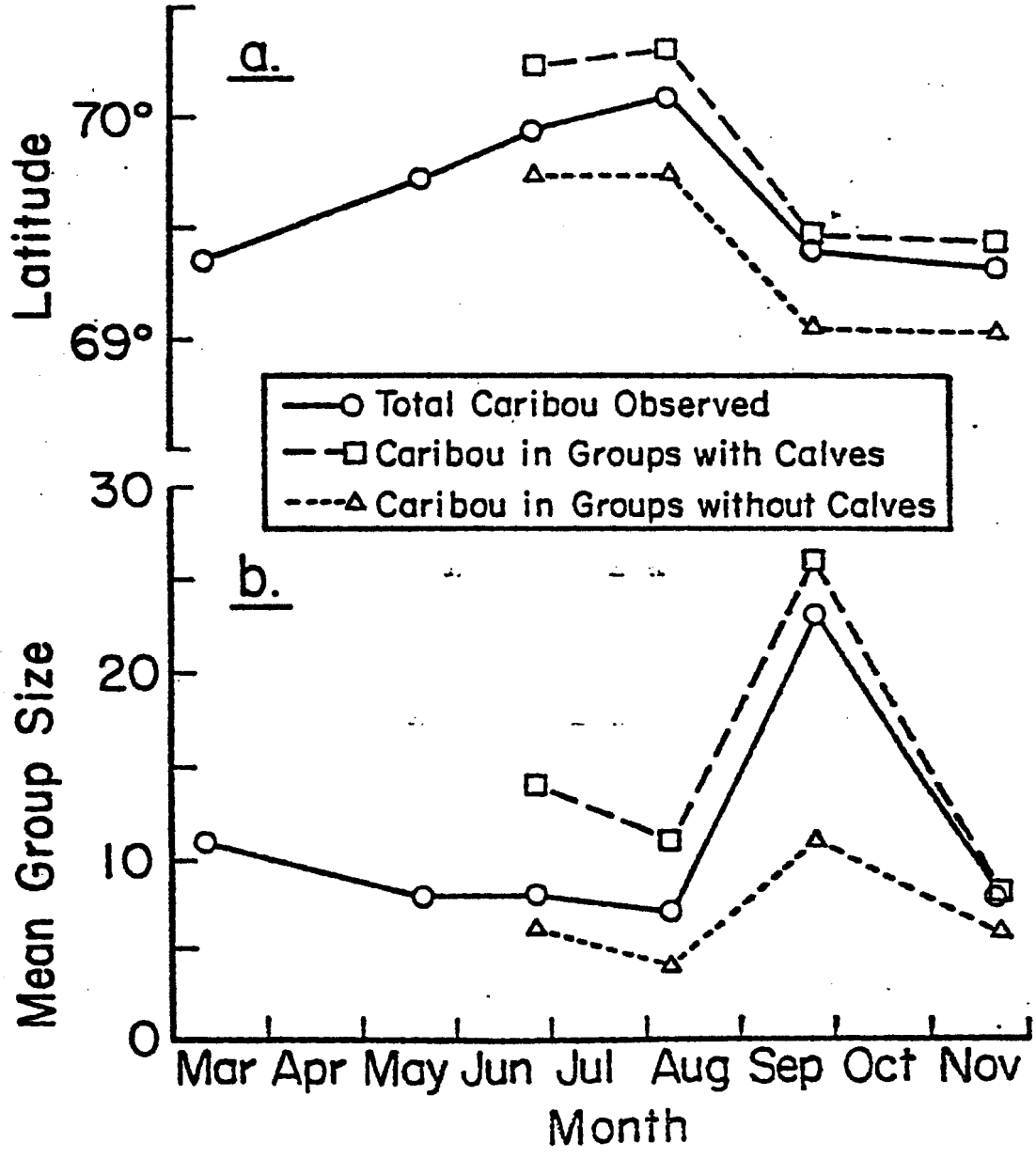

Fig. 3. Seasonal changes in the means of latitudinal distribution and group size of caribou.

the equivalent linear distances averaged only about 25 percent of those for latitude. Table 2 gives the mean composition of groups in each category and shows that the percentage of mature bulls in groups without calves was consistently higher than that for calf groups.

Changes in mean group size are shown in Fig. 3b. Highest values were obtained in late September and correspond to increased mixing of the sexes immediately prior to rut (Table 2). Although no surveys were conducted in July, peak means for calf groups would be anticipated then with the formation of large post-calving aggregations. Mean group size remained consistently higher for calf groups than for those without calves, but patterns of change were similar throughout summer and fall.

DISCUSSION

Herd Identity

In a historical account of caribou in Alaska's central and eastern Arctic, Skoog (1968) presented evidence for the existence of two separate herds during the 1920's and 1930's. Seasonal movements of one were characteristic of the present Porcupine herd and the other ranged between the central Brooks Range and the central arctic slope. The latter herd was thought to have disappeared during the 1950's, but our present findings and other recent reports suggest its continued existence.

Child (1973) observed calving near Prudhoe Bay in 1971 and 1972 and identified the coastal region as important summer range for an estimated 3,000 caribou. Based on summer and fall surveys in the study area Gavin (1973) reported a decline in caribou numbers from 26,000 in 1969 to 2,500 in 1972. Although calving was observed regularly, these caribou were thought to be part of the Western Arctic and Porcupine herds. It now appears that despite occasional influx from adjacent herds, a small "core" group remains and routinely calves in this region of the arctic slope. To date the calving area has not been accurately delineated, but survey observations approximately two weeks prior to and following parturition (Surveys 2 and 3, Table 1) indicate that major calving activity is north of Franklin Bluffs between the Colville and Canning Rivers (see Fig. 2).

Although not observed during the course of this study, the formation and subsequent movement of post-calving aggregations also recur with some degree of predictability. In mid-July, when mosquito densities are generally high (White et al. 1975), large groups consisting mainly of cows and calves assemble near the coast between Prudhoe Bay and Bullen and move rapidly eastward to the Canning River (see Fig. 2) which may be crossed by all or part of the aggregation (Roseneau et al. 1974). An abrupt reversal to the west follows (Roseneau and Stern 1974), accompanied by group fragmentation and gradual dispersal over the northern third of the study area. From survey observations in the vicinity of the lower Canning River, Roseneau (pers. comm.) concluded that this post-calving movement occurred in 1972, 1973 and 1974. No surveys were conducted in July 1975, but the westward shift in center of occupancy between June and August (Fig. 2) and the reduction in mean group size (Fig. 3b) in part reflect these occurrences.

Table 2. Comparison of numbers and composition of caribou in groups with and without calves, June-November 1975.

Survey No.	Total Classified				Groups With Calves				Groups Without Calves		
	No. of Caribou	No. of Groups	Calves (%)	Bulls[a] (%)	No. of Caribou[b]	No. of Groups	Calves (%)	Bulls[a] (%)	No. of Caribou[c]	No. of Groups	Bulls[a] (%)
3	667	79	18	36	370	26	33	2	297	53	79
4	542	78	24	34	351	31	37	2	191	47	93
5	637	27	16	41	593	23	17	37	44	4	91
6	960	125	18	21	700	84	24	6	260	41	60

[a]Approximate number of mature bulls (see Methods) expressed as a percentage of total caribou in each category.

[b]Total caribou in groups with one or more calves present.

[c]Total caribou in groups with no calves.

Synchronous movements are also characteristic of caribou in the study area. Histograms depicting caribou numbers as a function of both latitude and longitude were constructed for each survey and, with few exceptions, resembled normal (bell-shaped) distributions. This, together with the general paucity of caribou observed during occasional flights outside of but adjacent to the study area, suggests that survey observations were representative of herd distribution. Thus, despite latitudinal polarization of groups based on sex and/or age (Fig. 3a), caribou are present as a variably dispersed yet distinct unit which moves in a synchronized fashion throughout the year.

Skoog (1968) noted that caribou are characterized by repeated use of certain portions of their range, and he identified herds on the basis of fidelity to specific calving grounds. Thus, when a group of caribou establishes a calving area distinct from that of any other, the group itself is viewed as a distinct entity. In the present study caribou demonstrated regular use of a relatively fixed calving area, predictable formation and movement of post-calving aggregations, and synchrony of movement during the annual cycle. Combined, such characteristics distinguish these caribou from the Porcupine and Western Arctic herds, and herd status appears fully justified. Because of its location on the arctic slope this discrete subpopulation is referred to as the Central Arctic herd; total number in midsummer is currently estimated at 5,000.

Seasonal Movements and Sexual Segregation

Among barren-ground caribou sexual segregation is a normal but highly variable phenomenon. It may occur at all times of the year, ranging from simple polarization of individual groups to extensive geographic separation of herd components. Although complete sexual segregation is rare, the most obvious trait of spatially separated groups is the sex of adults which predominate. Most investigators agree that, in general, groups of two major types are distinguishable, one composed primarily of pregnant cows or cow-calf pairs and the other dominated by mature bulls; other cohorts are variably represented in these two categories. In this report caribou groups have been broadly classified based on the presence or absence of calves, a criterion which correlates with distinctly different percentages of mature bulls (Table 2). The presence of calves corresponds to a low percentage of males, implying group dominance by maternal cows. Groups without calves collectively represent the majority of the adult bull segment. In this discussion these categories will be referred to as "maternal cow" and "bull" groups, respectively.

Sexual segregation of a caribou herd develops gradually during the months prior to calving and is fully obvious by the time spring movements commence (Lent 1966a, Kelsall 1968), generally as snow cover disappears (Skoog 1968). A physiological drive associated with parturition is apparently the major stimulus for movement of pregnant females (Bergerud 1974) which dominate the forefront of the migration (Kelsall 1968). As social bonds weaken, calves and yearlings separate from parturient cows and drop back (Miller 1974), joining other nonbreeding animals and bulls which lag behind (Lent 1966b, Kelsall 1968). The migratory instinct may

be altered, halted or reversed by unseasonal snowfall (Kelsall 1968, Skoog 1968, Gavin 1973, 1975), but in most years the spring movements of parturient cows and variable numbers of other cohorts terminate at a calving area traditional for each herd. Pregnant cows often disperse just before calving and may remain alone for a short period post-partum (Miller 1974). Subadults and barren cows which accompanied the parturient females remain on the calving grounds in separate groups during the calving period (Kelsall 1968). Others are found in bull groups either on the periphery of the calving grounds or dispersed toward winter range in areas previously traversed by the head of the migration (Kelsall 1968; Lent 1966a, 1966b).

Group types were not identified during March and May, nor are data available for the actual calving period. However, sexual segregation was well developed in late June (Fig. 3a), observations being divided about equally between the maternal cow and bull categories (Table 2). Mean size of maternal cow groups was larger than that determined for either the bull category or the aggregate total (Fig. 3b). Similarly, Lent (1966a) noted that the mean size of groups with calves was larger than the composite mean group size during and immediately following the peak of calving in the Western Arctic herd. This change probably reflects an early tendency for post-calving aggregation which occurs as bands of maternal cows coalesce and are joined by subadults, barren cows, and bulls from the periphery of the calving grounds. In this study, however, the majority of bull groups remained some distance inland (Fig. 3a).

Although reliable calf counts were obtained throughout the survey series, percentages reported for mature bulls are subject to inconsistent errors. Identification of mature bulls was based on impressions of body size and/or antler development, features which are known to vary seasonally. Also, because of an occasional need to minimize flight time, some non-calves were simply classified as adults (see Methods) without attempting identification of bulls. Percentages obtained in November are known to be particularly low, but those reported for June, August and September are biased to a lesser degree and should be useful for describing trends in group composition.

Unpublished data on sex and age composition of the Central Arctic herd indicate that calf mortality between July and October 1976 was near zero; the calf:cow ratio remained constant at about 45 calves/100 cows, and calves constituted approximately 17 percent of total caribou classified in both months. Assuming similar production and survival in 1975, overall calf percentages shown for June, September and November (18%, 16% and 18%, respectively; Table 2) are reasonably representative. In contrast, the higher percentage of calves recorded in August suggests that other cohorts were present in lower numbers and presumably moved out of the study area. The aggregate percentage of mature bulls, calves, and lactating cows (assuming one per calf) increased from 72 to 82 percent between June and August, indicating that egress was primarily by young bulls, yearlings and/or non-lactating cows. There is no evidence for an influx of cow-calf pairs, which would otherwise account for the increased percentage of calves. In fact, the relatively low total number of animals observed in August (Table 1) suggests a net reduction

of caribou in the study area. Data in Table 2 show that a lower percentage of caribou were in bull groups; further, the percentage of bulls remained constant in maternal groups but increased from 79 to 93 percent in bull groups, indicating that caribou losses were chiefly from the latter. Egress to the east is the most likely possibility, since in both June and August longitudinal means for bull groups were displaced significantly farther in that direction than the means for maternal cow groups. Thus, August dispersal was characterized by a low mean group size (Fig. 3b), sustained sexual segregation (Fig. 3a), and a probable decrease in caribou density within the study area.

Fall migration appears to be initiated by the first widespread or heavy snowfall (Lent 1966b, Bergerud 1974). Aggregations form as the sexes mix in preparation for the rut (Skoog 1968, Bergerud 1974). The present results demonstrate a distinct southward movement between early August and late September (Figs. 2, 3a) and an associated increase in mean group size (Fig. 3b). In September maternal groups represented over 90 percent of total sightings (Table 2), indicating a breakdown of sexual segregation. Differences between latitudinal and longitudinal means for maternal cow and bull groups were statistically significant but are considered to be of little importance, since only 44 caribou in 4 groups were classified in the latter category. The composite calf percentage was reestablished at a presumed representative value (Table 2), suggesting that caribou which left the study area in August returned during the intervening period. Sexual integration was probably effected by southern movement of maternal groups, since there is no evidence for northward movement of groups dominated by bulls. Similarly, Kelsall (1968) noted that males isolated to the south may precede the females during fall migration and join them just prior to actual breeding.

In November mean group size declined (Fig. 3b) and sexual segregation resumed. The calf percentage remained nearly the same for total caribou classified but increased appreciably for the maternal cow segment (Table 2) as other cohorts formed separate bands to the south (Fig. 3a). As discussed above, bull percentages for November are thought to be erroneously low; assuming their validity for between-group comparisons, however, the data indicate that caribou departing the previously mixed rutting groups were predominantly mature bulls (Table 2). A similar observation was made by Lent (1966b), who reported an increasing number of bull bands toward the end of the breeding season. These larger males are thought to be more tolerant of heavy snow and better able to penetrate farther into winter range, thereby effecting a sexual stratification which may form the basis for segregation during the subsequent pre-calving movement (Kelsall 1968).

Spring migration of parturient cows appears to maintain or even increase this cohort separation. Movements generally coincide with improved snow conditions (Pruitt 1959) and the appearance of high quality forage (Skoog 1968). For the Western Arctic herd arrival on the calving grounds is closely correlated with the disappearance of snow from tussocks and emergence of new growth of *Eriophorum vaginatum* which is the most important forage during the calving period (Lent 1966b). However, the migration may proceed irrespective of receding snow with subsequent

parturition occuring under unsuitable conditions. In 1976, for example, pregnant cows from the Central Arctic herd overtook the retreating snow line and calved in a region of nearly continuous snow cover to the north. Thus, spring migration and parturition are not always accomplished under optimal conditions.

When available on the calving grounds and/or enroute, new spring vegetation is of high quality (Klein 1970, Chapin et al. 1975), but total biomass tends to be lower than in southern areas through which the migration had passed. Considering the energy expenditure associated with migration of pregnant females and the subsequent stresses of parturition and lactation, some doubt exists as to the net nutritional advantage of annual movements to high latitude calving areas. Bulls, juveniles and non-pregnant females, having no strong migratory incentive, follow at a distance which may permit optimal benefits in terms of both forage quality and availability. Non-pregnant caribou choosing to accompany the parturient cows are perhaps more responsive to social bonds than to the nutritional advantage of movement in relation to forage phenology.

Proceeding on the premise that spring migration of pregnant cows is not nutritionally controlled, it follows that less obvious benefits may be associated with the calving grounds themselves. Kelsall (1968) stated that "...areas chosen for regular use by calving caribou are among the least hospitable portions of the tundra during the calving season." Late developing flora, longer retention of snow and exposure to spring storms are cited as specific disadvantages. However, typical calving areas are characterized by the relative scarcity of predators. Wolves (*Canis lupus*) themselves reproduce during the caribou calving season and are less mobile, preferring drier areas with abundant prey. In addition, calving grounds are generally located within or adjacent to areas offering some relief from biting insects which emerge shortly after parturition. Access to such habitat is important as insect harassment increases energy expenditure and interrupts normal feeding and resting cycles (White et al. 1975). Thus areas selected for calving and the associated spring movements, although climatically and nutritionally less desirable, apparently provide for maximum neonatal survival by reducing the exposure to both predators and insect pests.

After parturition, increasing availability of high quality forage in or near the calving area permits growth of calves and fattening of lactating cows. Bull groups, however, remain to the south (Fig. 3a). Perhaps social incompatibility maintains this separation, but it is also possible that the widespread abundance of food eliminates the "need" for minor movements of bulls in response to plant phenology. On the other hand, if the location of nursing pairs is related to continued predator and insect avoidance, the inland position of bull groups may more closely reflect optimal feeding conditions, since these cohorts are not bound by instincts to maximize calf survival.

Survey Technique

The survey technique described in this report is systematic rather than random in nature, since it involves sampling over a preconceived

route. Grid surveys are also non-random but are more difficult to conduct, particularly in areas of poor ground reference or where navigational aids are infrequent or inadequate. The present technique utilizes the most prominent landmarks in the area (i.e. various drainages and the coastline), thus permitting positive position identification and ease of survey duplication.

Flight routes were distributed evenly within the area of interest, thereby minimizing any bias toward a given sector. The center of coverage (see Methods, Fig. 1) provides a common reference for the various centers of occupancy, which differ because of regional changes in caribou density. Thus, shifts in mean caribou occupancy reflect the net movement between surveys. Because coverage is fixed, the technique does not allow for loss of resident caribou or influx from adjacent herds. Thus, suspected egress to the east in August (see previous section) would deflect the true herd center farther in that direction than is shown in Fig. 2. Consequently, the westward shift between June and August (Fig. 2) represents the maximum possible movement of the herd. An influx of caribou would have the opposite effect.

Generally speaking, the total number of caribou observed during each survey reflects the total present in the study area. Thus, lowest numbers were obtained in August (Table 1), when partial egress of the herd was thought to have occurred. However, the total number of observations may not represent a constant fraction of caribou within the study area. Preference for riparian habitat, for example, may result in an unrealistically high number of sightings, since drainages constitute a disproportionately high percentage of the area surveyed. Conversely, preferential occupancy of non-riparian habitat would result in an underestimate of total numbers. Misleading estimates of total numbers may also result from between-survey differences in caribou viewability as influenced by weather, snow cover, and habitat. In this regard it is imperative that, for a given survey, conditions of visibility remain reasonably constant in order to minimize regional biases and insure representative sampling throughout the study area.

In summary, this survey technique may be applied if; (1) the survey route is properly balanced within the area of interest, (2) sampling includes representative habitats utilized by the species, and (3) viewability remains constant for a given survey.

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APPENDIX II

Caribou distribution and group composition along the Trans-Alaska Pipeline corridor on Alaska's Arctic Slope

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Abstract. Caribou surveys were conducted periodically along the Trans-Alaska Pipeline haul road on the central arctic slope between June and November 1975. Mean calf percentage observed in summer was approximately one-third lower than that obtained from concurrent aerial surveys of the adjacent region; fall means did not differ from expected values. In both summer and early fall mean latitudes calculated for groups with and without calves along the haul road were lower than for the corresponding groups observed from the air, and an analysis of regional distribution of caribou determined from comparable aerial and haul road surveys revealed local abnormalities in caribou occupancy and group composition. No caribou or relatively low numbers were observed in northern sections of the haul road near Prudhoe Bay throughout the study, and calf percentages in summer were consistently lower for each of four arbitrarily established regions than expected on the basis of aerial survey results; fall calf percentages did not differ appreciably. Mean caribou group size was generally lower along the haul road than in adjacent areas, suggesting corridor-related fragmentation of groups or interference with normal group formation. Responses of caribou to the pipeline corridor in general and by cows and calves in particular are discussed in relation to inherent avoidance tendencies as modified seasonally by terrain, group dominance, and intensity of human activity.

Introduction

The discovery of vast petroleum reserves at Prudhoe Bay in 1968 stimulated construction of the Trans-Alaska Pipeline, designed to transport crude oil to Valdez on the Gulf of Alaska. Currently in the final stages of completion, the pipeline is 122 cm in diameter and is alternately buried and above ground depending on soil stability. Elevated sections are held on vertical support members (VSM's), and ground clearances range from less than 1 m to a maximum of about 5 m. North of the Yukon River the pipeline and its associated haul road traverse the traditional ranges of two major subpopulations of barren-ground caribou (*Rangifer tarandus granti*), the Porcupine and Western Arctic herds (Skoog 1968, Hemming 1971), and concern was focused on potential restriction of caribou movements.

In 1971 and 1972 Child (1973), using simulated pipeline and pipeline crossing structures at Prudhoe Bay, attempted to assess the effectiveness of various above-ground designs in permitting free movements of caribou. The majority of approaching caribou avoided the simulation and, of the successful crossings, about three times as many were by use of ramps than by passage under the structure. This detailed study provided valuable preliminary data but was limited to observations on summer range. Thus, little was known of the seasonality of caribou responses to pipelines as potentially modified by weather, snow cover, insect harrassment, habitat preference and construction-related human activities. Consequently, a major study was undertaken to evaluate the reactions of caribou to the Trans-Alaska Pipeline on a seasonal basis and to document any associated shifts in annual movement patterns and range occupancy. To date this investigation has been largely restricted to

the pipeline route on the arctic slope (Figure 1).

Based on summer and fall surveys in this region between 1969 and 1972, Gavin (1973) reported a steady decline in caribou numbers from 26,000 to 2,500. These caribou were thought to be offshoots from both the Porcupine and Western Arctic herds, but Cameron and Whitten (1977) have recently identified a third subpopulation of about 5,000 head whose range is centered on the pipeline route along the Sagavanirktok River (Figure 1). Movements are primarily north-south between calving grounds near the coast and winter range in the northern foothills of the Brooks Range. The identity of this "Central Arctic herd" is apparently confounded by periodic influx from one or both of the larger adjacent herds. However, the area continues to support the relatively low numbers of caribou observed in 1972 (Gavin 1973), and influence by other herds was thought to be minimal during the course of this study. The present report deals with changes in latitudinal position, group size and composition of caribou along the Trans-Alaska pipeline corridor during summer and fall 1975. These data are compared with similar values obtained through aerial survey of adjacent areas.

The haul road between the Yukon River and Prudhoe Bay was completed in fall 1974 and pipeline construction efforts were near maximum during the major portion of this investigation.

Methods

Systematic surveys were conducted along the Trans-Alaska Pipeline haul road between June and November 1975. Generally these were scheduled twice-monthly and, except in October and November, each survey consisted of two complete trips over the 263 km distance between Pump Station #4 and Prudhoe Bay (Figure 1). As only half of the route could be covered in one day, most surveys required four days for completion. Due to inclement weather, survey components were not necessarily on consecutive days, but an attempt was made to minimize the time interval for each series. Inclusive dates are given in Table 1.

A pickup truck, generally with one driver/observer, was used for all road surveys. Speeds were adjusted between 40 and 65 km/hr, depending on visibility, to provide reasonably constant viewability of caribou for an estimated 1.5 km on either side of the haul road. Only caribou observed initially with the naked eye were recorded, but binoculars and spotting scope were used as required to obtain additional information. Pertinent data recorded for each caribou sighting included:

Location - road distance from a known point
Number of caribou per group (defined arbitrarily as a single caribou, or more than one caribou separated by less than an estimated 300 m)
Group composition -
- calf - less than one year old
- yearling - more than one year old but less than two years old
- cow - female more than two years of age

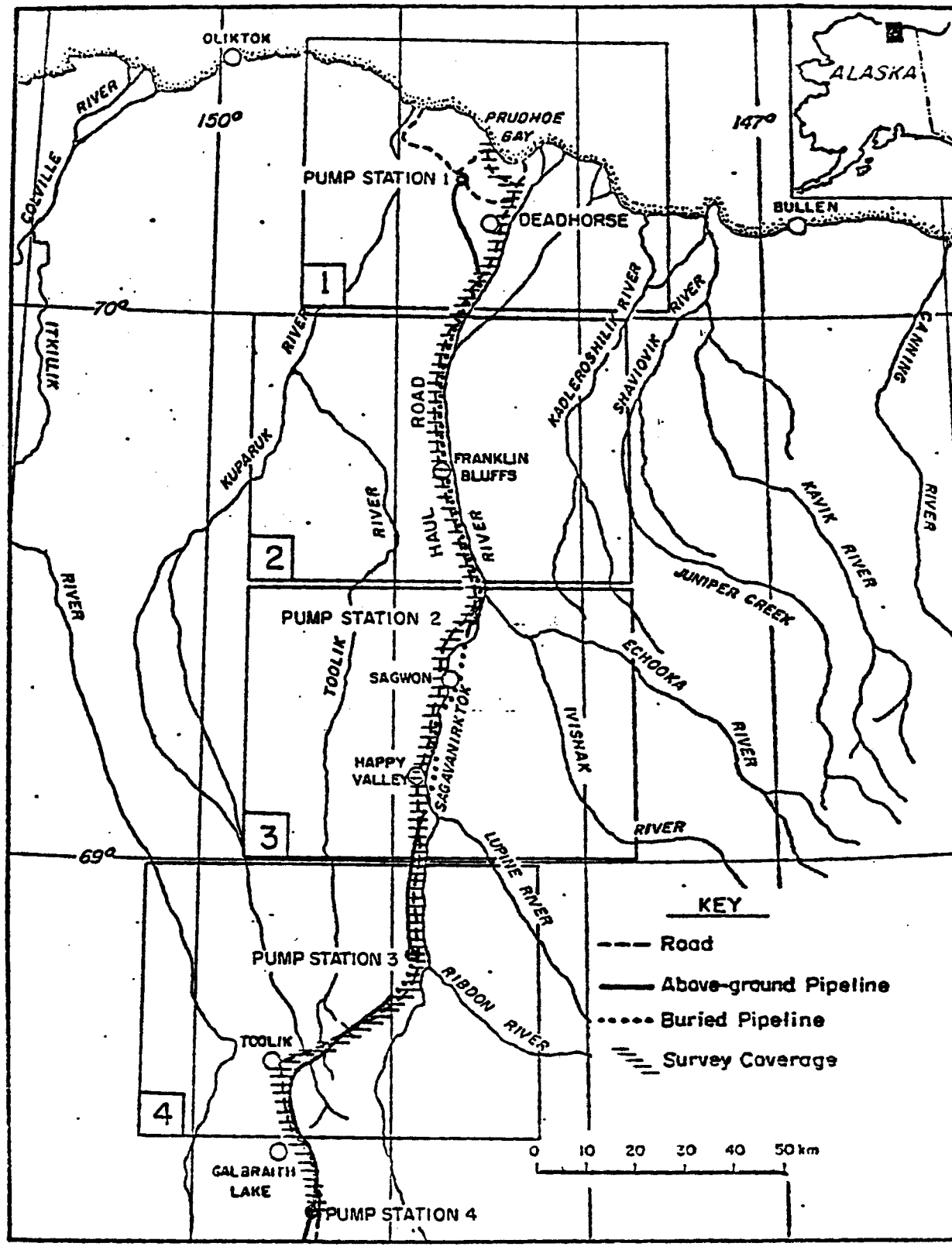

Figure 1. Survey coverage along the Trans-Alaska Pipeline corridor and regional boundaries established for comparison of haul road and aerial survey results.

TABLE 1 - Changes in caribou numbers and mean group composition along the Trans-Alaska Pipeline haul road, June - November 1975.

Survey dates	Total number of caribou observed	Total classified			Groups with calves			Groups without calves	
		Number of caribou[a]	Bulls, %	Calves, %	Number of caribou[b]	Bulls, %	Calves, %	Number of caribou[c]	Bulls, %
June 11-18	91	79	66	0	0	0	0	79	66
June 24-July 2	361	342	86	3	19	8	21	323	92
July 10-17	677	677	52	32	499	35	43	178	100
July 24-August 2	136	136	98	1	5	60	20	131	100
August 7-13	273	273	77	7	57	2	32	216	97
August 20-28	156	149	92	1	11	19	18	138	98
September 3-6	202	200	83	3	23	30	26	177	90
	Summer mean[d]		65	13(21)		31	40(35)		
September 20-28	602	416	44	17	333	30	23	83	99
October 24-28	54	31	36	24	25	26	30	6	80
November 5-10	176	37	49	10	19	25	19	18	74
November 19-25	92	36	43	11	25	30	17	11	73
	Fall mean[d]		43	17(17)		29	23(21)		92

[a] Total caribou in groups with no "unknowns" (see Methods).

[b] Total caribou in groups with one or more calves present.

[c] Total caribou in groups with no calves.

[d] Composite percentages; those in parenthesis were determined from aerial surveys (Cameron and Whitten 1977).

bull - male more than two years of age
adult - more than one year old, sex unknown
unknown - unclassified as to sex or age

Road locations were converted to their latitudinal equivalents using 1:63,360 scale maps of USGS Topography Series. For each survey series a mean latitudinal position of caribou was calculated as described previously by Cameron and Whitten (1977).

Results and Discussion

Caribou numbers and group composition

Numbers and composition of caribou observed from the haul road during each survey period are given in Table 1. Cows and yearlings were often difficult to distinguish and many individuals from these cohorts were knowingly classified as "adults" (see Methods) when more specific identification was impossible. Calves, however, were easily recognizable, and reported percentages are considered very reliable; similarly, identification of bulls was not frequently in question and the corresponding percentages are thought to be good estimates. Groups with one or more "unknowns" (see Methods) were not included in composition calculations. Of the total sightings in summer and fall, 98 and 56 percent, respectively, were successfully classified for an overall mean of 84 percent. Because no regional bias in classification success was suspected, composition values are assumed representative of total caribou observations.

For aggregate sightings along the haul road in summer, 13 percent were identified as calves, compared with a corresponding value of 21 percent obtained by systematic aerial survey of a large area centered on the pipeline route (Table 1, Cameron and Whitten 1977). In contrast, a mean of 17 percent calves was observed in fall for both road and aerial surveys, indicating that a more representative portion of the herd was present along the pipeline corridor. Within each season groups with calves showed similar calf percentages for the two survey methods, and in fact, comparable percentages were slightly higher for road than for aerial observations (Table 1). However, it can be calculated from the summer haul road data in Table 1 that the number of caribou observed in groups with calves averaged 33 percent of the total classified, whereas a mean of 60 percent of the caribou classified by air were observed in groups with calves (Cameron and Whitten 1977); respective mean values for fall were similar at 77 and 81 percent, respectively. Clearly, then, the low proportion of calves recorded during haul road surveys in summer was due primarily to a reduced occurrence of groups with calves rather than to a lower percentage of calves in such groups. On the other hand, composition determined from haul road observations in fall was more representative of caribou in the surrounding region.

The aggregate percentage of bulls varied inversely with that of calves for summer and fall (Table 1). Bulls consistently predominated in groups without calves, but were present in low numbers in groups with calves. However, the percentages did not differ appreciably with season

for either group type. Although reliable bull percentages are not available from aerial survey data for comparison, this constancy suggests further that seasonal differences in overall composition along the haul road are due to changes in the relative numbers, and not the composition, of groups with and without calves.

Latitudinal movements

Changes in mean latitudinal position of caribou along the haul road are depicted in Figure 2a. Means based on total sightings reached a peak in mid-July as did those calculated for groups without calves. However, calf groups attained higher maximum latitudes and remained in northern areas longer before initiating fall movements to the south. Throughout summer and fall groups without calves remained at lower latitudes than groups with calves, although the extent of separation varied throughout the study period. A similar trend was obtained concurrently from aerial surveys (Cameron and Whitten 1977), and the corresponding results are compared in Figure 3a in order to identify any abnormal distribution of caribou along the haul road.

In summer, the higher mean latitude shown for aggregate sightings by air is partially attributable to a greater proportion of groups with calves (Cameron and Whitten 1977), but corresponding means for groups with and without calves remained distinctly different. Although comparable means in September did not differ appreciably, the same trend is apparent during fall (Figure 2a), when no differences in composition were observed (Table 1). Thus, dissimilar composition does not fully account for the lower mean latitudes of caribou along the pipeline corridor; rather, local abnormalities in caribou distribution are indicated.

Group Size

Two distinct peaks in mean group size are shown for haul road observations, one in mid-July during post-calving aggregation and another in September just prior to the rut (Figure 2b). No data were collected during the actual breeding period, but it is likely that large groups continued to predominate through early and mid-October. Except for late July and early September the mean size of groups with calves was larger than that for groups without calves. A further comparison of these means with those determined from aerial surveys (Figure 2b, Cameron and Whitten 1977) indicates that in June, August and September the mean size of corresponding group types was higher for aerial than for haul road surveys. This was particularly striking for groups with calves, which differed by four to eight units in mean size throughout summer and early fall. A valid comparison is not possible for November because values from road surveys are based on extremely small samples (Table 1). Since the same criteria for group identification were used in both survey procedures (see Methods), these data indicate either a corridor-related fragmentation of groups or a decreased tendency toward group coalescence around the the pipeline corridor.

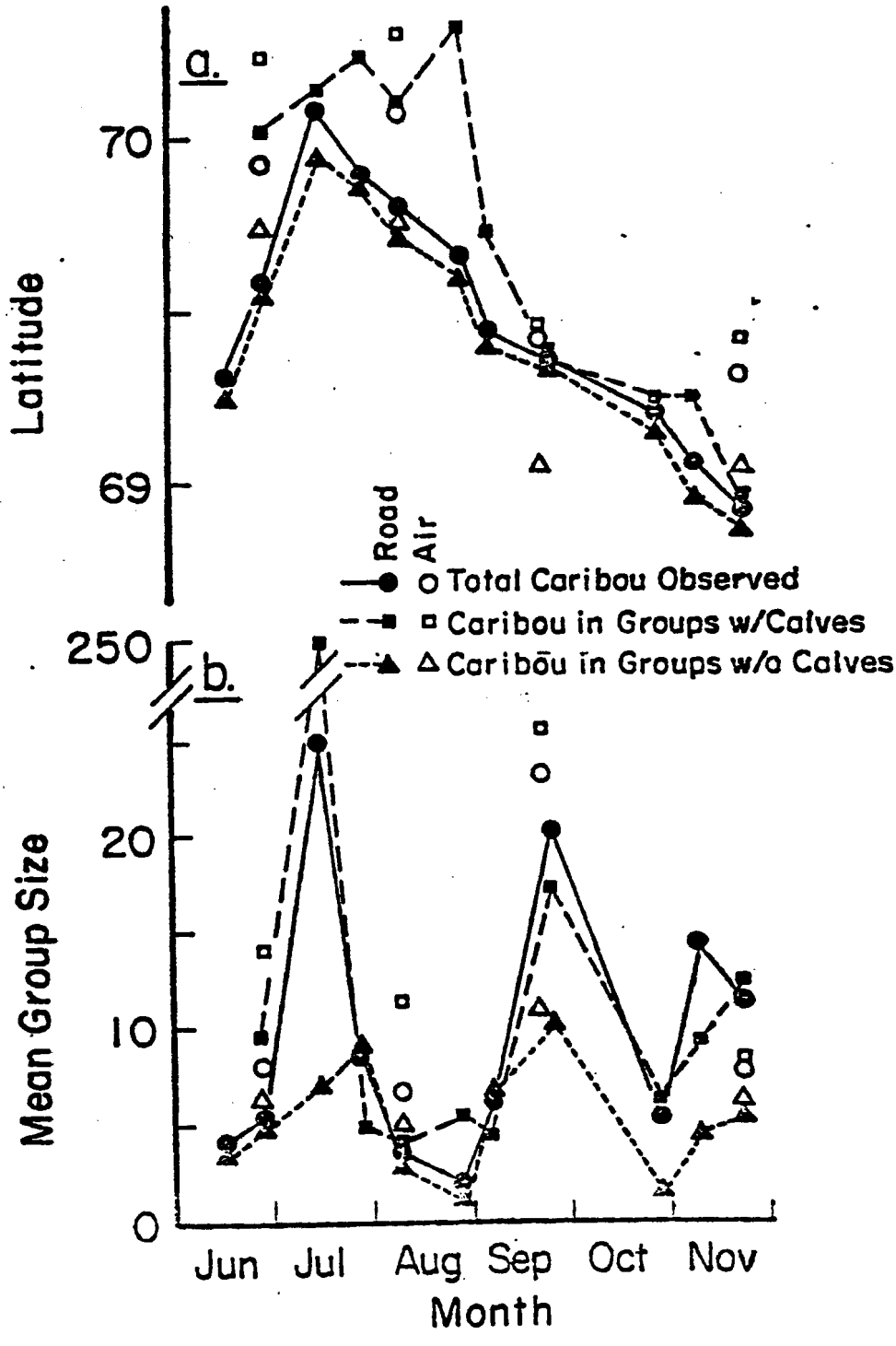

Figure 2. Seasonal changes in mean latitudinal position and mean group size of caribou along the haul road and a comparison with corresponding results from aerial surveys.

Regional differences in caribou distribution and composition

To permit a more accurate assessment of latitudinal distribution of caribou (Figure 2b), four regions were delineated along the pipeline corridor (Figure 1) for direct comparison of aerial and road survey observations. These regions were centered on the corridor to adjust for any east-west segregation of group types (Cameron and Whitten 1977), and each was bounded arbitrarily by one-half degree of latitude and two degrees of longitude. The regional distribution of total caribou observations during both aerial (Cameron and Whitten 1977) and road surveys (Table 1) is shown in Figure 3, and applicable calf percentages are presented in Table 2. It was assumed that aerial survey results reflect the true distribution of caribou among the four regions and provide representative data on composition within each region. Similar data obtained from the haul road are compared with these "expected" values. As sample sizes were frequently low, statistical analysis of differences in calf composition was not feasible, but some overall and regional trends are apparent from this analysis.

Figure 3 demonstrates a distinct north-south gradient in regional density of caribou for both June and August, with sightings in region 1 representing 50 and 55 percent of the total, respectively. In contrast, the majority of haul road observations during summer were in region 2, and relatively few caribou were observed in coastal areas. A slight northern shift occurred along the haul road in August but the proportion of total caribou in region 1 remained substantially lower than that obtained through aerial surveys. Calf percentages for regions 1 and 2 of the haul road were appreciably lower than had been expected, and few calves were noted in regions 3 and 4 (Table 2), corresponding to the more southerly distribution of groups without calves (Figure 2a). For all regions combined, calf percentages determined from aerial and haul road surveys, respectively, were 17 and 3 in June, and 20 and 7 in August. Thus, the more southerly distribution of caribou along the pipeline corridor in summer was apparently due to a general avoidance of northern sections (Figure 3) near Prudhoe Bay (Figure 1). In addition, aggregate and regional calf percentages were consistently lower than the expected values (Table 2), suggesting a disproportionate avoidance of the pipeline corridor by groups with calves. Bulls were observed in greater relative abundance, and they represented the dominant cohort along the haul road in summer (Table 1).

By late September a southward displacement of caribou was evident (Figure 2a). Approximately half of the total sightings from both air and haul road were in region 3, and no caribou were observed along the corridor in region 1, where nearly one-third of the total had been observed during aerial surveys (Figure 3). Despite these differences in regional distribution, corresponding latitudinal means were similar (Figure 2a). During both air and road surveys the majority of caribou were found in groups with calves (Cameron and Whitten 1977, Table 1), and mean group size increased (Figure 2b) as pre-rut aggregations formed. Although aerial observations indicate that groups without calves remained substantially farther south (Figure 2a), such differences are of little

TABLE 2. Regional comparison of calf percentages determined from corresponding aerial and haul road surveys, June-November 1975.

Month[a]	Survey method[a]	Region 1		Region 2		Region 3		Region 4	
		Number of caribou[b]	Calves, %	Number of caribou[b]	Calves, %	Number of caribou[b]	Calves, %	Number of caribou[b]	Calves, %
June	Air	231	27	159	10	65	2	4	0
	Road	26	12	195	4	121	0	0	-
August	Air	200	34	122	9	49	0	0	-
	Road	49	27	183	3	37	0	4	0
September	Air	99	20	18	22	174	21	32	0
	Road	0	-	232	25	125	9	59	6
November	Air	57	44	101	27	256	17	238	7
	Road	0	-	0	-	0	-	36	11

[a] Aerial surveys (Cameron and Whitten 1977) or haul road surveys within the regions shown in Figure 1.
[b] Number of caribou classified, i.e. total caribou in groups with no "unknowns" (see Methods).

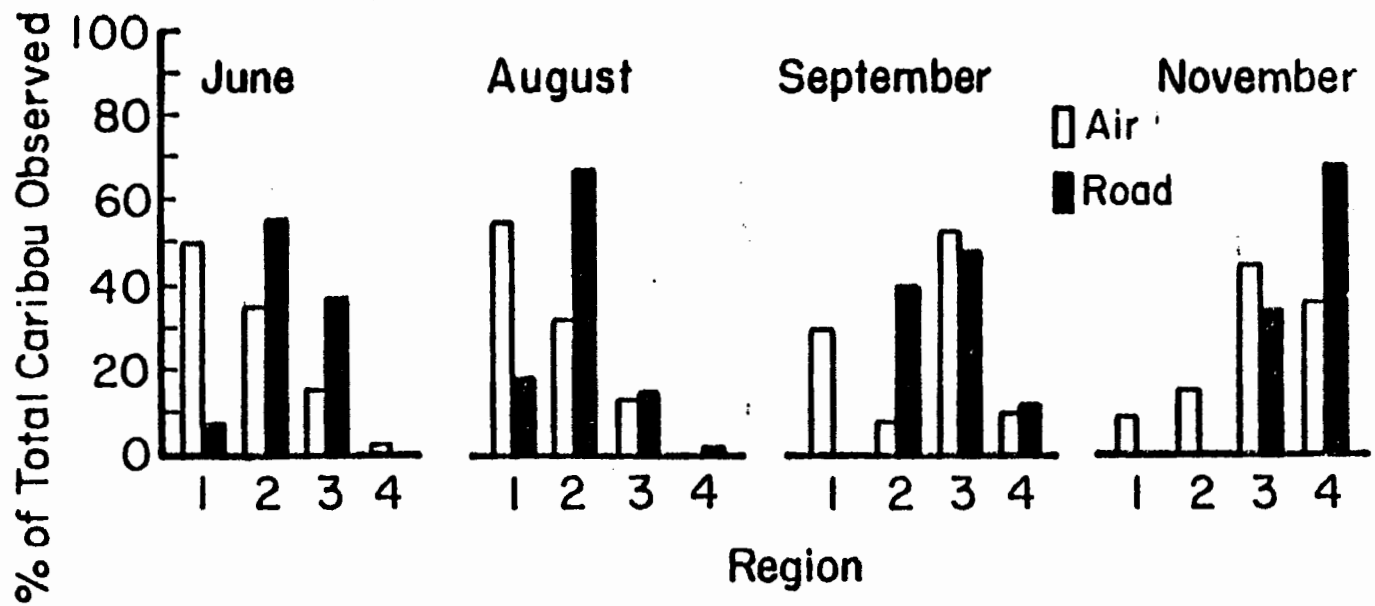

Figure 3. Regional distribution of caribou (see Figure 1) determined from corresponding aerial and haul surveys.

importance because these caribou represented less than 10 percent of total sightings (Cameron and Whitten 1977). Regional differences in calf percentage demonstrate no consistent trend (Table 2), but combining data for regions 2, 3 and 4 results in an estimated 17 percent calves for both air and road surveys. Thus, while a complete avoidance of the Prudhoe Bay area is indicated (Figure 3), sightings of caribou elsewhere along the haul road appear to reflect overall composition, and no differential avoidance by groups with calves was apparent. Aerial surveys in November established that relatively fewer caribou were occupying coastal areas. The majority of occupancy along the haul road was in region 4, and no caribou were observed in regions 1 and 2 (Figure 3). Total haul road sightings in November were among the lowest recorded (Table 1), and any conclusions regarding differences in calf composition would be equivocal because of inadequate sample size. Nevertheless, combined data for fall indicate that a more representative portion of the herd approached and was observed from the pipeline corridor (Table 1), although continued avoidance of northern areas is indicated (Figure 3).

Reduced numbers of caribou near the haul road in region 1 during summer and fall (Figure 3) may, in part, explain the lower mean group size of caribou within the pipeline corridor (Figure 2b). Groups with calves observed along the coast by air were generally larger than comparable inland groups, and their exclusion from haul road observation would tend to depress the calculated mean irrespective of other influences on group size. However, no such latitudinal gradient was discernible for groups without calves, which in summer exhibited a similar decrease in size along the haul road. Consequently, corridor-related reduction in group size remains suspect.

Avoidance behavior of caribou

Partial or complete avoidance of the Prudhoe Bay area was noted throughout the course of this study (Figures 1, 3) and in large part accounts for the lower mean latitudes of caribou occupancy along the haul road (Figure 2a). The coastal region near Prudhoe Bay, recently the site of increased construction and exploratory activity, was previously a portion of the calving grounds for the Central Arctic herd. As late as 1972 Child (1973) and Gavin (1973) reported calving within or immediately adjacent to the Prudhoe Bay complex. With local expansion and continued human activity over the past three or four years, an attrition of caribou usage has occurred, and in 1975 no neo-natal calves were observed from this northernmost section of the haul road. The area was also previously invaded by caribou during annual post-calving movements along the coast (see Cameron and Whitten 1977) and during oscillatory movements to and from the coast in response to changing insect density (Child 1973, White et al. 1975). Evidence for these occurrences is still visible in the form of caribou trail systems, and, although movements within the Prudhoe complex are still detectable, they are now mere remnants of past activities. However, post-calving and insect-related movements are still observed near the coast between the Sagavanirktok and Canning Rivers, indicating avoidance of a specific portion of summer range with continued occupancy of adjacent regions. Disturbance-related abandonment of range is believed

to be a gradual process, occurring with increasing avoidance of adverse stimuli (Klein 1971, Calef 1974). The recent history of changing caribou occupancy near Prudhoe Bay appears to reflect this pattern.

In summer, avoidance of the pipeline corridor is primarily by cows and calves. Cows are most sensitive to unusual stimuli just before parturition or during the early stages of labor (Lent 1966), but the present results suggest that heightened sensitivity extends through the first two or three months post-partum. Other reports indicate that cows and young calves are more easily alarmed by, and more likely to flee from, a potential threat than are male caribou, barren cows, or cows with older calves (De Vos 1960, Lent 1966, Bergerud 1974). Loud noises, unless associated with moving objects, do not generally alarm caribou, which perceive and identify adverse stimuli primarily through visual and olfactory means (Bergerud 1974, McCourt et al. 1974). However, cows with young calves consistently take flight from distant stimuli, using visual analysis without verification by scent (Bergerud 1974). Bergerud (1974) and Lent (1966) reported that alert posture assumed by individuals within a group did not generally induce group flight unless cows and neo-natal calves were present. Also, we noted that cow-calf pairs on the calving grounds were difficult to approach within 400 m.

Considering the importance of visual perception, terrain relief may influence the degree of avoidance by altering the nature of sensory contact with the pipeline corridor. North of Pump Station 2 the haul road traverses more than 100 km of continuous coastal plain (Figure 1). This is primary summer range for the Central Arctic herd (Cameron and Whitten 1977), and construction activity is frequently visible for 20 km or more. Thus, greater inherent sensitivity of cows and calves plus increased visibility provided by flat terrain may account for the observed avoidance of the haul road by these cohorts during summer. Bulls, yearlings, and non-breeding cows do not appear to be as sensitive to local human activity; however, since the mean latitude of groups without calves was also displaced southward (Figure 2a), some evidence exists for low-level avoidance.

During fall avoidance of the Prudhoe Bay complex continued (Figure 3) and the majority of caribou were observed farther inland (Figures 2a, 3). In September and October groups along the haul road were well mixed sexually (Table 1) and cow-calf avoidance of the pipeline corridor appears to have diminished (Table 2). This may be partially due to a change in group dominance associated with breeding; rutting bulls clearly influence group activity (Bergerud 1973), and may alter the "normal" avoidance behavior of cow-calf pairs. In addition, the more advanced age of calves may have reduced the sensitivity of maternal cows to human disturbance. Reduction of construction activity in fall and a commensurate decrease in road traffic could also contribute to the apparent decrease in cow-calf avoidance. Finally, fall range is predominately tussock tundra with greater terrain relief, and such habitat may moderate the threat stimulus of the corridor or permit closer association without constant visual contact. Conversely, the lack of relief in coastal areas may account for the absence of caribou around Prudhoe Bay.

Acknowledgments

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APPENDIX III. Elevated pipe crossings/deflections (1976).

Observ. No.	Date	Location[1]	Observ. Type[2]	Composition[3]	Dir.	Pipe Height (m)	Remarks
36	1/26	5.1 S	T	6 U	E	2.7	Approached and crossed at right angles; two other caribou deflected about 200 m north and crossed over buried pipe.
37	4/28	67.2 S	V	4 ca	NC[4]	0.6	Paralled pipe to NNE. Did not approach closely.
38	5/14	20.2 S	T	5 A 3 A 2 A 5 A	W W W W	1.7 2.25 2.1 -	Group fragmented and deflected at least 3 times; 5 additional caribou crossed 100 m south where a section of pipe was missing.
39	5/15	19.2 S	V	17 B 2 B	E/W NC		17 B crossed under the pipe at a run, 2 B did not cross; worker shouting nearby; 17 B recrossed to the east.
40	5/16	17.4 S	V	10 B 1 C	E E	3.5-5.1	"Special big game crossing" site. Some bulls showed no alarm; cow was last to cross.
41	5/17	17.4 S	V	26 B 2 C 1 ca	W W W	1.85-4.0	Near "Special big game crossing" site, but many crossed at periphery where pipe was lower; some milling with hesitation for up to 10 min; crossed at a run.

APPENDIX III (Continued).

Observ. No.	Date	Location[1]	Observ. Type[2]	Composition[3]	Dir.	Pipe Height (m)	Remarks
42	5/17	19.2 S	V	9 B 17 B	E NC	1.95	9 B crossed after considerable milling, remainder did not; road traffic and helicopter disturbance present.
43	5/19	17.3 S	V	6 B	E	2.05	Deflected once before crossing.
44	5/22	17.6 S	T	4 U	W	2.4	All crossed in exact same location.
45	5/22	19.8 S	T	1 U	E	1.65	
46	5/22	18.4 S	T	20+ U	W	1.95	Crossings distributed along several sections of pipe; may have involved more than one group.
47	5/25	21.1	V	7 B	E	2.4	Deflected once before crossing; jumped 8" gas line on 4" blocks beneath 48" pipe.
48	5/27	11.2 S	V	3 B	W	1.3	One bull deflected twice before crossing to join others.
49	6/23	Prudhoe Bay	V	1 B 2 B	S NC	1.4	Pipe was only 0.5 m high on either side of crossing; 2 other bulls in group did not cross.

APPENDIX III. (Continued).

Observ. No.	Date	Location[1]	Observ. Type[2]	Composition[3]	Dir.	Pipe Height (m)	Remarks
50	8/15	128.0 N	V	1 B	E, W	2.1	Severe warble fly harrassment; crossed beneath pipe three times, then remained in shade of pipe.
51	8/24	85.9 S	V	1 B	NC	0	Bull deflected; 48" pipe on the ground.
52	10/12	27.8 S	T	2 U	E	1.9	One caribou changed direction briefly and crossed 15 m south of the other.
53	10/12	91.8 S	T	3 U 3 U	W NC	2.2 -	Paralleled pipe at least 0.5 km before crossing beneath pipe just south of incomplete sag bend; only about half of the group crossed.

Note: Observations 1-35 appear in Cameron and Whitten (1976).

[1] km north (N) or south (S) of Happy Valley
[2] V = visual observation, T = data from track record
[3] B = bull, C = cow, ca = calf, Y = yearling, A = adult, U = unknown
[4] NC = no crossing