

BEHAVIORAL PATTERNS OF BARREN-GROUND CARIBOU OF THE CENTRAL ARCTIC HERD AD-JACENT TO THE TRANS-ALASKA PIPELINE

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OF THE CENTRAL ARCTIC HERD ADJACENT TO

THE TRANS-ALASKA OIL PIPELINE

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BEHAVIORAL PATTERNS OF BARREN-GROUND CARIBOU OF THE CENTRAL ARCTIC HERD ADJACENT TO THE TRANS-ALASKA OIL PIPELINE

A

THESIS

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ABSTRACT

Concern over impact of the pipeline and haul road on normal caribou behavioral patterns prompted study of environmental factors affecting herd activity. Seasonal and sexual differences were found in activity budgets and cycles. In winter, the period of the rest and activity cycle is approximately twice that for summer. In summer, the cycle period for cow groups is longer than for bull groups; the winter cycle is not sex dependent. Circadian activity patterns are synchronized with dawn and dusk. Northward spring movements of parturient cows and their avoidance of riparian habitats are attributed to wolf predation pressure. Caribou harassment by parasitic insects results in distinct behavioral and movement responses. Winter snow characteristics are primarily responsible for caribou distribution and movements. Pipeline construction resulted in little apparent disruption of behavioral patterns of bulls; however, its influence was most evident on distribution and activity of cow-calf groups between calving and rut.

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"'Well,' I added, as the duck paddled along slowly, displaying its intricately patterned feathers, 'that's just the way I feel right now, as though the universe were too frighteningly queer to be understood by minds like ours. It's not a popular view. One is supposed to flourish Ockham's razor and reduce hypotheses about a complex world to human proportions. Certainly I try. Mostly I come out feeling that whatever else the universe may be, it's so-called simplicity is a trick, perhaps like that bird out there. I know we have learned a lot, but the scope is too vast for us. Every now and then if we look behind us, everything has changed. It isn't precisely that nature tricks us. We trick ourselves with our own ingenuity. I don't believe in simplicity.""

- Loren Eiseley, All the Strange Hours

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INTRODUCTION

Background

Any reliable assessment of the impact of resource development on the behavior of caribou is contingent upon an understanding of the influence of other environmental factors. Factors responsible for and orientation of extensive seasonal movements of the larger herds have been poorly understood. Although some insight into the problem has been gained through recent studies, caribou migrations remain to a large extent enigmatic.

Caribou on the arctic slope must obtain their food from beneath snow during the greater part of the year. Nasimovich (1955) emphasized the importance of snow in the winter ecology of caribou and concluded that migrations and winter distribution are largely in response to the changing character of the snow cover. Firnification of snow (i.e. the formation of depth hoar) has been associated with major habitat changes by wild reindeer in late winter, and Nasimovich described an increase in mean group size as snow accumulated. Pruitt (1959) related winter movements and the onset of spring migration to changes in snow depth and density. A general avoidance of deep snow and a preference for movement over hard-packed snow was observed by Henshaw (1968). There is evidence that unseasonal snow conditions can halt, impede, or redirect spring migration to the calving grounds (Skoog 1968, Kelsall 1968, Lent 1966a, Gavin 1975). In addition, the first snowstorms of autumn are thought to influence the onset and extent of fall migration, despite the small

accumulations which may be involved (Lent 1966a, Kelsall 1968, Hemming 1971, Bergerud 1974). Deep snow can alter activity budgets by increasing the time required to obtain forage and thus reduce the time available for other activities (Baskin 1970).

Caribou in the arctic are subject to an extremely wide range of temperatures through the year. However, temperature alone has not been demonstrated to have a major effect on caribou behavior. Zhigunov (1968) stated that reindeer can easily withstand air temperatures as low as -62°C (-80°F) and suggested that high temperature was more detrimental. It is difficult to separate the effects of high temperature from that of insect harassment since the two are generally concurrent. For example, in Newfoundland, caribou sought shade beneath trees during hot weather only if insects were active (Bergerud 1974).

Wind is thought to have a greater influence on caribou behavior than temperature. In association with low winter temperatures, high winds can induce a cessation of feeding; caribou form tight groups and either stand and face into the wind or lie with their backs to the wind (Thomson 1971). Henshaw (1968) observed caribou moving from exposed mountain ridges and treeless flats to more protected areas just prior to winter storms. In summer, wind speed and level of insect harassment are closely related. Normal activity patterns are disrupted and the rate and direction of caribou movements change as an indirect result of wind velocity and direction (White et al. 1975).

Severe insect harassment completely disrupts normal activity patterns of caribou for extended periods of time (White et al. 1975). High mosquito (Aedes spp.) densities are associated with the formation of large, close-packed groups which move rapidly <u>en masse</u> to relief habitat upwind (White et al. 1975). A subsequent return to preferred feeding areas with fragmentation into smaller groups occurs when insect attack subsides. Similar behavior has been observed for wild reindeer in Norway (Thomson 1971). In contrast, the appearance of warble flies (<u>Oedemagena tarandi</u>) in midsummer may sever social bonds within a group and cause caribou to scatter in a phase of the annual cycle known as "August dispersal" (Curatolo 1975). The important role of parasitic insects in the summer ecology of reindeer is well known to herders in the Soviet Union. Shelters, smudge pots, insecticide applications, and strategic relocation of herds assist in minimizing the adverse effects of insects (Zhigunov 1968).

The extent to which predators, including man, influence regional or seasonal movements of caribou is unknown, but some effects on local movements and activity patterns have been noted. In general these effects are strong and immediate but short-lived relative to the effects of insects (Thomson 1971, Curatolo 1975). On taiga winter range barrenground caribou are frequently found in areas around frozen lakes which are used as escape terrain when wolves approach. In addition, feeding is confined to periods of the day when wolves are less likely to be hunting (Miller 1975). Kelsall (1968) hypothesized that relative

scarcity of wolves, grizzly bears, and other predators is one of the most important criteria for the selection of calving grounds which are frequently inhospitable during the calving period in most other respects. For example, weather encountered on the calving grounds is often cold, windy and wet. Snow melt is relatively late and feeding is restricted to small patches of exposed ground.

Barren-ground caribou are highly gregarious. Behavioral studies have indicated that differences in group size and composition are associated with differences in activity patterns and reactions to environmental stimuli. Larger groups tend to move faster, perhaps in response to increased competition for preferred forage (Baskin 1970). Skoog (1968) found a direct relationship between the regional density of caribou and the extent of herd movements. Thomson (1971) felt that sexual segregation of reindeer in winter was due to different activity patterns of bulls and cows. The percentage of cows and calves in a group tends to vary directly with group size (Curatolo 1975, Cameron and Whitten 1977). The more gregarious nature of adult cows is apparently a response to predation pressure on the young (Treisman 1976), and it is noteworthy that flushing distances of cows with calves during the calving season are the greatest for caribou at any season (Bergerud 1974).

Caribou demonstrate a distinct seasonal preference for certain forage species. Each forage species exhibits niche requirements and consequently caribou select different habitats during the year (Gaare et

al. 1970, Lent 1966a, White et al. 1975). Klein (1970a) pointed out that during the summer nutritional requirements for growth, fattening, and lactation are high and caribou select the highest quality forage available. Selection is a phenological as well as a taxonomic phenomenon. Caribou tend to select each species during early growth stages when the amounts of protein, soluble carbohydrates, and various essential nutrients are highest. Preference for specific plant communities also occurs in winter when carbohydrates are most important. Access to high-energy forage is often limited and the search for suitable feeding areas may therefore influence local movements to a great extent. Skoog (1968) suggested that the search for food primarily affects local movements since adequate amounts of palatable food are generally available. Snow conditions mask forage preference by altering the availability of certain plant species (Gaare et al. 1970, Miller 1976).

Physiological influences on the behavior of free-ranging caribou must be inferred. Changes in endocrine levels related to parturition and rut have important consequences for caribou activity and movements. These changes may occur irrespective of environmental influence and are part of endogenous circannual rhythms. Photoperiod appears to be the main synchronizer for these rhythms but endogenous components still trigger the behavioral changes (Pollock 1974). Bubenik (1965) stated that circadian patterns of active and resting periods, although partially responsive to various environmental stimuli, are mainly under endogenous control. Rumen capacity and turnover rate are additional variables

dependent on a combination of environmental and endogenous control and have important effects on daily activity budgets and rhythms. Nutritional deficiencies, disease, and injury are internal stresses which may modify behavior. All of these influences are largely invisible to the field observer who is relegated to describing behavior in the absence of measurable causes.

Development of northern regions has proceeded rapidly in the last decade, and has stimulated concern for the future of caribou and wild reindeer populations for two major reasons: 1) the potential disruption of movements and traditional migrations (Klein 1971, Banfield 1974) and 2) the disturbance of normal behavior including social interactions, patterns of activity, and selection of forage for quality (Espmark 1964, 1971, Shea 1978, Thomson 1971, Klein 1970b). The extensive seasonal migrations which take caribou to ranges not recently grazed are considered essential to the maintenance of large herds. Without these movements the carrying capacity of the total range would be greatly reduced (Klein 1970b) and the population would be quite vulnerable to predation. Each year pregnant caribou return to a traditional calving ground, the most predictable element of the annual cycle (Skoog 1968). Any delay of parturient cows in these spring movements induced by man-made barriers could have a potentially disastrous effect on survival of young (Banfield 1974).

Recent evidence suggests that certain types of human constructions can prevent free movement. In Norway a wild reindeer herd whose alpine

tundra winter range was divided by a road and parallel railroad, gradually ceased crossing these obstructions altogether (Klein 1971). However, other roads in Canada and Alaska which traverse caribou range have been crossed repeatedly even with locally intensive hunting (Skoog 1968, Bergerud 1974). For instance, portions of the Nelchina herd in interior Alaska have crossed the Richardson Highway for several decades. Unlike the area traversed by the Norwegian road and railroad, the traditional crossing sites for the Nelchina herd are in a forested region and the combined railroad and road traffic was much greater than in the Alaskan situation (D. Klein pers. comm.). Roads, railroads, and their associated traffic, and pipelines in treeless regions may be more effective barriers to caribou because they are visible for long distances. An above-ground gas pipeline constructed in the Taimyr region of the Soviet Arctic in 1969 diverted many wild reindeer from traditional fall migration routes, resulting in large areas of unutilized winter range (D. Klein, pers. comm.). A study of the effect of simulated aboveground pipeline at Prudhoe Bay indicated that despite underpass and ramp crossing provisions, 76.8 percent of the caribou encountering the structure either reversed direction or moved around the ends (Child 1975). Of the four Alaskan caribou herds whose ranges have been traversed by roads (the Nelchina, Fortymile, McKinley and Delta herds), all have experienced severe population declines in the last decade (Bos 1975, LeResche 1975, F. Dean, pers. comm., J. Davis, pers. comm.). It is not known how important the disruption of movements by these transportation corridors has been in each decline.

Speculation on the impact of human disturbance on caribou has focused on five major concerns: 1) the effect on efficiency of forage and habitat utilization, 2) the energy cost of reaction to disturbance, 3) the socially disruptive consequences of disturbance, 4) the associated risk of physical injury during the flight response, and 5) the effect on daily activity patterns and seasonal budgets. Justification for the first area of concern are the lower rates of fattening and growth observed for herded reindeer relative to free-ranging reindeer (Klein 1970b). Herding is, in effect, low intensity harassment which reduces individual spacing of reindeer and increases competition for preferred forage (Klein 1970b). The energetic cost of various reactions to disturbance can only be estimated and it is difficult to assess the importance of these increased expenditures in the context of seasonal energy budgets and critical levels for survival and reproduction. Reindeer herders in the Soviet Union have noted that when cows lose 17-24 percent of their body weight in winter, fetuses will be resorbed or the young will die soon after birth (Zhigunov 1968). A thorough evaluation of social disruption requires that individuals within a disturbed group be identifiable. Dominance hierarchies and cow-calf bonds are important social phenomena operating within caribou groups (Espmark 1964, Lent 1966b). The disruption of this social organization would be expected to decrease survival (Shea 1978). Physical injury as a result of disturbance is frequently subtle but no less severe. Particularly instructive is the extensive experience gained through the

practice of herding semi-domestic reindeer (Geist 1975). Geist (1975) pointed out the considerable danger of emphysema, fetus displacement, abortion and necrobacillosis resulting from harassment. Zhigunov (1968) described reindeer husbandry practices in the Soviet Union which minimize these injuries by avoiding unnecessary disturbance, particularly during the late winter and calving periods.

Caribou exhibit an activity <u>pattern</u> which consists of regular alternations of the two basic activities: feeding and lying. Thomson (1971) has referred to this pattern as a short-term polycyclic rhythm. The efficient consumption, fermentation, absorption, and assimilation of forage materials is probably dependent on the stability of this cycle and frequent digression from this pattern may be detrimental. These cycles are also synchronized to the 24 hour period so that circadian patterns of feeding and lying are apparent (Segal 1962, Bubenik 1965, Baskin 1970, Thomson 1971). Bubenik (1965) observed that captive cervids under environmental or social stress displayed abnormal patterns of activity, and suggested that the condition of an animal could be evaluated in part by its activity patterns.

An activity <u>budget</u> is a measure of the time (expressed as a percentage) devoted to a number of distinct activities (i.e. feeding, lying, standing, walking, etc.). These budgets have been used primarily in the construction of energetics models, but Segal (1962) indicated their helpfulness in judging the condition of reindeer and range status. Disturbance or harassment can also alter these activity budgets, both by

increasing avoidance behavior and by providing a source of low level chronic stress which increases the incidence and duration of unproductive activity. Under certain conditions of heavy hunting in Norway the normal activity budget can be disrupted to the extent that trotting and running become the dominant activities (31%) and feeding and lying are greatly reduced (Thomson 1971). Gaare et al. (1975) suggested that the energy cost to the animals of an intensive hunt, aimed at substantially reducing the population, is 10 percent of the <u>annual</u> energy budget.

Objectives

- To characterize seasonal and circadian behavior patterns of caribou on Alaska's central arctic slope.
- To investigate the influence of various environmental factors on patterns of caribou activity, including:
 - a) weather
 - b) forage phenology and distribution
 - c) insect harassment
 - d) snow conditions
 - e) predators
 - f) other caribou
 - g) presence of the pipeline and associated haul road

STUDY AREA

Description of Study Area

The study area is bounded by the Beaufort Sea to the north, the crest of the Brooks Range to the south, the Canning River to the east and the Colville and Itkillik Rivers to the west, and includes that portion of the arctic slope traversed by the Trans-Alaska pipeline corridor (Fig. 1). This region has been referred to as the "Central Arctic Region" by Olson (1959). Although the concentration of effort was within 10 km of the pipeline, additional information on movements and distribution of caribou was made available through systematic aerial surveys of the study area carried out by the Alaska Department of Fish and Game (Cameron and Whitten 1976, 1977).

The study area includes three major physiographic provinces: Arctic Coastal Plain, Arctic Foothills and Arctic Mountains (Wahrhaftig 1965). The Arctic Coastal Plain is subdivided into the Teshekpuk Lake and White Hills sections. Most of this area is characterized by flat, poorly drained, polygonal tundra which is dotted with north-south oriented thaw lakes and ponds. The region is underlain by perennially frozen sands, gravels and silts and maximum elevation of the region is 200 meters (Selkregg 1975). Wet sedge meadows cover most of the Arctic Coastal Plain (Spetzman 1959) and are predominately associations of moisture-loving monocots, particularly of the genera <u>Eriophorum</u> and <u>Carex</u>. In addition, several species of low willow (<u>Salix</u> spp.) are common, as are a few dicotyledonous herbs. Mosses usually form a high



Fig. 1. Map of the study area showing the route of the Trans-Alaska Pipeline, haul road, and physiographic regions.

percentage of the ground cover while lichens are sparse. More xeric conditions are found on the alluvial deposits of major rivers, on stream banks, along the coast, and on sand dune areas adjacent to river deltas. Numerous pingoes and two isolated upland areas, Franklin Bluffs and the White Hills, constitute the only major terrain relief. The latter two areas are underlain by poorly consolidated conglomerates, sandstones, and siltstones and vegetation in these upland areas is similar to that found in the foothills to the south.

The Arctic Foothills Province is divided into the northern and southern sections. The southern section is structurally similar to the Brooks Range but consists of less resistant rocks. The northern section is underlain mostly by simple folds of Cretaceous sandstones and conglomerates that form east-west trending hills with maximum elevations of about 500 meters (Gryc 1958). These differences account for the more varied topography in the southern section as compared to the northern section. The primary vegetation community throughout the Foothills is Eriophorum vaginatum tussock tundra, with low willows (Salix spp.) and dwarf birch (Betula nana) usually well represented. Patches of tussockheath tundra dominated by various ericaceous shrubs are also found, but under more acidic soil conditions. River floodplains support a greater diversity of plant life because of a thicker active layer and more varied substrate and drainage conditions. Dense stands of shrub willows (Salix alaxensis, S. lanata, S. glauca), mesoxeric mountain avens-legume associations, and sedge-horsetail marshes all exist in a complex mosaic of river terrace communities.

The Arctic Mountains Province (Brooks Range) is rugged, poorly vegetated terrain mostly over 1200 meters in elevation with some glaciated peaks 1850 meters high. These mountains are formed of late Paleozoic limestones, dolomites, and shales. The major plant community on the lower slopes is dry upland meadow dominated by <u>Dryas octopetela</u>. Braided rivers, with extensive outwash plains and seasonally highly variable discharge rates, flow through U-shaped valleys frequently vegetated by riparian willow stands.

The study area is north of treeline and has been classified into three major vegetation zones: High Arctic Tundra, Low Arctic Tundra, and Alpine Tundra (Alexandrova 1970 cited by Webber 1975). Alpine Tundra is limited mostly to the Brooks Range, and High Arctic Tundra is limited to a narrow coastal band. The great majority of the study area is classified as Low Arctic Tundra.

Temperatures on the central arctic slope range from +33°C (Anaktuvuk 68°10') to -53°C (Umiat 69°25'). Due to the maritime influence of the Beaufort Sea, average daily maximum and minimum temperatures near the coast are cooler in summer (8°C and 2°C at Oliktok, 17°C and 6°C at Umiat). During winter mean temperatures near the coast are higher than further inland (-21°C and -32°C at Oliktok, -24°C and -35°C at Umiat). Extreme maximum and minimum temperatures follow the same trends. Proximity to the Beaufort Sea also influences wind speeds. During winter mean monthly wind velocity at Barter Island (12.7 knots in January) is about twice that recorded for Umiat (6.1 knots in January).

Summer wind speeds at Umiat (6.2 knots in July) average about two-thirds those recorded at Barter Island (10.3 knots in July). Both annual snowfall and total precipitation increase from the coast to the Brooks Range (Selkregg 1975). However, the snow cover is frequently deeper and persists longer on the coastal plain than farther south. The structure of snow on the arctic slope has been described generally as "a hard, high density, fine grained, wind packed layer overlying a coarse, low density, depth hoar layer" (Benson et al. 1975). This is in contrast to the deeper, low density snow cover characteristic of interior Alaska. Snow cover is present over most of the study area for at least seven months of the year. The nature and depth of the snow cover appears to vary widely from year to year, particularly on the coastal plain, but in general the Brooks Range is largely wind swept, occasionally to the point that even valley bottoms are nearly devoid of snow. Snow on the coastal plain is usually deep (30-40cm), hard-crusted, and visually characterized by barchans and sastrugi (snow surface features characteristic of areas subject to high wind volocities). In contrast a less dense and less wind-blown snow cover is usually present in the foothills.

The Trans-Alaska Pipeline and haul road traverse all three physiographic provinces of the arctic slope (Fig. 1). From Pump Station 4 in the Brooks Range it is routed north and enters the southern foothills just north of Galbraith Lake, then from Toolik Camp east across the headwaters of the Kuparuk and Toolik Rivers, past Slope Mountain and down onto the floodplain of the Sagavanirktok River at Pump

Station 3. From there the pipeline and road roughly parallel the Sagavanirktok River to Prudhoe Bay. The road traverses sections of river floodplain several times as it passes Happy Valley Camp and Sagwon in the northern foothills. At Pump Station 2 the pipeline and road leave the foothills and enter the coastal plain. After passing Franklin Bluffs Camp, Franklin Bluffs upland and traversing nearly 100 kilometers of coastal plain the road reaches Prudhoe Bay and the arctic coast.

Construction of the pipeline haul road on the arctic slope commenced in April 1974 and was completed September 1974. Pipeline construction started in June 1975 and all 48 inch pipe was in place by the end of 1976. An 8 inch gas line from Prudhoe Bay to Pump Station 4 was constructed from February 1976 to April 1977.

History of Caribou Movements in the Study Area

Hemming (1971) recognized two distinct caribou populations on the arctic slope. The summer ranges of the Western Arctic and Porcupine caribou herds were thought to overlap in the area of the pipeline corridor, although summer distribution of the Western Arctic herd has reportedly extended as far east as the Canning River (Hemming 1971).

Olson (1959) reported an eastern movement of about 25,000 caribou from the Anaktuvuk to the Canning River during the spring migration of 1956 and during August of that year about 3,500 were seen at the head of the Sagavanirktok River. The following winter well over 100,000 animals remained in the "Central Arctic Region" of the north slope in small widely scattered bands. Similarly, in 1958 over 150,000 caribou wintered on the central arctic slope. Just prior to calving in 1958 about 125,000 caribou moved west from the Shaviovik River. Although little calving was observed in the Central Arctic that year, 10-12,000 caribou were seen just south of Oliktok Point during the summer, and on September 11, 25-30,000 were seen moving south between the upper Ivishak and Sagavanirktok Rivers.

Child (1973) pointed out that "very little is known of the historical importance of the Central Arctic area...to caribou as calving, summering, and wintering grounds." Skoog (1968) coined the name "Central Brooks Range Herd" to describe this subpopulation and identified its center of habitation as the Central Arctic; however he thought that this herd merged with the Western Arctic herd in the early 1950's.

In reference to the spring migration of 1972, LeResche (1975) wrote "the line of separation between the Arctic (west-turning) and Porcupine (east-turning) herds occurred at the Sagavanirktok and Atigun River drainages." LeResche noted no calving between the calving grounds of the Porcupine herd in the Arctic National Wildlife Range and the traditional calving ground of the Western Arctic herd with the exception of "a few hundred animals in the Prudhoe Bay-Kavik area." This population he describes as a "small, isolated group, probably fewer than 5,000, that used the Prudhoe Bay area" and noted that "very few animals...(in relation to total numbers on the arctic slope) have crossed the pipeline route during spring and fall migrations in most recent years."

More recent information on movements and numbers of caribou in the Prudhoe Bay area was reported by Gavin (1971, 1972) and Child (1973). Child (1973) considered the Prudhoe Bay area as "important summer range for a small population of approximately 3,000 animals." During the summers of 1969 and 1970 Gavin estimated that there were as many as 30,000 caribou using the Central Arctic Region. His surveys for 1971 produced only about 15,000 animals, and in 1972, only about 2,500 animals. These sources state that "considerable" calving occurred in the White Hills in 1971 and some calving occurred in the Prudhoe Bay oilfield during 1971 and 1972. White et al. (1975) observed groups as large as 1,500 head in the oilfield during the summer of 1972, but fewer caribou were observed during the summer of 1973 and maximum group size was 130. Nursery bands were the most commonly observed group type, but during severe insect harassment larger groups with a high percentage of bulls moved through the area.

Most recently Cameron and Whitten (1976) identified a herd of approximately 5,000 caribou called the Central Arctic herd (CAH). The seasonal ranges of this herd appear to be almost entirely within the present study area. The north slope section of the pipeline corridor roughly bisects both summer range on the Arctic Coastal Plain and winter range in the Arctic Foothills. The majority of calving in 1975 and 1976 was apparently within 30 km of the Beaufort Sea. Summer post-calving movements occurred mostly parallel to the coast, first to the east and then back to the west with some oscillations to the coast and inland in

response to changing insect densities. Southward fall movements commenced in early September and were nearly complete by rut in early October. During the winters of 1974-75 and 1975-76 small groups wandered throughout the foothills with no apparent directional trend. Spring movements north to the calving grounds in 1975 and 1976 commenced in late April.

Regular aerial surveys of the study area have been conducted since the summer of 1974 and no major influence from the Western Arctic or Porcupine herds was detected. However, in October of 1976 approximately 1200 caribou, thought to have originated from the Western Arctic herd, moved to the western edge of the pipeline corridor near Galbraith Lake and spent early winter in the area of Itkillik Lake, thereafter fragmenting and moving southward into the Brooks Range (K. Whitten, pers. comm.). Egress from the Central Arctic herd appears similarly low, although one caribou collared near the pipeline route was observed in a post-calving aggregation of the Porcupine herd in 1976 (J. Curatolo, pers. comm.).

Thus available information indicates a gradual decline in caribou numbers in this region from the mid-fifties to the present. However, as recently as 1970, approximately 20,000 caribou crossed what is now the pipeline route on the north slope. It appears that groups of caribou occasionally wander in from adjacent areas occupied by either the Porcupine or Western Arctic herds. Some mixing may occur among the three known arctic herds, but interchange does not appear to be frequent.

METHODS

Bands of caribou were located by driving the Trans-Alaska Pipeline haul road in a pickup truck. No prescribed method of location was followed but an attempt was made to survey the entire north slope section of the haul road every two weeks (Fig. 1). A helicopter was occasionally used to locate groups away from the pipeline corridor to assure a more representative sample of the Central Arctic herd in terms of composition and group size.

Groups were observed with the aid of 8x binoculars and a 15x -60x zoom spotting scope. Bands of caribou chosen for observation were suitably located for viewing but not likely to be disturbed by my presence. Observation usually continued until the group moved out of sight or darkness set in. Otherwise observations were initiated and terminated at random.

Quantitative activity data were collected using the instantaneous scan method described by Altmann (1974). Each group under observation was scanned at five-minute intervals, but groups larger than approximately 50 individuals were scanned every 15 minutes. Each scan was performed as quickly as group size would allow. A tally counter was used when necessary.

The following information was recorded for each group observed:

- 1) Observation number
- Previous observation number (if group was observed on a previous day)

- 3) Date
- 4) Time (Alaska Standard Time)
- 5) Location (recorded as road mileage north or south of Happy Valley construction camp and east or west side of the road)
- 6) Group size (defined as aggregations of animals in which the maximum distance between animals did not exceed 300 m).
 (For groups over 200 size was estimated.)
- 7) Composition of group (number of bulls, cows, calves, yearlings, adults, unknowns)
- 8) Topography (on a scale of 1-3: 1 = flat; 2 = moderate; 3 = steep
- 9) Distance from observer (estimated in meters)
- Description of nearby terrain features (e.g. rivers, streams, lakes, mountains, etc.)
- 11) Habitat type-identified on the basis of the following , classification. (A more detailed description is given in Appendix C).
 - a. Eriophorum tussock tundra
 - b. Tussock-heath tundra
 - c. Upland Dryas meadow
 - d. Wet sedge meadow
 - e. Birch-willow shrub
 - f. Riparian willow
 - g. Well-drained alluvial
 - h. Poorly-drained alluvial

- i. Raised-center polygons
- j. Artificially revegetated
- k. Unvegetated

Caribou activity was recorded as one of eight possible activities as described by Thomson (1971):

- 1) Feeding includes feeding-related activity such as cratering in snow and the olfactory search for forage (consequently it is not an indication of actual forage intake). This activity also included ingesting food while walking, a common method of feeding during the snow-free period.
 - 2) Lying
 - 3) Standing stationary, feeding not included (while under insect attack caribou frequently stand with head lowered and at a distance would appear to be feeding. Under such conditions animals which did not move when scanned were assumed to be standing).
 - 4) Walking head elevated, no ingestion of forage.
 - 5) Trotting/running includes running play by calves.
 - 6) Sparring antlers in contact.
 - 7) Nursing includes both the nursing calf and the suckling cow.
 - 8) Other includes a wide range of activities such as antler scratching, urination, and "bush-thrashing."

Observations were recorded as the number of animals engaged in each activity during a given scan. If group size or density precluded a complete count, activities were recorded for as many caribou as possible without duplication.

For each activity count time elapsed since sunrise and time before sunset were calculated. Sunrise and sunset data were obtained from the Nautical Almanac for the appropriate date and approximate latitude and were corrected for longitude. The time of each activity observation was expressed as the number of five minute periods after (plus) or before (minus) sunrise and sunset. Rate of group movement, slope movement, and spacing within the group (average individual distance) were estimated every 15 minutes; thus each measurement of these variables was associated with 3 activity counts. Group movement rate was a visual estimate of the distance that the center of the group had moved during the previous 15 minutes. Slope movement was recorded as: 0 = on the flat or along the sidehill; + = upslope; - = downslope. Group density was expressed as the mean estimated distance between each member of the group and its nearest neighbor.

Various abiotic and biotic environmental parameters were also recorded every 15 minutes:

- 1) Temperature (°C) recorded in the shade at approximately 0.5 1.0 m above the ground at the observer's position.
- 2) Wind speed (miles per hour) measured using a SIMS model Bt anemometer held at arm's length.

- 3) Wind direction categorized into one of eight true points.
- 4) Cloud cover recorded on a scale of 0-6: 0 = clear, 6 = overcast
- Type and rate of precipitation rate visually categorized on a scale of 0-5.
- 6) Mosquito (<u>Aedes</u> spp.) harassment level recorded on a scale of 0-5 based on subjective observer discomfort level.
- 7) Oestrid fly (<u>Oedemagena tarandi</u> and <u>Cephenomyia trompe</u>) harassment level - recorded on a scale of 0-5, this variable was subjectively evaluated by observing the behavior and apparent discomfort level of caribou.
- 8) Slope recorded on a scale of 1-5: 1 = flat, 5 = steep.
- 9) Slope shape recorded on a scale of 1-5
 - 1. flood plain or coastal plain
 - 2. lower slopes
 - 3. mid-slopes
 - 4. upper slopes
 - 5. ridge or hilltops

10) Exposure - recorded on a scale of 1-5 as follows:

- 1. north-facing slopes
- 2. northeast and northwest-facing slopes
- 3. east or west-facing slopes or no slope
- . 4. southeast or southwest-facing slopes
 - 5. south-facing slopes
- 11) Elevation estimated using the appropriate 1:250,000 topographic maps (U.S.G.S.).
- 12) Distance from pipeline haul road or pipeline estimated in meters.
- 13) Vehicle rate on haul road or pipe pad number of vehicles passing the observer's location during the previous 15 minute period.
- 14) Weighted vehicle rate rate adjusted for vehicle size and noise level.
 - 2 pickups and suburbans
 - 3 graders, oiler trucks, fuel trucks
 - 4 semi-tractor trailers, belly-dumps
 - 5 scrapers, giant earth movers
 - 6 low-flying fixed wing aircraft

7 - low-flying helicopters

15) Intensity of behavioral reaction to traffic and other pipeline-related activities - recorded on a scale of 0-4:

0 - no visible reaction

1 - head raised to alert position

- 2 movement away from the stimulus at a walk
- 3 movement away from the stimulus at a trot
- 4 movement away from the stimulus at a run The behavioral reaction value assigned to each activity count was the most extreme reaction observed during the previous 15 minute period.

Observations of interactions between caribou and potential/actual predators were noted. Reactions of caribou to pipeline-related activity and attempted or successful crossings of the haul road and elevated pipe were described in detail. When possible, these and other important events were recorded using 35mm photography. Above-ground pipe clearance was measured for each attempted or successful pipeline crossing inferred from the track record or observed. Social interactions within or between caribou bands were described between instantaneous scans.

Measurements of snow depth and resistance were occasionally collected at caribou feeding sites when it was possible to do so without disturbing the group. In addition, during the winter of 1975-76 depth and resistance were measured at each of 13 locations along the haul road approximately every two weeks to determine regional differences in the character of the snow cover. These sampling stations were located in flat areas to avoid the local effects of slope variation. Some were on hilltops and others on floodplains to assess any basic differences in snow cover between these two land forms. Snow sampling areas were intended to be representative of the surrounding region only in a broad sense. A standard Rammsonde penetrometer (Testlab 1970) with a 1 or 3 kg hammer was used to determine snow depth and hardness. At each station 10 measurements were taken at one foot intervals on a line perpendicular to the direction of the prevailing wind. Each station was sampled at least eight times during the winter.

Forage preferences were recorded during the snow-free period of the year by observing caribou with a spotting scope at close range and examining clipped stems in areas where caribou were observed feeding. During the winter months feeding craters were inspected and marked for examination after snow melt. In some winter feeding areas percent cover of the dominant plant species was estimated and the site was photographed. All shrub names are after Viereck and Little (1972) and all other plant names are after Hulten (1968).

Statistical analyses were performed with programs in the BND package (Dixon 1974) utilizing a Honeywell Level 66, Model 40 computer. Computer programs used included OlD (simple data description), O3D (correlation matrix with item deletion), O7D (description of strata with histograms). For the OlD and O3D programs the data were divided into the following phases of the caribou annual cycle.

1) Spring migration and calving (May 14-June 21)

2) Post-calving (June 22-July 24)

3) August dispersal (August 2-September 2)

4) Pre-rut (September 4-September 28)

5) Rut (October 3-October 26)

6) Early winter (October 31-December 6)

7) Midwinter (January 24-February 23)

8) Late winter (March 2-May 5)

No data were collected during the periods July 25-August 1, September 29-October 2, October 27-October 30, December 7-January 23, and February 24-March 1.

For BMD program 07D the data were divided into two groups only due to the large sample sizes required:

1) Snow-free period (May 14-September 28)

2) Winter (November 9-May 5)

RESULTS AND DISCUSSION

The annual cycle

Activity data has been divided into eight categories which coincide with major phases of the annual cycle (Tables 1 and 2). The inclusive dates of these phases for a given herd may differ between years due to weather variations. The chronology of events varies between herds because of climatic differences which influence the timing of rut, calving, and migrations. Plant phenology and emergence of parasitic insects vary regionally as well as annually and have an important influence on caribou behavior. Nevertheless, similarities in circumpolar environments have dictated comparable seasonal changes in the behavior of tundra populations.

As defined for this study, the spring period began with the emergence of new plant growth and ended with the appearance of mosquitos. It included most of the northward spring migration of cows and the calving period. All spring migration by males was also included. The peak of calving in the Central Arctic herd (CAH) was about June 4-9 (Cameron et al., unpubl. data).

The post-calving period was defined in this study by the presence of mosquitos. During this period most of the herd was found in large aggregations of mixed composition near the arctic coast. The emergence of warble flies marked the end of the post-calving period and the beginning of the August dispersal phase when small, sexually segregated groups dispersed over the coastal plain. Mosquitos continued to be

Season	Spring	Post-calving	August Dispersal	Pre-rut	Rut	Early Winter	Mid- Winter	Late Winter
Dates	May 14- June 21	June 22- July 24	Aug 2- Sept 2	Sept 4- Sept 29	Oct 3- Oct 26	Oct 31- Dec 6	Jan 24- Feb 23	March 3- May 5
Number of Groups Observed	103	48	77	46	90	35	[.] 86	154
Number of Activity Counts	963	477	504	277	430	340	1151	973

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Table 1.	Seasonal distribution of caribou activity counts observed from February 19	75
	to August 1976 on the range of the Central Arctic herd.	

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	Season								
	Spring	Post-calving	August Dispersal	Pre-rut	Rut	Zarly Vinter	Mid-Winter	Late Vinter	
Percent com (pean)	18.0	20.8	15.4	24.1	30.5	17-5	11.7	16.9	
Percent calves (mean)	9.6	10.7	9.3	11.7	17.8	9.9	7.7	6.8	
Percent bulls (sean)	61.0	58.6	72.3	55.9	40.7	45.3	61.8	51.4	
Naul road mileare [®]	••••						••••		
Bran	+17.8	+66.7	+53.7	+30.9	+13.8	-11.7	-10.8	-27.4	
Bax I Bull	+91.6	+92.0	+90.0	+68.0	+38.8	+15.7	+ 9.0	+22.6	
minimum	-56.8	+ 1.4	-22.0	-49.5	-50.5	-49.7	-50.1	-60.7	
Elevation (ft)									
Bean	856	169	274	707	973	1388	1253	1980	
max i mum	2800	900	900	2700	2550	2550	2650	3050	
minimum	25	10	40	100	200	900	825	350	
Exposureb (mean)	3.1	3.0	3.0	3.4	3.2	2.9	3.1	3.4	
Slope ^C (mean)	1.6	1.0	1.1	1.7	1.7	2.1	· 1.5	2.0	
Slope shaped (mean)	2.1	1.0	1.1	1.8	1.9	2.7	1.8	2.7	
Bean	+ 1.1	411.8	+13.5	- 5.1	-16.0	-29.9	= 30.1	- 9.0	
maximum	+15	+25	+26	+ 6	- 2	-25	- 7	+ 5	
minimum	-12	- 6	- 3	-18	-24	-35	-48	-23	
Wind speed (mph)		•	-						
Bean	8.5	11.7	7.4	5.9	5.6	3.0	8.3	8.3	
Max 1 min	28	31	18	15	19	11	25	40	
minimum	0	4	0	1	0	0	0	0	
Cloud cover ^e (mean)	4.3	3.7	2.8	4.3	3.8	2.9	2.9	2.3	
Precipitation rate (mean)	0.6	0.4	0.2	0.5	0.4	0.7	0.6	0.2	
Snow depth (cm)		•••							
mean	0.4	•	-	1.9	7.1	15.1	25.3	4.3	
Baxinus	4.0	-	-	10	17	17	40	30	
minimum	0	-	-	Ō	0	12	. 15	Ō	
Snow resistance (Ram hardn	esa valu	e)		-	-			-	
meaa		-, ,	-	-	-	0.2	1.9	1.1	
Baximum	-	-	-	-	-	1.0	5.0	4.0	
minimum	-	-	-	-	-	0	0	0	

Table 2. Seasonal description of caribou group composition and environmental conditions during the collection of activity data from the Central Arctic herd.

^ALocations of caribou groups were recorded as haul road mileage north (plus) or south (minus) of Happy Valley Camp. ^bNorth-south exposure was recorded on a scale of 1-5: 1 = north, 5 = south.

^CRecorded on a scale of 1-5: 1 = flat, 5 = steep.

^dRecorded on a scale of 1-5: 1 = valley bottom, 5 = ridge top:

*Recorded on a scale of 0-6: 0 = clear, 6 = overcast.

 $f_{\text{Recorded on a scale of 0-5: 0 = none, 5 = heavy.}$

active, but were present in relatively small numbers. However, it is clear from the changes in caribou behavior discussed in a later section that harassment by warble flies had a stronger effect on caribou activity.

Pre-rut occurred between the end of the oestrid fly season and the actual breeding period. In 1975 pre-rut included most of the southward fall migration, but the timing of these movements appeared to show notable annual variation. During this period antler velvet was shed by bulls, followed by considerable sparring and bush-thrashing. The onset of rut was marked by the initiation of driving and tending of cows by mature bulls. In 1975, intense rutting activity occurred from October 7-20 and copulation was observed on October 10 and 11 (G. Milke, pers. comm.). Rut was considered over when large bulls began dropping their antlers and tending of cows subsided.

The three winter periods were distinguished mostly on the basis of changing snow conditions as they appeared to affect caribou distribution and feeding behavior. Miller (1976) described comparable divisions for barren-ground caribou wintering in the taiga. The differences between the winter phases were more subtle than the previously described seasonal differences and hence had less distinct cut-off dates. In general, early winter was characterized by snow depths which did not restrict movements or feeding and consequently groups remained fairly mobile. By midwinter snow depth and density had increased so that groups were relatively sedentary ("yarded up"), and feeding was more concentrated in areas with higher standing crops of winter forage. In late winter most

groups moved farther south to areas in the southern foothills where wind had removed most of the snow. Areas of high quality forage at lower elevations were largely abandoned due to increased snow depth and hardness.

A comparison of Bergerud's (1974) division of the annual cycle of Newfoundland caribou with that of the CAH is shown in Fig. 2. The important differences appear to be a result of shorter summers and longer winters on Alaska's north slope. Fall migration occurs after rut in Newfoundland. Also spring migration commences much earlier in Newfoundland. Seasonal trends in mean group size are similar for the two populations; however, the period of maximum aggregation is different. Maximum mean group size occurs during rut in Newfoundland but was observed during post-calving on Alaska's north slope. This is probably due to differences in available insect relief habitat, the absence of forest in the range of the CAH, and/or the absence of wolves in Newfoundland. Wolf predation of barren-ground caribou populations selects for clumping shortly after calving. The formation of large aggregations is disadvantageous where areas of insect relief habitat are small and dispersed (Bergerud 1974).

To examine seasonal changes in activity budgets, activity counts were converted to the percentages of a group involved in each of the eight activity categories. This approach permits the calculation of the mean seasonal percentage of time allocated to each activity (Appendix A). The marked seasonal differences which appear in this as well as



Fig. 2. Annual cycles of the Central Arctic herd and Newfoundland caribou

*cross-hatched areas are periods of no data

other basic behavioral parameters such as group size, group movement rate, and average individual distance are discussed below.

More time was devoted to feeding than any other activity during all phases of the annual cycle except spring and post-calving (Fig. 3). In spring, lying occupied a higher percentage of time than feeding while during the post-calving phase the two activities occupied comparable amounts of time. Highest values for feeding occurred in midwinter, prerut and early winter. High values in midwinter were undoubtedly due to the additional time required to expose forage by cratering in snow. During pre-rut increased feeding was probably a result of reduced availability of green forage and fattening requirements prior to rut. The low feeding percentage during rut was a result of rut-related behavioral effects. In lieu of normal feeding or lying activities, mature bulls stood hunched over in what Lent (1965) has described as the "trampling" posture or they chased cows and rival bulls. Low feeding percentages during the post-calving and August dispersal phases were partly induced by mosquito and oestrid fly harassment, respectively. But the feeding value was also low in spring when parasitic insects were not active. During this season lying took up more time than feeding, probably because increased forage quality and availability and small rumen capacity made it relatively easy to fill the rumen. In late winter when the percentage of time spent feeding was low compared to early and midwinter, forage quality is also low but feeding occurred mostly in wind swept areas where cratering is unnecessary.



Fig. 3. Seasonal allocation of time to various activities for CAH caribou.

The percent of time spent standing remained at between 1.7 and 3.2 percent throughout the year, except during post-calving, August dispersal, and rut when respective values were 4.8, 17.4 and 7.3 percent. These exceptions were due to insect harassment and breeding behavior. Standing for long periods of time was a common response to oestrid fly attack which occurred during August dispersal.

The incidence of walking was lowest during August dispersal, midwinter and late winter. Low values in winter accompanied restrictive snow conditions. In August, insect-harassed caribou commonly stood or ran and walked very little. When insect activity is low, the abundance of preferred forage and small group size reduces the need for continuous movement. The fraction of time spent walking during the pre-rut and rut periods was high, apparently in response to lower forage quality and a shift to winter forage of lower standing crop, which required more frequent movement between feeding areas. In addition, this period coincided with migration toward winter feeding areas.

Like standing, trotting/running was more common during post-calving, August dispersal, and rut than during other phases of the annual cycle. Parasitic insects and reproductive behavior were again clearly the major causes. The highest seasonal values for trotting/running occurred during the post-calving period due to mosquito harassment (4.1%), while standing was quantitatively most important during August in response to oestrid flies. During rut the mean percentage of time spent trotting/ running was 3.4.

The incidence of sparring was very low during spring and unobserved during the two summer periods because the growing condition of the antlers makes them sensitive to touch (Appendix A). Sparring was quantitatively most important in pre-rut and rut (1.3% and 1.1%, respectively) but continued throughout the winter. It is interesting that a slight resurgence of sparring among young bulls occurred in late winter. This "false rut" was probably in response to increased day length.

Nursing activity gradually declines after calving and was rarely observed and never recorded for an activity scan during rut (Appendix A). Activities classed as "other" were most common during spring, postcalving and August dispersal (Appendix A) due to frequently observed bouts of antler "scratching." During pre-rut, bush-thrashing and antler cleaning replaced antler scratching.

Sexual differences in seasonal activity are also apparent (Fig. 4 and 5) (see also Appendix B). The percent of time spent feeding was much higher for bull groups than for cow groups in early winter and somewhat higher in midwinter, but by late winter bull groups spent more time lying than cow groups. Groups dominated by cows demonstrated higher mean values for standing and walking throughout winter. These differences probably result from the relatively poor condition of bulls following rut and consequently a greater demand for forage intake in order to avoid undernutrition.



Fig. 4. Seasonal allocation of time to various activities by bull-dominated and cow-dominated caribou groups (May-September).



Fig. 5. Seasonal allocation of time to various activities by bull-dominated and cow-dominated caribou groups (October-April). *Sexes mixed.

During spring, lying is quantitatively a more important activity for cow-dominated groups than for bull-dominated groups. Lying is the predominant activity for young calves and cows also appear to rest more frequently the first two weeks after calving. During the post-calving, August dispersal, and pre-rut phases, female groups spend more time feeding than bull groups. A greater tolerance by cows of oestrid fly harassment is indicated by lower percentages for standing, trotting and running for female groups during August.

Mean group size was highest during post-calving and small secondary peaks in group size occurred during pre-rut and late winter; the lowest value was obtained during August dispersal (Fig. 6). Mean individual distance was lowest during post-calving and highest in August (Fig. 6). Means of group size and individual distance tended to vary inversely except during rut when mean group size and individual distance were both relatively low. This appears to be due to a tendency for rutting bulls to keep group members close together by tending cows. Seasonal changes in the mean rate of group movement clearly indicate a seasonal difference in mobility (Fig. 7). Maximum movement rates were observed in August, and minimum values were obtained in midwinter.

Seasonal activity data for wild reindeer (<u>Rangifer tarandus</u> <u>tarandus</u>) on the Hardangervidda plateau, Norway (Thomson 1971) are similar to the results from the CAH in several respects. The percentage of time spent feeding declined in both populations during snow melt and remained low until a sharp increase in late summer. In Norway hunting



Fig. 6. Seasonal variation in mean group size and average individual distance of caribou in the Central Arctic herd.



Fig. 7. Seasonal variation in the mean rate of group movement for the Central Arctic caribou herd.

in September caused a drastic reduction in feeding time (Gaare and Thomson 1976). In contrast the percentage of time spent feeding was very high for the CAH which has little or no hunting pressure. Reduced feeding during rut, reduced walking during winter and a decrease in lying through the summer were apparent in both herds.

A difference in the activity budgets of the Central Arctic herd and reindeer on the Hardangervidda plateau existed during midwinter. In the CAH feeding reached a peak of 60.7 percent whereas for reindeer in Hardangervidda feeding occupied about 45 percent of the time. This was probably a result of less restrictive snow cover and/or better winter range in Norway which resulted in higher lying values. However, the CAH spent more time lying in summer which may indicate more favorable summer conditions for this herd. During summer the percentage of time spent standing is higher in the CAH than for reindeer in Norway either because of greater oestrid fly harassment or due to a difference in behavioral reaction to oestrid flies.

Thomson (1973b) calculated an activity budget for the CAH during the post-calving period from his studies of caribou near Prudhoe Bay in 1972. Comparison with results from the present study indicates feeding times were higher and lying times lower. Thomson's results for time spent walking and trotting/running were also higher. The most likely explanation for these differences is that the groups Thomson observed were more harassed by mosquitos.

Curatolo (1975) calculated seasonal activity budgets during the summer of 1973 for the Fortymile herd in interior Alaska. A striking difference in the activity of the Fortymile herd and the CAH was the consistently greater feeding values and lower lying values in the Fortymile herd, a pattern which Segal (1962) suggested is an indication of poorer range conditions. Larger mean group size in the Fortymile herd may have the effect of increasing feeding and reducing lying times. In addition, the two herds showed a major difference in the seasonal mean movement rates. For example, during the post-calving period rates for the Fortymile herd averaged seven times greater than the mean rates for the CAH. Mosquito densities were unusually low in 1973 (Curatolo 1975), consequently differences in insect harassment are not the cause of the discrepancies. These differences could be indicators of a combination of poor range quality and high predation pressure on the young, primarily by wolves, in the Fortymile herd. This herd has recently experienced a severe population decline from approximately 40,000 in 1953 to 6,000 in 1975 and summer calf mortality has been high (Curatolo 1975). It is possible that strong differences in movement rates and activity budgets between the CAH and the Fortymile herd reflect the unfavorable environmental conditions presently experienced by the declining Fortymile herd. Alternatively, the Fortymile herd may still be following summer movement patterns which were developed during the period of maximum herd size when rapid, extensive movements were advantageous. This behavior is now vestigial.

Circadian rhythms

Rhythmic patterns of activity also occur at the diel level. These patterns are responsive to environmental and intrinsic factors; hence strict adherence to the typical activity rhythm is rare. The diel patterns were apparent only after the activity data had been divided into half hour periods and the means calculated for each period. It was obvious in the field that groups were alternating periods of feeding with periods of lying. Individuals within a group exhibited a high degree of synchronous activity, but unpredictable variation in the duration and timing of these periods was noted. For example, a group observed on January 29 remained lying for 50 minutes from 1305 to 1355 while a group observed on February 7 maintained a lying period for 185 minutes from 0950 to 1255.

Data were divided into summer and winter periods for analysis of circadian rhythms because of major differences in activity patterns observed during these two seasons (Thomson 1971). Further breakdown was prohibited by sample size. The results show a distinct pattern of feeding and lying during winter and a clearly different but less distinct pattern in summer (Fig. 8). Lying and feeding showed the clearest circadian rhythms but diel patterns were observed in other activity categories as well.

In winter a daily peak in lying occurs at about 1230 (Fig. 8) and peaks in feeding activity occur at approximately 0900 and 1530 (Fig. 10). Thus the mean period of the winter feeding-lying cycle is between



Fig. 8. Comparison of the circadian incidence of lying in groups of caribou between summer and winter seasons.

6 and 6.5 hours. Walking also showed diurnal peaks during winter, one occurring at about 0930 and coincident with the morning feeding peak. The time of the second walking peak does not coincide with the afternoon feeding peak at 1530 but instead occurs after 1800.

During summer, peaks in lying occurred at about 0900, 1200, 1500, and 1930 with feeding peaks interspersed at about 1030, 1300, and 1730. Additional feeding peaks were indicated at 0800 and 2130. A series of peaks and troughs was observed in the diel distribution of standing, but did not clearly correspond to the feeding or lying pattern. After 1900 the incidence of standing was particularly low.

Distinct seasonal differences in the period of feeding-lying cycles is a response to changing forage availability and quality (Segal 1962, Thomson 1971). Increased availability necessarily reduces the time required to fill the rumen and increased quality would be expected to reduce rumen turnover times. In addition, the less distinct peaks and troughs in activity cycles during summer reflect reduced synchrony between groups, probably due to continuous daylight, greater differences between bull and cow activity patterns, and/or the disruption of normal patterns by parasitic insects.

Once these general daily activity patterns had been identified, the winter and summer data were divided into groups with calves and those without. The calf criteria were used because groups with calves were almost always predominately adult cows and groups without calves were predominately bulls. Sexual differences in activity rhythms were apparent in both summer and winter (Figs. 9, 10, 11, 12).



Fig. 9. Comparison of the diel pattern of lying during winter between bull and cow groups of caribou (November 9 -May 5).



Fig. 10. Comparison of the diel pattern of feeding during winter between bull and cow groups of caribou (November 9 -May 5).



Fig. 11. Comparison of the diel pattern of lying during summer between caribou groups with calves and groups without calves (May 14 - September 28).



Fig. 12. Comparison of the diel pattern of feeding during summer between caribou groups with calves and groups without calves (May 14 - September 28).

In winter, the midday peak in lying for groups with calves was greater in both amplitude and duration (Fig. 9). It is unclear whether less synchrony in bull groups during winter is the cause of lower mean lying percentages between 0930-1500 or whether bulls do in fact devote less total time to lying during the daily cycle. Unfortunately, the latter possibility could not be examined because of the lack of nocturnal data. As mentioned in the previous section, higher feeding percentages for bulls may be due to their poor physical condition entering winter and a consequent requirement for increased forage intake.

Sexual differences in activity patterns are more distinct in summer. The summer peaks of feeding and lying for combined sexes mentioned above (Fig. 8) reflect primarily the pattern exhibited by bull groups because the majority of data was obtained from bull groups. Groups with calves (cow-dominated) displayed a circadian cycle asynchronous with the cycle for bull groups (Figs. 11 and 12). The feeding peak for bulls between 1000 and 1030 (Fig. 12) coincides with a peak in lying for cow-calf groups at 1000 (Fig. 11). Similarly, a feeding peak for bull groups at 1330 (Fig. 12) corresponds to a lying peak in cow groups (Fig. 11). This asynchrony apparently results from a difference in the mean duration of activity cycles. Bull groups complete a cycle of feeding and lying every 3-3.5 hours whereas cow-calf groups require about 4-4.5 hours. If the duration of the feeding-lying cycle remains fairly constant during the 24 hour period then these results indicate that bull groups would complete 7 or 8 cycles whereas cow

groups might complete only 5 or 6. The mean duration of a summer cycle of feeding and lying was nearly half the winter one, irrespective of group type.

Thomson (1971) felt that sexual differences in activity rhythms may be largely responsible for sexual segregation in winter. He noted that bulls appeared to be less synchronized than cows. If this were true, a lower amplitude would be expected for the activity cycles of bull groups because peaks would be less distinct. Thomson's hypothesis is supported by the results from the CAH (Figs. 9 and 10).

In contrast to the results of this study Thomson found no sexual differences in activity cycles during the summer. However, Segal (1962) observed a different frequency of activity cycles for reindeer depending on sex and he felt this was responsible for sexual segregation in summer. His results indicate shorter mean periods of feeding-lying cycles for cows than for bulls; bulls consistently fed for longer periods of time than cows. These results contradict the results of this study (Figs. 11 and 12). However, Segal obtained activity data using tame reindeer on a tether. Free ranging caribou with the ability to select the most favorable habitats might behave differently.

Shorter summer feeding-lying cycles for bull groups in the CAH may be due to sexual differences in habitat and forage selection discussed in the next section. By occupying habitats with greater available biomass of higher quality forage, bulls would require shorter activity periods than cows. Turi (1931) stated that fixed resting frequencies

for reindeer occurred only on good pasture, thus feeding times were closely related to the extent to which each feeding bout supplied nutritional needs. If the habitats occupied by bulls in summer are of higher quality, as indicated by shorter feeding times, it is curious that cow-calf groups do not occupy these same habitats unless there are other overriding factors such as vulnerability to predation on calves.

From about May 1 to August 15 most of the CAH lives in continuous daylight but day length in midwinter is less than 4 hours. It is obvious that caribou could not survive winters in northern latitudes if feeding activity was limited to daylight hours. To a certain extent caribou must feed and ruminate despite changes in photoperiod. An attempt was made to determine if caribou feeding and lying activity was somehow synchronized to the changing times of dawn and dusk through the winter. Activity budgets were computed for each half hour interval before and after both sunrise and sunset, and the results suggest a response of activities to dawn and dusk, regardless of timing.

Few caribou were lying at sunrise and the mean percentage of animals lying gradually increased to a peak at about four hours after sunrise (Fig. 13). The corresponding decline in the incidence of feeding after sunrise is not as distinct as the increase in lying but the lowest mean value for feeding does occur about four hours after sunrise (Fig. 13). Nean percentages for walking were highest the first hour and a half after sunrise, subsequently declining to a fairly constant level of about seven percent.



Fig. 13. Incidence of feeding, lying, and walking activities in relation to sunrise during winter (November 11 - April 28) in the Central Arctic caribou herd.

Approximately one half hour before sunset a decline in the mean percentage of lying occurred and continued for at least 1.5 hours after sunset (Fig. 14). A corresponding increase in the mean percentage feeding was observed (Fig. 14).

It is difficult to explain how caribou manage to feed at sunrise and after sunset while maintaining a midday resting period as day length increases. Preserving this pattern as winter progressed would require that midday lying periods be lengthened in late winter. The average duration of lying periods in late winter (103 min., n=13) is not greater than that of lying periods in midwinter (120 min., n=12). It is probable that the resting period at midday is a tendency related to feeding at sunrise and sunset during short midwinter days and is not significant as a synchronizer of the 24 hour activity cycle.

Midday resting periods during winter have been observed in reindeer from the Soviet Union (Segal 1962) and Norway (Thomson 1973a). Also, Segal mentioned that reindeer were usually active at dawn. Thomson (1973a) felt that the midwinter pattern of lying at midday gradually shifted to a pattern of lying both before and after midday with a midday feeding period as day length increased during late winter. This would enable animals to feed at sunrise and after sunset without altering the duration of the feeding-lying cycle. Cycle amplitude for feeding and lying is greater when the data are compiled in relation to sunrise and sunset (Figs. 13 and 14) than it is when organized by time of day (Fig. 8). This suggests that dawn and dusk are more important



Fig. 14. Incidence of feeding, lying, and walking in relation to sunset during winter (November 11 - April 28) in the Central Arctic caribou herd.

synchronizers of daily activity than midday. The habit of feeding at dawn and dusk appears to be the means by which circadian rhythms are entrained to photoperiod and hence may be important to the timing of seasonal phenomena such as rut and migrations. Bubenik (1965) theorized that crepuscular feeding activity was an adaptation to the circadian pattern of hunting activity by wolves. However, in open habitats such as the arctic slope of Alaska a feeding group of caribou would not necessarily have an advantage over a resting one in detecting wolves. During the snow-free period crepuscular feeding is advantageous because of cooler temperatures, lower insect densities, and higher forage moisture.

Forage, snow, and habitat selection

Small numbers of caribou usually remain on the arctic slope of Alaska during winter, and occasionally large numbers have over-wintered on what is generally classified as summer range. The south slope of the Brooks Range and the flats beyond (traditional wintering grounds of the large Western Arctic and Porcupine herds) are considered good winter range due to the abundance of fruticose lichens. Because the north slope is relatively poor in lichens, it is generally assumed that other forage species, such as sedges, constitute the bulk of the winter diet (Skoog 1968). However, examination of winter feeding areas in the present study indicates this is not the case (see Appendix D). Lichens were consistently selected despite low standing crops and localized

distribution. In general, winter feeding appeared to be specialized. Two species in particular, <u>Cladonia rangiferina</u> and <u>Cetraria cucullata</u>, were heavily utilized throughout the winter. In addition, one wintergreen species, <u>Equisetum variegatum</u> (horsetail) was intensively grazed at localized stands along major rivers. Various other species were taken on occasion and no doubt some species were consumed incidental to the above three species (Appendix D).

The summer diet of the CAH was much more varied and appeared to be dependent on the highest quality forage available at a given time (Appendix D). The first spring growth to appear in the foothills (Fig. 1) was the floral heads of cottongrass (<u>Eriophorum vaginatum</u>). In years of good flower production this species was consumed exclusively for nearly a month. However in 1976 when flower production was low, the previous year's growth of <u>Equisetum variegatum</u> remained an important forage until other new growth appeared.

By the third week in June the new leaves of various species of shrub willow (Salix spp.) appeared and until late August willow seemed to be the forage most often selected. <u>S. planifolia</u> was the willow species most frequently consumed. A wide variety of dicotyledonous herbs were also taken during the growing season. The flowers of the genus <u>Pediculari</u>, were especially preferred. Several similar, sequentially flowering species of this genus are present on the arctic slope, and caribou were observed selecting each as flowering occurred. Various legumes such as Hedysarum Mackenzii, Astragalus umbellatus and Oxytropis nigrescens
were favored forbs later in the season. Several grasses and sedges, including <u>Eriophorum angustifolium</u> and <u>Arctogrostis latifolia</u>, were utilized through the summer but were more heavily utilized late in the season when willows and most herbs had declined in quality due to senescence.

Pregnant cows in the CAH encounter poor forage conditions at the end of their northward trek to the calving grounds. No new forage was present near the arctic coast during the estimated peak of calving in both 1975 and 1976. Examined feeding areas revealed very low standing crop of lichen. Apparently <u>Thamnolia vermicularis</u> and <u>Cetraria</u> spp. were being selected but there was little evidence that other forage was being consumed. <u>Cochlearia officianalis</u> (scurvy grass) and small numbers of <u>Eriophorum vaginatum</u> flowers appear shortly after calving and may be important until other growth appears.

The importance of new growth to parturient cows of the Western Arctic herd was demonstrated by Skoog (1968) in 1964. Spring thaw in that year was particularly late and <u>E. vaginatum</u> flowers had not yet appeared as the cows arrived on the calving grounds. Many of the cows were severely weakened and some apparently died of starvation. Lactation places a tremendous demand on the low protein and fat reserves remaining at calving time. This is well illustrated by the following observation from the Soviet Union. Reindeer calves which conceive are able to bring fetuses to full term without lasting deleterious effects on productivity. However, if these yearlings are allowed to nurse their

calves, their own growth rates are reduced and they frequently remain barren for the duration of their lives (Zhigunov 1968). There is apparently strong selection for movements of CAH cows toward the coast at calving time as opposed to remaining in the foothills. This selection is apparently not primarily related to forage quality.

The distribution of preferred forage species in the study area is not uniform, either locally or area-wide. Variations in soil moisture, acidity, organic content, exposure, and depth of active layer all influence plant distribution and abundance (Webber and Walker 1975). Equisetum variegatum is restricted mostly to poorly-drained alluvial deposits on floodplains (see Appendix D and E for a more detailed description). Periodic inundation and the resultant deposition of silt appear to be a requirement for sustained vigorous growth of this species (Gill 1971). Low standing crops of Cladonia and Cetraria on the coastal plain are due primarily to high moisture soil and competition with mosses and sedges. More favorable conditions for growth of lichens exist in the foothills, particularly in areas of poor soil composed of dry, peaty or stoney material. These conditions generally inhibit the faster growing mosses and sedges. Dry soils are often found on river bluffs while peaty material is common on old river terraces or the shores of receding lakes. Acidic, peaty soils also favor growth of various ericaceous shrubs, such as Ledum, Vaccinium and Empetrum, which are usually found in association with relatively high standing crops of fruticose lichen (see Appendix EC). Well-drained glacial till in the

southern foothills can also support relatively high standing crops of lichen. In midwinter caribou were mostly restricted to river valleys in the foothills, apparently in response to the local distribution of <u>Equisetum variegatum</u> and the proximity of lichen stands. By late winter the majority of caribou had shifted south to lichen stands found on well-drained glacial deposits. These areas were frequently wind-swept whereas snow continued to accumulate and harden in the river valleys.

Reindeer herders in the Soviet Union consider lichens to be the limiting factor in the carrying capacity of a range (Baskin 1970). As in the case of the CAH, <u>Cladonia rangiferina</u> is apparently preferred over <u>Cetraria cucullata</u> by reindeer. However, it is recognized that reindeer do poorly on straight lichen diets due to the extremely low protein, vitamin, and mineral content. Winter-green forage is important in prevention of emaciation, barreness, stillborns, and neonatal death (Zhigunov 1968). <u>Equisetum variegatum</u> is mentioned as one important source of winter-green forage in the Soviet literature (Zhigunov 1968). Some species of horsetail retain a protein content of 6-7 percent through winter (Florovskaya 1939).

As snow melt progressed in the spring, groups of caribou were again observed on river floodplains where <u>Equisetum variegatum</u> was being exposed. With the widespread emergence of <u>Eriophorum vaginatum</u> flowers in the foothills caribou became widely dispersed. <u>Eriophorum</u> flowers appear first in the southern foothills and emergence proceeds northward. Although most cows have departed for the calving grounds

near the coast prior to the appearance of <u>Eriophorum</u>, the bulls are able to follow the peak of Eriophorum flower quality as it moves north.

The Western Arctic and Porcupine herds of arctic Alaska may subsist mostly (or almost entirely) on <u>Eriophorum vaginatum</u> flowers in May and early June (Lent 1966a, Skoog 1968). In the CAH, movements of the bull segment appear to reflect this spring preference for <u>Eriophorum</u>. Parturient females, however, differ with respect to forage utilization in spring. Previous to the spring of 1975, it was assumed that calving took place on rolling terrain vegetated with <u>Eriophorum vaginatum</u> tussocks since these areas large amounts of preferred new forage early in spring. It has since been found that the majority of calving occurs on the coastal plain where <u>E. vaginatum</u> is sparse. On-ground inspection of feeding areas within the calving grounds revealed no other new plant growth was present. The selection of coastal areas for calving was an enigma, because high quality forage was lacking.

Soviet reindeer herders recognize benefits of moving their herds to the arctic coast prior to calving. Availability of sodium is considered important for the cows since cows which were not moved to the coast bore smaller calves and grew smaller antlers (Baskin 1970). There was no evidence of this type of nutrient shortage in the CAH since most cows remain several miles south of the coast until mosquitos cause movements to coastal relief habitats. Once new growth appears near the coast it may remain higher in quality for a longer period than farther inland. Lower temperatures and moister conditions in the coastal

fog belt are considered favorable for the maintenance of forage with high energy and nutrient content (Klein 1965). But prior to the appearance of new forage, cows near the coast apparently select lichens and winter-green plants which are more abundant and more palatable farther south.

By the time <u>Eriophorum</u> flowers had declined in quality, <u>Pedicularis</u> <u>Kanei</u> (lousewort) and <u>Salix</u> leaves had appeared on the river floodplains. Bulls again concentrated in river valleys and appeared to follow the progressive emergence of these and other species. The standing crop of willow is much higher in seral riparian habitats than on undisturbed coastal plain tundra. Consequently, bulls continued to be more numerous on river floodplains through the summer. During calving, the distribution of cows was influenced primarily by the location of exposed ground. Shortly after calving new growth began to appear on the slightly elevated, better drained sites which were heavily utilized by cows and their attendant calves.

As the plant growing season drew to a close in August, caribou concentrated in wet pockets of vegetation that had remained green. At this time some caribou were attracted to artificially revegetated sites and areas where the natural drainage pattern had been altered by human constructs. The shift to a winter diet high in lichens occurred in late September, and caribou moved south toward the foothills where lichens were more abundant.

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The percent of total caribou groups observed in each of the 11 habitat types (see Appendix C) was calculated for each phase of the annual cycle (Fig. 15). Eriophorum tussock tundra was the habitat most frequently occupied in all periods except post-calving, August dispersal, and midwinter. The preferred habitat for parturient cows was raised-center polygon areas which were first to be exposed near the coast. Well-drained alluvial deposits were used most in spring when new growth first appeared. During the two summer periods wet sedge meadow was the most frequently used habitat type. Riparian willow habitats were occupied during summer when willow leaves are preferred forage. Unvegetated areas were utilized for insect relief during periods of mosquito and oestrid fly harassment. Revegetated areas were used in fall because grasses in these areas had been frozen in the green state after other vegetation had senesced. In midwinter poorly drained alluvial habitats were preferred along the haul road. Upland Dryas meadows are most important in late winter but are utilized in midwinter as well. Tussock-heath tundra, a habitat with relatively high standing crop of lichens, is only preferred during the winter periods.

Some sexual differences in habitat selection are apparent from Table 3. During spring only cow-calf groups utilized raised-center polygon habitat. Bulls were farther south feeding in well-drained alluvial and <u>Eriophorum</u> tussock habitats where new growth was available. Bulls also made little use of wet sedge meadow habitat



Fig. 15. Seasonal occupancy of habitats by the Central Arctic caribou herd.

								Se							
Habitat Type	Spring		Post-calving		Aug Disp	ust ersal	Pre	-rut	Rut	Early Winter		<u>Hid-v</u>	inter	Late Vinte	
	<u>Cov</u>	<u>Bull</u>	Cov	Bull	Cov	Bull	Cov	Bull	Mixed	Cov	<u>Bull</u>	Cov	<u>Bull</u>	Cov	<u>Bull</u>
Eriophorum tussock tundra	28	55		14		11	43	14	43	67	50	35	26	51	50
Tussock-heath tundra					-		9	5	12	8	22	29	17	5	13
Upland <u>Dryan</u> meadow		7				8			2	8		6	11	41	28
Wet medge meadow	16		43	34	75	13	26	9	27	17			-		
Birch-willow shrub		3		7	8	4		5	1						
Riparian willow		1		14		25		18			11				
Well-drained alluvial	4	15	10	24		4	4	18	2		~-		3		
Poorly-drained alluvial	16	15	10	3		9	17	18	12		17	29	43	3	9
Raised center polygon	36		29				-					-			
Artificially revegetated						6		9	-				-		
Unvegetated	-	4	10	3	17	21		5				****			

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Table 3. Seasonal and sexual differences in caribou habitat selection.

*Percentages of observations for a given season. -

during spring whereas cow groups were forced to cross large areas of this habitat to reach the calving grounds.

During the post-calving period cow groups were most frequently observed in wet sedge meadow and raised-center polygon habitats when mosquito harassment was low. In addition to wet sedge meadows, bulls were frequently seen in Eriophorum tussock tundra, riparian willow, and well-drained alluvial habitats. This affinity for riparian habitats by males was most pronounced in August. Groups of cows were not observed on floodplains along the haul road except during intense oestrid fly harassment when river gravel bars were utilized for insect relief. During the pre-rut period bulls again occupied riparian habitats more frequently than cow groups; the latter were observed primarily in Eriophorum tussock tundra and wet sedge meadows. These data suggest a preference by bulls in summer for seral vegetation which is abundant only on the repeatedly disturbed floodplains of major rivers. Cow-calf groups did not show this preference and were observed feeding in climax communities such as wet sedge meadows. Cow groups were common along the Sagavanirktok River only when insect harassment was severe.

Sexual differences in habitat selection were much less distinct during the three winter periods. Throughout the winter it appears that bull groups are more attracted to wet alluvial habitats where <u>Equisetum</u> <u>variegatum</u> is selected. There is also some indication that cow groups showed a greater preference than groups of bulls for upland <u>Dryas</u> meadow habitats in late winter. Otherwise, habitat selection of the two group types appears similar during winter.

Data collected from snow stations during the winter of 1975-76 indicated regional differences in snow conditions on the arctic slope (Table 4, Fig. 16). The three northernmost snow stations (i.e. on the coastal plain) showed consistently higher Rammsonde hardness values and somewhat greater depths than stations to the south. The lack of relief on the coastal plain affects relatively homogenous snow conditions. Very little use of the coastal plain by caribou was observed after rut except for a few animals which apparently wintered along the arctic In the northern foothills means of both snow depth and coast. resistance were greater in upland areas (stations 5, 7 and 9) than on river floodplains (stations 6, 8 and 10, Fig. 18), and was due in part to the more sheltered nature of the floodplains. During midwinter caribou were concentrated in river valleys, feeding on both lichen and horsetail. Lowest snow depths were consistently found in the southern foothills, although conditions appeared quite variable. Caribou which fed within this region exploited local variations in snow due to wind and sublimation. Strong southerly winds from the Brooks Range cause considerable redistribution of snow in the adjacent foothills during late winter. Areas directly north of valley mouths may be completely exposed while more sheltered areas may collect considerable amounts of dense snow. Station 13 was located in the path of southerly winds emerging from the Atigun River valley and mean snow depth was lower there than at any other station. Station 11, at about the same latitude but not in the path of Atigun valley had a greater average

**	. Snow Station Number												
Dates	1	2	<u>3</u>	4	5	<u>6</u>	7	8	<u>9</u>	<u>10</u>	<u>11</u>	<u>12</u>	13
Oct 31-	D 21/	12/	15/	12/	16/	11/	13/	17/	12/	15/	12/	16/	15/
Nov 1	R 4.2	5.0	3.0	2.0	2.8	2.1	2.1	2.0	2.3	2.0	3.0	2.1	2.4
Nov 8-16	D 25/	13/	25/	15/	23/	16/	21/	19/	15/	17/	16/	14/	16/
	R 6.7	6.4	2.7	3.0	2.6	3.1	2.1	2.0	2.2	2.0	2.5	2.0	2.9
Dec 6	D 24/	19/	17/	15/	20/	11/	22/	25/	16/	15/	15/	15/	14/
	R 13.1	18.6	7.4	3.2	6.7	4.8	2.8	2.0	2.4	2.8	10.1	2.2	7.2
Jan 24	D 28/ ^b	33/	29/	25/	33/	22/	32/	27/	26/	29/	26/	21/	16/
	R 11.5	8.4	12.0	2.6	5.5	4.1	3.2	2.2	2.3	2.4	5.7	2.1	4.2
Feb 8 -9	D 29/ ^b	28/ ^b	32/ ^b	30/	34/	23/	31/	22/	31/	23/	25/	20/	13/
	R 11.2	8.8	12.8	3.3	12.4	5.4	7.5	3.3	3.3	3.9	15.1	2.4	5.7
March 5	D 36/ ^b	44/ ^b	31/ ^b	25/	31/	25/	30/	20/	31/	23/	21/	16/	12/
	R 13.3	11.5	11.0	3.5	6.3	4.4	5.5	3.2	2.7	3.4	6.2	2.5	5.3
March 24	D 33/ ^b	35/ ^b	44/ ^b	27/	29/	30/	44/	23/	37/	29/	28/	20/	16/
	R 10.8	11.1	14.3	4.2	10.6	5.8	4.4	2.6	3.2	3.4	11.4	2.7	2.8
Apr 9-10	D 36/ ^b	42/ ^b	44/ ^b	29/	32/	31/	42/	24/	36/	28/	30/	27/	15/
	R 13.4	16.9	9.6	4.6	5.0	5.4	3.5	2.1	2.9	2.9	8.2	3.0	3.9
Means	D 29/	28/	28/	21/	26/	20/	28/	22/	25/	22/	22/	19/	15/
	R 10.5	10.8	8.3	3.4	6.0	4.1	3.6	2.5	2.7	2.8	7.9	2.4	4.3

Table 4. Snow depth (D) and resistance (R) at snow stations along haul road during winter 1975-76.^a

^aLocations of snow stations are shown in Figure 18.

^bResistance measured using 3 kg hammer.



Fig. 16. Locations of snow sampling stations along the arctic slope section of Trans-Alaska Pipeline haul road.

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snow depth and very high hardness values, similar to those encountered on the coastal plain. In late winter caribou tend to shift feeding areas from river valleys to low ridges in the southern foothills, areas at the mouth of mountain valleys receiving highest use. The above generalizations do not necessarily apply to all winters since conditions appear to vary between years and caribou would be expected to seek out the most favorable feeding conditions available.

Observations of winter feeding on the arctic slope indicated that caribou were selective on several levels in order to minimize the effort necessary to expose forage. LaPerriere and Lent (1977) described three levels of selectivity on the winter range of the Porcupine herd. Caribou occupy a general area such as a valley, choose feeding areas within, and finally select specific cratering sites. On the arctic slope in midwinter caribou apparently occupied river valleys in preference to the surrounding rolling uplands because of shallower and softer snow. Within the river valleys slightly raised areas were frequently utilized due to the removal of snow by wind. Another method commonly observed in late winter was feeding on south-facing slopes where sublimation had reduced snow depths. In areas of tussocky micro-relief, caribou often cratered on the windward side of the tussock.

Selection of feeding areas on a broader, regional scale was indicated by the results of the snow station data along the haul road. Abandonment of the coastal plain in fall, and winter occupancy of the

foothills seemed to be a response to regional adverse snow conditions. This interpretation is supported by the delayed fall migration of the CAH in 1976. The majority of the herd remained on the coastal plain until midwinter, apparently due to unusually low accumulation of snow in late fall and early winter. The normal stimulus for fall migration appears to be the first heavy or widespread snowfall (Kelsall 1968, Bergerud 1974).

Whether forage abundance or favorable snow conditions determine the location of feeding areas may be a moot question; in fact the two factors may be inseparable. In winter, preferred forage beneath the snow is located by olfaction (Tushinskii 1949). The strength of the olfactory stimulus is dependent on both the quantity of preferred forage beneath the snow and the character of the snow itself. A certain threshold stimulus may be necessary in order to initiate cratering and feeding (O. Erikson, pers. comm.).

Gaare et al. (1970) described a pattern of reindeer feeding on the Norwegian alpine barrens similar to that exhibited by the CAH. Lichens were the most important forage through the winter but by mid-April increasing snow depth confined feeding to windswept ridges. Lichens of the genus <u>Cladonia</u> were most important in midwinter but <u>Cetraria nivalis</u> became more heavily utilized as the snow restricted feeding. On the taiga winter range of barren-ground cairbou in Canada arboreal lichens are easily available when snow is deep in late winter. Winter-green forage is preferred in early winter but

by midwinter deep snow restricts feeding to terrestrial lichens in forested areas (Miller 1976).

Snow depth and hardness were recorded at some winter feeding areas. The effect on caribou activity of increased effort in order to expose forage was examined using these data. The parameter which was used to categorize winter activity data was the product of snow depth and the Rammsonde hardness value for the entire snow layer. This is an estimate of the total resistance to cratering, but is probably not an accurate indicator of the effort required by caribou to paw through the snow cover since they may exploit certain compacted snow conditions to their advantage (LaPerriere and Lent 1977).

Categorization of behavioral data on the basis of snow cover resulted in several significant differences between the data groups but few easily identifiable trends (Table 5). Percent feeding tended to increase and percent lying generally decreased with increasing snow cover, but other factors apparently confound the relationship. Both group movement rate and average individual distance are greater at low snow cover indices. Thus deep, hard snow tends to concentrate groups and reduce the extent and frequency of movements to new feeding areas. In midwinter it was not uncommon to observe the same groups in the same general area for over a month. More frequent group movements during this period were not necessary because of small mean group size.

In summary, the northward spring migration of bulls to coastal habitats appears well timed for the utilization of forage at the peak

		Sı	now Cove	r		Significance
	0	1-29	30 59	60-79	80+	F ratio
Percent feeding	38.8	59.7	36.8	56.0	64.2	<u><</u> 0.001
Percent lying	51.6	20.1	54.9	30.5	27.9	<u><</u> 0.001
Percent standing	3.1	4.1	1.5	4.2	1.5	<u><</u> 0.005
Percent walking	6.0	15.9	5.5	8.5	5.6	<u><</u> 0.001
Percent trot/running	0.4	0.7	0.9	0.3	0.6	N.S.
Group movement rate (meters/hour)	206	249	80	133	124	<u><</u> 0.001
Average individual distance (meters)	8.5	8.3	5.2	6.0	7.2	· <u><</u> ປ.001
Slope shape ^b	2.7	2.2	3.4	1.5	1.9	<u><</u> 0.001

Table 5. Caribou activity at different snow cover values.^a

^aA product of snow depth (cm) and snow resistance (Ram hardness value). ^bRecorded on a scale of 1-5: 1 =valley bottom, 5 =ridge top. of quality, but the spring migration of cows is not. Fall migration appears related to snow conditions. These movements are toward areas of higher lichen standing crop. Occasionally favorable snow conditions permit use of the coastal plain as winter range. Snow conditions and the distribution of preferred winter forage appear to control winter movements and distribution of the Central Arctic herd.

Weather

Temperature, wind speed, cloud cover, and precipitation were all recorded in conjunction with data on caribou activity. Using computer methods, an attempt was made to identify correlations between weather parameters and behavioral variables. Where the results indicated a significant relationship or where previous studies suggest causality, the data were examined in greater depth.

The results of the correlation matrix indicated several significant relationships between temperature and caribou behavior (Table 6). The strong correlation between temperature and level of insect harassment during the post-calving and August dispersal phases precludes any consideration of the direct effects of temperature on summer behavior. For example, time spent standing and running are positively correlated with temperature but this was due primarily to high insect densities during warm weather.

During mid- and late winter, temperature was negatively correlated with time spent feeding and positively correlated with the incidence of

		Te	mp e	rat	ure						C1	oud	Co	ver					Vin	d S	pee	đ			Precipitation Level							L
	5	2	4	<u>F</u>	<u>R</u>	E	¥	Ţ	<u>s</u>	<u>P</u>	<u>*</u>	<u>F</u>	R	E	Ħ	Ŀ	<u>s</u>	<u>P</u>	<u>Å</u>	<u>F</u>	R	Ē	Ħ	ī	5	2	<u>^</u>	Ĕ	R	Ē	Ä	ľ
Peternlage feeding			•	++				•	+		++						-		-	++	++			+	++					++		
Percentage lying	-		•	-				++			++			-					-			+		-			++	++	+			
Percentage standing		++	++	•	•		++	+			•							•	++		•											
Percentage walking	- ++						++							++						++									-	++	-	
Percentage running		++	++	•						+	•		-						+		-					+						
Percentage sparring				-		-																										+
hivement rate		+	+	++			++					++	•	++	++		+	-	-	++	-			+		+			•	++		
Average Incl. distance	++		++						-		-	+	++					+	++		+	+	-		-	-	•	++				
lope movement			+				++	+	-						+				-												+	
Lope shipe	++		•		-	-	++	++						-	+		-	-		+	-	++	-						•			
slope				+			++		++				-	++			-			++			-								++	
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roup size	•	++	•	-			+	++	++		++	-	+		-	-	-	-		-	+	++			++		++			-		
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											50						VI	nd		ed .									++	-	++	

Table 6. Correlations between weather variables and caribou behavioral variables.

.

S = spring and calving

P = pest-calving

A = August dispersal

F = fall migration and pre-rut

R = rut

E = early winter

M = ald-winter

L = late winter

++ strong positive correlation (P<0.01)
+ positive correlation (P<0.05)</pre>

negative correlation (P<0.05)
 atrong negative correlation (P<0.01)

standing, walking, and lying. Movement rate increased and average individual distance decreased with increasing temperature during midwinter. In order to clarify these effects of temperature on winter activity budgets, activity percentages were grouped according to intervals of 5 degrees Celsius (Fig. 17). In general, with decreasing temperature, the mean percentage feeding increased while that for lying declined. The mean percentage feeding was 40 percent between 0° and -5° and 65 percent in the -40° to -45° interval. The combined percentages of feeding and lying remained fairly constant over the range of winter temperatures so that the two activities appeared inversely related. There are two possible explanations for this pattern. The heat generated by cratering in snow might be important in thermoregulation at extremely cold temperatures. Increased forage intake during cold periods would also increase energy reserves and increase the heat of fermentation within the rumen. Percent standing, walking, and running are apparently not related to temperature except below -35°C when these activities are all relatively infrequent. Movement rate is also relatively low at extremely cold temperatures. All of these results suggest that at extremely low temperatures caribou tend to remain sedentary and feed intensively.

Skoog (1968) stated that, "during periods of intense cold (-50°F or so) [he had] observed among Alaskan caribou a tendency to remain rather sedentary." Henshaw (1968) observed intensive feeding during cold periods between storms. These observations are supported by the results



Fig. 17. Incidence of feeding and lying in caribou groups as a function of temperature in winter.

of the present study; most movement between feeding areas in winter was observed during relatively warm periods.

Means for slope shape occupied by groups of caribou were calculated for the same temperature intervals as above. The results indicate that during cold weather groups usually occupied river valleys but in warm weather they tended to be higher on slopes or on ridge tops. This difference may represent a response to wind at low temperatures since the river valleys are generally characterized by lower wind velocities. Even slight air movement at 40°C significantly increases heat loss from human skin and may be sufficient to elicit behavioral thermoregulation in caribou.

During summer, wind speed influences insect densities (White et al. 1975) which in turn relates directly to caribou activity patterns. During rut, wind velocity is positively correlated with percentage of time spent feeding and average individual distance, but is negatively correlated with movement rate and the percentages of time spent standing and running. This suggests that stronger winds cause a reduction in the reproductive activity of bulls.

For winter data, correlations between wind velocity and the various behavioral parameters were not consistent. Average individual distance was negatively correlated with wind speed in midwinter but no correlation existed in the late winter data when average wind speed was greater. Slope shape was negatively correlated with wind speed in mid- and late winter; supporting the hypothesis that caribou select the more sheltered valleys during windy weather.

The combined effect of strong winds and low temperatures on caribou behavior during winter is obscured by the high, positive correlation between temperature and wind speed. Using the computer, windchill values were transgenerated from wind velocity and temperature according to the formula derived by Siple (1945) for calculation of wind-chill equivalents:

 $K_o = (v \ge 100 + 10.45 - v) (33 - T_a)$ where $K_o =$ windchill equivalent

v = wind velocity (mph)

 $T_a =$ ambient temperature (°C)

The results indicate that as windchill increases the percentages of lying and feeding decrease and increase respectively (Fig. 18). This response to windchill appears similar to that for low temperatures (Fig. 17). However, at windchill values greater than approximately 2200, the incidence of feeding declines sharply and percentage of time spent lying increases. Apparently under conditions of high windchill lying is more effective in reducing heat loss than continued feeding.

Both group movement rate and average individual distance appear to change in response to windchill during winter (Fig. 19). Average individual distance is inversely related to windchill. This could reflect bunching of downwind individuals within a group to reduce exposure to the wind, particularly at low temperatures. The effect of windchill on group movement rate is apparently complex. Very high



Fig. 18. Incidence of feeding and lying in caribou groups as a function of windchill during winter.



Fig. 19. Mean rate of caribou group movement and average individual distance at different windchill values during winter.

windchill values are associated with low movement rates, in part because most animals are lying. However, maximum mean movement rates occurred at moderate windchill values, and may indicate a tendency for caribou to seek shelter when conditions are less severe. Alternatively the main purpose of the movements may be the generation of heat. Movements during severe windchill may not generate enough heat to compensate for rapid heat loss.

Thomson (1973a) found that high windchill in late winter was responsible for clumping, lying, and bouts of undirected running. Presumably the latter movements are related to a need for increased heat production. Baskin (1970) and Henshaw (1968) also remarked that a combination of high winds and low temperatures was associated with an increase in the incidence of lying. Reduced activity was noted in the present study when windchill values exceeded 2200, although considerable feeding occurred even under such adverse conditions. A few observations of increased motor activity including short bursts of trotting were recorded during periods of very high windchill but, in general, movements were relatively restricted. Caribou frequently continued feeding in exposed, windy areas when more sheltered terrain was available nearby.

The effect of wind direction on the direction of group movements was analyzed on a seasonal basis and classified broadly into insect (Table 7) and insect-free periods (Table 8). Movements were categorized as either toward, perpendicular to, or away from the wind. During four of the eight phases of the annual cycle (late winter, spring, post-

	Season									
	Pre-rut	Rut	Early winter	<u>Mid-winter</u>	Late winter	Spring				
Into wind (percent)	38	27	42	33	51	28				
Perpendicular to wind (percent)	31	40	17	29	19	34				
Away from wind (percent)	31	33	42	38	30	37				
Sample size	80	55	53	260	223	268				
X ² value	1.70	5.86	1.58	2.94	16.87	14.69				
Significance (P=)	N.S.	N.S.	N.S.	N.S.	.005	.005				

Table 7. Direction of caribou group movement in relation to wind direction (no insects).

					Seas	on							
		Post-	-calv:	ing		August Dispersal							
	N	L	М	н	T	N	L	M	н	Т			
Into wind (%)	55	22	53	86	53	19	12	33	-	21			
Perpendicular to wind (%)	16	17	18	0	13	37	41	17	_	32			
Away from wind (%)	29	61	29	14	34	44	47	50	100	48			
Sample size	56	36	17	28	137	27	17	18	1	63			
x ²	6.71	7.29	0.96	25.56	15.41	3.42	3.75	0.69	-	6.69			
Significance (P+)	.05	.05	N.S.	.005	.005	N.S.	N.S.	N.S.	-	.05			
									κ.				

Table 8.	Direction	of	caribou	group	movement	in	relation	to	wind
	direction	(1)	nsect sea	ison).					

N = no insect activity L = low insect activity

M = moderate insect activity

H = high insect activity

T = total seasonal count

calving and August dispersal) wind direction apparently influenced movements. During the post-calving period 53 percent of all recorded movements were into the wind (expected value independent of wind = 37.5%). Movements into the wind reduce mosquito harassment by increasing the flow of air past the body and keeping insects off the sensitive areas of the head. During August dispersal 48 percent of all movements were away from the wind (expected value independent of wind = 37.5%). Oestrid flies are much stronger fliers than mosquitos and have little difficulty following a caribou moving into a moderate wind. Even if the caribou does succeed in moving away from the fly, the parasite can easily relocate the caribou by following the scent trail upwind (D. Klein, pers. comm.). But by rapidly moving downwind a caribou might successfully lose the fly. The unexpectedly high percentage of downwind movements during August dispersal does not appear to be a result of herd movements happening to coincide with the direction of the prevailing wind. Prevailing winds are from the east and the predominate direction of movements was north (Figs. 20 and 21).

In late winter caribou tend to move into the wind (51%)(Table 8). Herd movements during this period are primarily southward (toward more favorable snow conditions) into prevailing winds. Thus this relationship may be unrelated to wind direction per se. Also, highest mean wind velocities occur in late winter (Table 2) and feeding into a strong wind might aid in the olfactory location of forage and removal of snow during cratering. During spring there appears to be the opposite









tendency, as only 28 percent of all recorded movements were into the wind (expected value independent of wind = 37.5%). This is difficult to explain but may be due to northward precalving movements which occur irrespective of wind direction.

Thomson (1971), White et al. (1975), and Curatolo (1975) noted a tendency for caribou to move into the wind during periods of insect harassment. Thomson (1973a) also observed upwind movement in late winter during periods of high winds. Curatolo (1975) reported a similar correlation during calving but felt that the relationship was not biologically significant. The results of this study agree with the above reports and, in addition, indicate that movement into the wind during summer is a response to mosquitos, not oestrid flies (Table 7). White et al. (1975) remarked on the predictability of caribou movements in midsummer based on wind direction and insect harassment level.

Cloud cover is negatively correlated with both percentage of time spent running and movement rate, and is positively correlated with average individual distance during rut (Table 6). Sparring frequency is negatively correlated with cloud cover during pre-rut and early winter (Table 6). Thus the intensity of reproductive behavior declines with increasing cloud cover.

Curatolo (1975) obtained a negative correlation between rutting behavior and cloud cover and hypothesized that increased rutting behavior on sunny days was due to the greater effectiveness of social signals transmitted by the white mane and belly stripe. In the present

study higher wind velocities also seemed to inhibit rutting behavior. This might be explained by a reduced effectiveness of social signals transmitted by olfaction. Olfaction is clearly important as evidenced by many behaviors exhibited by adult bulls in rut which increase the olfactory threat (Lent 1965, Guthrie 1976).

In midwinter group movement rate is positively correlated, and average individual distance negatively correlated, with cloud cover. However, the high, positive correlation between cloud cover and temperature during this period (Table 6) suggests that increased movements and reduced spacing may be due only to higher temperatures and that the apparent effect of cloud cover is fortuitous. Cloud cover by itself does not appear to influence components of the winter activity budget.

No consistent correlations between precipitation rate and caribou behavior were observed. During spring and early winter precipitation rate was positively correlated with the percentage of time spent feeding. In addition, the incidence of walking was positively correlated with precipitation rate during early winter. Apparently precipitation stimulates some increase in activity, at least in spring and early winter. The incidence of sparring was also positively correlated with precipitation in late winter; there is no obvious explanation for this result. Results of this study indicate that precipitation has little effect on caribou behavior. The correlation between precipitation and mosquito activity is the one statistically significant exception. Curatolo (1975) came to similar conclusions.

Although fall migration results in a shift to better winter range, the timing is so variable from year to year that an environmental stimulus is probably involved. Bergerud (1974) felt that endogenous factors "primed" caribou for fall migration with a heavy snowfall as the "threshold stimulus for movement." However, Curatolo (1975) found no correlation between initial snowfall and the commencement of fall migration in the Fortymile herd. My own observations in the fall of 1975 support Bergerud's theory that weather affects the timing of fall migration. Prior to 20 September the majority of caribou observed along the haul road occupied the coastal plain region. Groups of cows with calves tended to be farther north than bull groups. On 20 September a snow storm moved through the central arctic slope followed by a cold snap. By 21 September most groups observed were moving to the south, frequently in lines of up to 40 individuals, despite the fact that snow accumulation was only a few centimeters and caribou could easily feed through the snow without pawing. One result of this southward movement was that relatively large groups of up to 200 individuals formed as small groups coalesced. The southward movement took some groups into the Brooks Range while others stopped at the northern edge of the foothills; a few groups remained near the coast. Thus essentially the same weather conditions elicited different responses in CAH animals. A keen olfactory sense is perhaps responsible for these unexplained differences. Caribou may be stimulated to move south by changes in the scent of forage related to the first lasting snow and continue to move

until the olfactory stimulus of forage was strong enough to overcome the impetus to continue south (O. Erikson, pers. comm.). During September 1976 only a few groups moved from the coastal plain into the foothills, the majority remaining farther north. Apparently the weather stimulus was not sufficiently strong to induce migration.

Predation

Potential predators of caribou which were observed in the study area include wolves (<u>Canis lupus</u>), grizzly bears (<u>Ursus arctos</u>), wolverines (<u>Gulo luscus</u>), red foxes (<u>Vulpes fulva</u>), arctic foxes (<u>Alopex</u> <u>lagopus</u>), golden eagles (<u>Aequila chrysactos</u>), and ravens (<u>Corvus</u> <u>corax</u>). Of these species wolves, grizzly bears, red foxes, arctic foxes and ravens were observed interacting with caribou. Wolverines are rare in the study area and were only observed a few times in the foothills. I am not aware of any sightings of wolverines on the coastal plain during the study period. Adult golden eagles were first observed in the Brooks Range in early April. A few non-breeding eagles, particularly immatures, spent the summer on the coastal plain where the majority of calves were present. On seven occasions golden eagles were observed in this portion of the study area. At least two of the four birds observed near the arctic coast were immatures, one of which was observed on the calving grounds during the calving period.

Wolves, red foxes, arctic foxes and ravens are common along the pipeline corridor throughout the year. Red foxes are restricted

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primarily to the foothills, although denning is known to occur along rivers as far north as Franklin Bluffs (R. Garrott, pers. comm.). In contrast, arctic foxes rarely den in the foothills and are most common near the coast. In winter, arctic foxes range widely and are found throughout the study area. Ravens are common permanent residents along the corridor.

Wolves were found mostly in the Foothills and Brooks Range and were not observed north of Franklin Bluffs Camp during the study period. However, fresh wolf tracks were seen at the north end of Franklin Bluffs on June 10, 1976. Apparently wolves prefer more inland habitat where suitable den sites are much more plentiful, but occasionally denning on the coastal plain does occur (R. Stephenson, pers. comm.). A lack of den sites on the coastal plain due to poorly drained soils and shallow active layer may be the most important factor in the scarcity of wolves on the calving grounds during the spring and summer. Increased mortality in the past from human hunters along the coast is a possible additional factor.

Generally, grizzly bears are inactive from mid-October to mid-April, although a few, accustomed to handouts along the pipeline, were observed throughout most of the winter. During the summer, bears were observed throughout the study area and most frequently seen along major rivers. One bear was even seen near the arctic coast during the second week of May 1976 (G. Milke, pers. comm.).

Two interactions between grizzly bears and caribou were observed and both elicited avoidance behavior by the caribou, despite an apparent lack of interest by the bears. A grizzly bear was observed on a caribou carcass near Pump Station 3 in October 1975 (K. Whitten, pers. comm.). It was not possible to determine the cause of death but it did not appear to have been killed by either the bear or wolves.

Caribou were observed bunching up and running short distances in response to red foxes on several occasions during the winter months. On two of these occasions foxes showed an interest in the responses of the caribou but did not chase them. In contrast, arctic foxes ignored caribou which appeared to have little fear of them. The bones of a young calf were found at an abandoned arctic fox den near the coast and the carcass of an adult cow was discovered near an active den (W. Eberhardt, pers, comm.). These were probably instances of scavenging which is common during the winter months at wolf-killed carcasses.

Interactions between caribou and ravens were infrequent. Observations were made of ravens threatening and displacing caribou and vice-versa. A raven was observed to displace several lying caribou in late winter, apparently seeking hair for nest lining. No physical contact between the two species was observed.

Arctic foxes, eagles, and ravens are all known to attack newborn calves (Zhigunov 1968, Skoog 1968, Kelsall 1968, J. Davis, pers. comm). All three species, particularly arctic foxes, are present on the calving grounds during calving but their influence on neonatal survival in the
CAH is unknown. A cow with a newborn calf remained within a few hundred yards of an active arctic fox den for at least five days with no apparent threat to the calf. Few grizzly bears are present on the calving grounds during calving and predation would probably be limited to calves less than two weeks old which have difficulty keeping up with their mothers. Since the cows remain in the open and rarely cross willow thickets during summer there is little opportunity for bears to approach calves close enough for a kill.

Wolves were the only species known to prey on CAH caribou. Most of this predation occurred between late September and late May, during which time 12 wolf-killed caribou were located (see Appendix F). Seven were discovered within 200 meters of the haul road, and three of these caribou were killed on the road and later dragged off. During winter wolves travel on the snow-free surface of the road and wolf tracks were commonly observed along the road shoulder. Some wolves became habituated to road traffic and were observed taking food handouts from workers in vehicles. Consequently, wolves were attracted to roadside areas throughout the year. Further, the proximity of caribou carcasses to the haul road indicates that wolves were using the road to their advantage in stalking and killing caribou. First, the location of caribou along the road required less effort because of the lack of snow on the road surface. Secondly, the road berm could be used as cover while stalking groups of caribou near the road. One wolf was actually observed using this tactic and tracks found near kills indicated it was not rare.

Finally, caribou bands near the haul road are ostensibly habituated to movement and noise of traffic and are probably less sensitive to the presence of wolves.

Tracks around wolf-killed carcasses suggested fairly short chases of a few hundred meters, hence the element of surprise appears to be important to a successful kill. Most kills were apparently made during the dark or crepuscular hours. Only one stalk was actually observed by the author and it did not result in a kill. Four wolves were involved but only one actually stalked the caribou band. Using available willow cover the wolf crept up as close as possible to the lying caribou and when detected rushed in quickly. A chase of approximately 1 km ensued. Very little snow was on the ground, facilitating the pursuit. I believe that such long chases in winter are uncommon because of the difficulty for wolves of running in deep snow. Observations of a pack of 10 wolves in interior Alaska during late winter revealed no evidence of long chases; instead, the strategy seemed to be to "surprise the [caribou] at close range and charge" (Burkholder 1959). On several occasions caribou were observed after being startled by wolves. The escape strategy was to run downhill at top speed followed by an upslope movement to a position downwind of the wolves, thereby eliminating the chance of another undetected approach.

The caribou carcasses examined did not indicate selection by the wolves on the basis of sex or age (Appendix F). In no case was it possible to determine if the caribou had been crippled or otherwise

disadvantaged prior to the attack. One old cow had molars which were worn to the gums but the visual appearance of the bone marrow indicated that the animal was not starving.

Observations suggest that wolves are the most important cause of winter mortality among the CAH. However, no evidence for wolf predation was found in summer. This appears to be largely a result of differences in the distribution of predator and prey, wolves being mostly limited to the foothills and caribou primarily occupying the coastal plain. A few bulls do remain scattered in the foothills throughout the summer and predation rates on these animals would probably be relatively high. Post-calving surveys and fall composition counts in 1976 indicated a very low rate of calf mortality between July and October (Cameron et al., unpubl. data).

The most likely explanation for the northward spring movement of parturient cows to the coast is the relative paucity of predators near the coast. Forage quality and/or abundance did not appear to favor these early movements (see previous section). Mosquitos do not become bothersome in the foothills until about two weeks after the peak of calving by which time most calves would be old enough to make the 100 km trip to the coast (see following section). Nolves are recognized as an important mortality factor on the calving grounds of some caribou herds. Niller and Broughton (1974) concluded that wolf predation was the most important source of calf mortality in the Kaminuriak herd. One-third of all dead calves examined had been killed by wolves, a minimum estimate

since it was not known how many well-utilized carcasses were not discovered. These authors estimated that 25 wolves were present on the calving grounds although no evidence of denning was found.

Bergerud (1974) maintained that highly synchronous calving in barren-ground caribou is an adaptation to wolf predation on calves. With regard to pre-calving movements he wrote: "The directions taken in the spring migration could be based on traditions but involves the initiation of females that are shifting to areas where their calves have an increased chance of survival." It is also noteworthy that no spring migration of cows occurs in Newfoundland where wolves have been extirpated (Bergerud 1974). Murie (1944) noted that resident wolves in McKinley Park lived mostly on calves during the calving period. Some wolves were known to move over 32 km daily, between den sites and the calving grounds.

The above evidence supports the contention that calves born in the foothills are more vulnerable to wolf predation than calves born near the coast. Apparently the reduced risk of predation outweighs the disadvantages of adverse coastal weather and/or poorer range, even considering the attendant stresses of birth and lactation.

In view of the vulnerability of young calves to wolf predation it seems strange that non-breeding wolves (i.e. those not occupied with the care of pups) do not follow parturient cows of the CAH to the calving grounds. Reportedly almost all wolves preying on calves in the Kaminuriak herd were non-breeders (Miller and Broughton 1974).

This may be due to differences in wolf densities between the two areas. Thus lower densities in the Central Arctic may be associated with the emigration of fewer wolves from the more favorable denning areas in the foothills. In addition, most bulls remain in the foothills until late June; hence, caribou are still available to wolves and there may be little incentive for wolves to move north with the cows. Straggling bulls may thus inadvertently act as decoys in minimizing predation on noenates. By the time most bull caribou have left the foothills many alternative sources of food are available. In the Soviet Union, wolves rarely attack reindeer during summer because of the abundance of microtines, ground nesting birds and their eggs and young (Zhigunov 1968).

Bergerud (1974) felt that the rapid aggregation of cows with calves after calving is a response to wolf predation. Cows in the CAH disperse over a large area to calve, and lone cows with newborn calves are commonly observed. Shortly after the peak of calving mean group size increases rapidly and remains relatively high throughout the postcalving period regardless of mosquito harassment. During calving and post-calving groups of cows and calves are easily put to flight by a person on foot at distances as great as 800 meters. Cumming (1975) concluded that "clumping by prey tends to reduce predation unless predators take counter measures (a) by changing their catching methods or (b) by clumping in response." Since wolf packs have spacing mechanisms (territories) which appear to prevent clumping, wolf predation selects for clumping behavior in caribou. Treisman (1976) theorized that the

individual's chances of avoiding predation in open habitats continues to increase as group size increases. Thus most predation selects for unlimited group size. Powever, availability of resources (i.e. food, shelter, etc.) is the main factor limiting group size. Since forage is abundant and high in quality during the post-calving period, large group size is possible and serves to increase a cow's chances of successfully rearing a calf.

Miller and Broughton (1974) noted that after July 1 all wolf-killed caribou of the Kaminuriak herd found were in or near dense stands of willow or birch, suggesting that the caribou had been ambushed. Henshaw (1968), Curatolo (1975) and R. Stephenson (pers. comm.) observed that caribou were hesitant to cross patches of riparian willow. It has been noted above that bull groups appeared to prefer seral riparian habitats where dense willow stands occur whereas cow-calf groups preferred more open areas. A possible explanation for this difference is the increased susceptibility of calves to predation in riparian habitats. Thus, it appears that throughout the summer cows continue to sacrifice improved grazing conditions for reduced risk of predation.

During winter the distribution of caribou did not appear to be related to wolf predation. Caribou continued to occupy areas in close proximity to wolf kills. Wolves are extremely mobile during winter and avoidance of wolves by occupation of particular areas appears unlikely. Groups of about 10 individuals are maintained in winter. This group size appears to be small enough to permit effective utilization of

available winter forage and yet sufficiently large for detection of wolves and the reduction of the threat of predation.

The rapidity and extent to which wolves habituated to haul road traffic and pipeline construction on the arctic slope surprised biologists with the Joint Fish and Wildlife Advisory Team who were concerned with minimizing the ecological impact of the project (J. Hemming, pers. comm.). Banfield (1974) observed that cleared seismic lines in wooded areas gave wolves an advantage in hunting caribou. Caribou frequently moved along these lines during migration and wolves developed the habit of hunting along them because of favorable snow conditions. The extent to which the pipeline haul road assists wolves in their efforts to hunt caribou is unknown and the net impact on indigenous caribou is therefore speculative. However, it is clear that wolves receive some benefit and the ostensibly high frequency of wolf-killed caribou observed in winter suggests that the haul road represents an appreciable advantage to the predators.

Insects

Two types of parasitic insects are ecologically important to the CAH, mosquitos (<u>Aedes</u> spp.) and oestrid flies (<u>Oedemagena tarandi</u> and <u>Cephenomyia trompe</u>). Mosquitos are the first to appear in summer. In the study area emergence is earliest in the Brooks Range and progresses northward to the coast. In 1975 mosquitos first attained moderate densities in the Foothills on June 21, but were not bothersome near the

coast until July 6. In 1976 mosquitos were moderately active on June 12 at Galbraith Lake (Fig. 1) and a few were present near Prudhoe Bay by July 5 but did not represent a severe harassment near the coast until July 18. Persistant cool and windy weather had prevented any earlier increase in mosquito activity.

The phenology of oestrid flies on the arctic slope is more difficult to determine because the principal indicator of their presence is the defense reactions of caribou. The behavioral effects of warble flies and nose bot flies were combined because of the difficulty in distinguishin; the responses of caribou to these two parasites. Considerable coughing and snorting was heard in early July, suggesting that some caribou are parasitized by nose bots. However, behavioral observations indicate that warble flies are more bothersome than nose bots.

During 1975 oestrid fly harassment was first observed in the southern Foothills on July 29 when mosquito harassment was still severe. By the second week of August, however, mosquitos were less active and oestrid flies became a severe harassment for caribou, even near the coast. By August 13 few mosquitos were present in the foothills but oestrid flies remained very active. A few oestrid flies were still active on September 2, but after this date no insect avoidance behavior was observed. Although black flies (<u>Simulium</u> sp.) were occasionally bothersome in the foothills during August of 1975, significant numbers were never encountered on the coastal plain during that year.

Summer activity data of caribou was classified into four levels of mosquito and oestrid fly harassment. Analysis of variance was performed to determine any significant differences between sets of weather variables related to each level of insect harassment (Table 9). Temperature, wind speed, and precipitation are all significantly different at the various levels of mosquito harassment. Mosquito harassment level increases with temperature increase and decreases with increased wind velocity and precipitation. Cloud cover was not significantly different between harassment levels.

Oestrid fly harassment increased with increasing temperature and wind velocity but decreased with increasing cloud cover and precipitation rate. The positive correlation with wind velocity was unexpected and difficult to explain. Wind velocity averaged during periods in which no oestrid fly harassment occurred was 8.0 kilometers per hour while at severe harassment levels the mean wind velocity was 17.9 kilometers per hour. Presumably at winds exceeding 30 kilometers per hour oestrid fly harassment is reduced but such high winds are uncommon during August on the arctic slope (Table 2). Light breezes apparently assist oestrid flies in locating caribou by broadcasting the scent. Oestrid flies are strong fliers and their habit of flying close to the ground is well adapted to windy conditions.

Many highly significant correlations were obtained between levels of insect harassment and various parameters of caribou behavior (Table 10). The following behavioral parameters were positively correlated with mosquito harassment:

			Har	assment	Level ^a				Significance
	N	one		Mild	Mo	derate	S	evere	Level of
Environment	Mosq.	W. fly	Mosq.	W. fly	Mosq.	W. fly	Mosq.	W. fly	F Radio
Nean temperature (^O C)	6.8	5.8	14.3	15.5	17.4	18.2	20.1	19.9	<.001
Mean cloud cover ^b	3.4	4.8	3.8	2.0	4.0	2.1	4.0	0.6	N.S. (mosquito) <.001 (warble fly)
Mean wind speed (mph)	15.2	5.0	9.8	7.5	9.6	8.6	6.4	11.1	<.001
Nean precipitation rate	0.3	0.5	0.6	-	0.4	0.1	0.4	-	<.05 (mosquito) <.001 (warble fly)
Mean elevation (m)	132	276	288	258	121	302	61	252	<.001 (mosquito) <.025 (warble fly)

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Table 9. Weather conditions during various levels of mosquito and oestrid fly activity.

^aSubjective assessment

^bScale of 0-6; 0 = clear, 6 = overcast

^cScale of 0-5; 0 = none, 5 = down pour

	Mosq	uit	<u>o H</u>	are		ent	: L	<u>evel</u>	Warl	ble	Fly	Ha	788	sne	nt	Level		Sr	ov.	Dep	th				Sn	~	Ren	1.	tanc	e	
*	<u>5</u>	<u>P</u>	<u>^</u>	<u>F</u>	R	E	M	Ŀ	<u>s</u>	<u> </u>	<u>^</u>	<u>F</u>	R	E	M	L	<u>s</u>	<u>P</u>	4	F	R	<u>E</u>	M	Ŀ	 <u>s p</u>		<u>^ 1</u>		<u>R Z</u>	×	Ŀ
Percent feeding			-								-									•	-	-	+						-		
Percent lying																				++	++										-
Percent standing		++	+								.++																				
Percent walking																				+	-	+								•	++
Percent running		++	++								++	•																		+	•
Percent sparring																				-	-										
Novement rate		++	+																			++	•	•						-	++
Average incl. dist.		-	+								++	•	٠								-	-		-							++
No. of crossings		++	-								-									++		++	-							+	+ ++
Group size		++																		++											
Elevation		•	-							-										++	++										
Exposure			-																	-			-						•	+	
Slope		-	-							•										-	+										
Slope shape		-								-												-		++						•	
Distance from road		-	•																		-			•							
Avoldance											+																			+	+

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Table 10. Correlations between insect harassment/snow cover conditions and caribou behavioral variables.

S = spring and calving

- P = post calving
- A = August dispersal
- F = Fall migration and pre-rut

R = Rut

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- E . Early winter
- M = Mid-winter

L = Late winter

++ strong positive correlation (P<0.01)

- + positive correlation (P<0.05)
- negative correlation (P<0.05)
- strong negative correlation (P<0.01)

1) percent standing

2) percent running

3) group movement rate

4) group size

5) number of road crossings

The following parameters were negatively correlated with level of mosquito harassment:

1) percent lying

2) average individual distance

3) elevation

4) slope

5) slope shape

6) distance from the haul road

The large aggregations of CAH caribou observed during the postcalving period appeared to be largely in response to mosquito harassment. Mean group size during periods of no mosquito harassment was 44 (Table 11), in part reflecting a tendency for formation of larger groups in response to predators (see above). However, at high levels of mosquito harassment, mean group size increased to 383. The largest aggregation observed was a group of approximately 2000 caribou near the coast during warm, calm weather when mosquito harassment was severe. Aside from the apparent instinctive response to predation, the maintenance of realtively large groups during post-calving when mosquitos are not active could be a residual effect from past periods of severe harassment.

				Harassme	nt Level	A			Significance
		one	н	118	Hod	erate	Sev	ere	Level of
Laribou Behavior	Mosq.	W. fly	Mosq.	W. fly	Moaq.	W. fly	Mosq.	W. fly	F KAL10
wan percent feeding ^b	42.5	52.0	37.5	46.5	52.0	9.2	30.7	6.3	<.001
Nean percent lying ^b	39.4	40.7	45.5	18.8	17.0	10.8	20.4	8.0	<.001
Yean percent standing ^b	2.6	2.1	4.7	24.0	10.7	68.0	15.2	59.1	<.001
Man percent walking ^b	12.4	4.4	9.6	7.5	14.8	4.9	16.0	6.6	<.001 (mosquito) N.S. (warble fly)
Mean percent trot./run. ^b	2.4	0.1	1.8	3.2	5.2	7.1	17.5	21.0	<.001
Mean percent nursing ^b	0.3	0.3	-	-	-	-	0.1	-	<.025 (mosquito) N.S. (warbie fly)
Mean average individual distance	5.9	18.7	6.6	33.6	5.0	58.4	4.2	70.9	<.001
fran gjoop movement rate	5.2	6.2	4.6	6.6	11.5	11.5	12.1	12.2	<.001
kan group size	44.4	9.7	55.3	7.0	225.6	7.8	382.9	4.4	<.001
wan haul road crossing rate	0.2	0.2	0.4	-	0.5	-	0.7	0.1	<.001

Table 11. Caribou activities at various levels of mosquito and cestrid fly harassment.

aSubjective assessment bPercentage of individuals within observed groups engaged in each of eight activities ^CMean distance between individuals within a group dMeters/minute

Observations of group movements in response to mosquito attack agree with those of White et al. (1975). Dense aggregations moved upwind at a trot or run toward relief habitat on the coast. Cool coastal breezes off the pack ice usually occurred during warm weather providing some relief. River deltas and associated sand dunes were preferred areas for insect relief because of the lack of vegetation and suitable mosquito breeding habitat. A change to cooler temperatures and higher wind speeds was accompanied by fragmentation of these large aggregations and dispersal away from the coast. Bulls and cows tended to resegregate, cow groups being characteristically larger than bull groups in the absence of mosquito harassment. Usually bulls reoccupied riparian habitats while cow-calf groups primarily utilized wet sedge meadows.

Extensive post-calving "migrations" occur primarily when the animals are aggregated and mosquito harassment is severe. A 2.5 fold increase occurred in the mean rate of group movement during a change from no mosquito harassment to severe harassment (Table 11). This increase represents a minimum estimate since rapidly moving groups were soon out of sight and hence the data was biased toward the more visible sedentary groups. Post-calving movements, unlike the seemingly random movements during August dispersal, are strongly directional and have a marked effect on overall distribution of the herd. Prevailing easterly winds in summer seem to be responsible for a major shift in the center of occupancy of the CAH to the east. A drift back to the west usually occurs once mosquito numbers have declined (Cameron and Whitten 1976).

Some bulls do not join post-calving aggregations but rather remain in the Foothills or Brooks Range throughout the summer. These animals are frequently found in association with large patches of aufeis (overflow ice) which persist through most of the summer. During periods of severe insect harassment these bulls seek relief on the ice where the relatively low temperatures inhibit insect attack (Skoog 1968).

Many of the behavioral responses to oestrid flies were similar to the responses due to mosquito harassment, but with important exceptions. The following behavioral parameters are positively correlated with oestrid fly harassment:

1) percent standing

2) percent running

3) average individual distance

The following parameters were negatively correlated with oestrid fly harassment:

1) percent feeding

- 2) percent lying
- 3) group size
- 4) distance from the haul road
- 5) number of road crossings

There is little effective oestrid fly escape terrain on the coastal plain. Caribou do not aggregate in river delta or dune areas when under severe oestrid fly harassment. Solitary animals are frequently seen on unvegetated gravel bars or on bare ridges along Franklin Bluffs or in the northern Foothills. The most dramatic response to oestrid flies is panicked running at top speed ("aberrant running," Curatolo 1975) frequently observed during warm, sunny days in August. The animals appear so disturbed that the social bonds which maintain group cohesion breakdown and individuals run until they are exhausted. Only cow-calf bonds appear to be strong enough to withstand the stresses of oestrid fly harassment, although occasionally these bonds are disrupted as well. This tremendous expenditure of energy must impose limitations on the growth of calves and the fattening of adults during summer.

The dispersal of caribou during August is primarily a response to ocstrid fly harassment (Curatolo 1975). Average individual distances increase from 18.7 meters during periods of no oestrid fly activity to 70.9 meters during severe harassment. This dispersal is also reflected in a decrease in mean group size from 9.7 to 4.4. In 1975, disintegration of post-calving aggregations in early August coincided with the appearance of behavior associated with oestrid fly avoidance and small groups, cow-calf pairs, and lone animals were observed scattered over the entire coastal plain.

Unlike mosquito harassment, oestrid fly harassment appeared to be limited to the warmer portion of the day (Zhigunov 1968). Usually by 1700 or 1800 hours the violent reactions of caribou to oestrid fly attack began to subside and caribou tended to regroup somewhat during the evening. Not until the following morning did oestrid flies again disrupt feeding and lying activities and fragment groups.

The results indicate that oestrid fly harassment is associated with higher percentages of standing and running, and lower percentages of lying than at similar levels of mosquito harassment (Table 11). In addition, there was a striking difference in both mean group size and average individual distance. The effects on rate of group movement were similar but movement rate was higher during August dispersal in the absence of oestrid fly harassment than for the post-calving period in the absence of mosquito harassment.

The distinctly different reactions of caribou to mosquitos and oestrid flies (aggregation vs. dispersal) reflect the method of host location by these parasites. Mosquitos respond to the localized carbon dioxide gradients and warm, moist convection currents associated with warm-blooded animals (White et al. 1975). Oestrid flies locate caribou primarily using olfaction and are consequently more efficient at locating caribou. Treisman (1976) showed that aggregation of prey does not reduce the chances of being located if the predator locates prey through olfaction. The scent stimulus produced by the aggregation would attract a proportionately larger number of predators. These principles apparently apply to oestrid fly parasitism.

There is also an important difference in the relative impact of the two insect parasites. Caribou are tolerant of minor annoyance by a few mosquitos and, even during extreme harassment, are capable of feeding and lying, but a single oestrid fly can cause a caribou to run at top speed for several hundred meters. Some relief from intense mosquito harassment can be obtained by aggregating, thereby "swamping" the

mosquitos with potential hosts. Also, the constant movement of tightly bunched caribou helps to decrease the impact of mosquito attack on an individual caribou within the groups. Only the outer rows in a dense aggregation are subject to attack (Baskin 1970). Swarming of prey also tends to confuse predators, an additional advantage of bunching behavior (Cumming 1975), and this principle seems to apply to mosquito parasitism.

A comparison of activity budgets during the post-calving and August dispersal periods indicated that a higher incidence of unproductive behavior (not related to feeding or rumination) occurred during August dispersal (see Appendix A). The combined percentages of standing, walking and running was 25.6 during August dispersal and 20.1 during the post-calving period. This difference supports the hypothesis that oestrid flies had a greater total influence on the energy expenditure of the CAH than mosquitos. Mean group movement rates at comparable levels of mosquito and oestrid fly harassment were nearly the same (Table 11).

Caribou in large aggregations are not as responsive to potential predators as are caribou in small groups (Murie 1944, my own observations). This generalization also seems to be true for the response to oestrid flies. Because of the severe physiological stress imposed by heavy loads of oestrid fly larvae (a single warble fly can lay 500-700 eggs; Zhigunov 1968) it is to the individual's advantage to react to oestrid fly attack. Lone caribou probably react most violently. Espmark (1968) observed that reindeer are most susceptible to warble fly parasitism when lying down. An alert animal, standing with head lowered and facing

downwind would have a much better chance of detecting warble flies before they could lay eggs.

Weather conditions favoring mosquito and warble fly activity have an indirect adverse effect on growth and fattening of caribou during the summer months (Zhigunov 1968). Both calves and adults are affected, with consequences to winter survival and productivity. The importance of successfully avoiding insect harassment is apparent from body and antler size data from certain island populations of caribou and reindeer. Very fat and large-bodied caribou inhabit Coats Island in Hudson Bay where insect densities are low (Parker 1975). Introduced caribou on Adak Island in the central Aleutians achieve maximum growth and development where there is a complete lack of parasitic insects (Hemming 1971). Introduced reindeer on the sub-antarctic island of South Georgia are also free of insect harassment and attain large body and antler sizes (Bonner 1958). Parasitic insects are absent or low in density on St. Matthew and St. Lawrence Islands off the coast of Alaska and the introduced reindeer reportedly averaged heavier and larger than mainland populations (Klein 1970b). Geist et al. (1974), in discussing the very large Osborn's caribou in the Wolf Lake region, stated that the limited availability of terrain which provides escape from insect pests appears to be "a bottleneck in caribou biology." Presumably the availability of windy, cool, glaciated terrain on the summer range of Osborn's caribou is a contributing factor to the characteristically large body size.

Two distinctly different strategies for extending the period of peak forage quality are available to northern ungulates: northward migrations or altitudinal movements - both are synchronized with the progressive emergence of preferred forage. Both of these options are open to the CAH yet the great majority of animals migrate northward to the arctic coast in spring and early summer. Only a few scattered bulls are present in the Brooks Range during summer. This is apparently due to low precipitation in the Brooks Range and the resultant scarcity of perennial snow and ice for insect relief. Unlike the high, glaciated peaks in the summer range of Osborn's caribou (Geist et al. 1974), insect escape terrain is not readily available in the Brooks Range. By moving north to the coast the emergence of mosquitos is effectively delayed by 2-4 weeks. In addition, cool and windy weather with frequent coastal fog greatly reduces the frequency and duration of severe insect harassment. Cooler temperatures also help to maintain moist conditions by reducing evaporation rates. Consequently peak forage quality could possibly extend longer in coastal areas than in the Brooks Range.

Novements of the CAH during July and August are primarily in response to parasitic insects and secondarily a result of regional and local variations in forage quality. It is difficult to over emphasize the importance of insects because of the dramatic effects of harassment on behavior during the short season when caribou have access to forage high in protein, minerals, and carbohydrates.

Group structure and social environment

Social organization in caribou is highly responsive to environmental conditions such as insect harassment, range quality, predation, and weather (Bergerud 1974). It has been suggested that changes in group size and composition may effect changes in the behavior of Rangifer (Baskin 1970, Curatolo 1975). However, it is difficult to separate the affects of social environment on caribou behavior from the direct affects of other environmental factors which also influence group size and composition. For example, in the CAH during the postcalving period the incidence of standing was highly correlated with group size while during August dispersal, standing was negatively correlated with group size (Table 12). In these cases group size was not the causal factor in the frequency of standing. Instead, parasitic insects which affected group size also influenced the incidence of standing. This section discusses changes in caribou behavior which appear to be related to changes in group size and composition. It also presents correlations between the activities of some individuals in the group and the activities of other group members.

The relationship of group size to caribou behavior was examined first by identifying correlations between group size and various behavioral parameters during midwinter and late winter. In midwinter group size was positively correlated with the incidence of walking $(P \le 0.01)$ and negatively correlated with both the incidence of feeding $(P \le 0.01)$ and average individual distance within the group $(P \le 0.05)$.

			Cr	nup	51	ze_					Per	cen	t C	W8				P	erc	ent	Cal	lvei	5			,	erc	ent	Bu	111		
	<u>5</u>	<u>P</u>	<u>^</u>	F	R	E	M	L	<u>s</u>	2	<u>^</u>	<u>F</u>	R	£	M	ĩ	<u>s</u>	<u>P</u>	<u>^</u>	F	R	Ē	M	Ľ	<u>5</u>	<u>P</u>	4	<u>F</u>	ĸ	Ē	Ä	Ľ
Percent feeding			÷						-			++			-	+	-		++	+					++		•	-		++	++	-
Percent lying									+					++	++		+		+	-		++	++		-		-	+		-		
Percent standing		++							+	-	-		+					-							-	+	++					
Persent walking			+				++	+	-								-			÷			-								+	
Percent running		•	-																-	++			+			+						
Pirint sparing							+						-	-							-								+			
Sevenent rate	++		+					++				++	+				-			++								·			++	
Average Ind. dist.			-	-		-	-			++	-	++			-		-	++	-	++		-	-					-		++	++	+
Miliage		++			++	++			++	++	++			++		++	++	++	++		+	++	•		-	-			•		++	-
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Flevation	++		++	++						-		-	++		+				-	-		-		++	++	++	++	++		++		++
Slope	+			-						+			++	-	-	++		+		-		-	-		++	-		++		+	++	+
Slope shipe													++	-		++	-	+		-	-				- ++	-		++				
Distance from road			-			++	++		++	++	++	++				-	++	++	++	++			-							-		-
Aviddance	++		++	-				+	-	-			++	-				-		++	-	-	++			++		-		++		+
	Gre	oup	Si	te						++	-				++	-	-	++		-		-		-	++	-	++		-		-	+
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										-							Pe	rce	nt	cal	ves						-		-		-	

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Table 12. Correlations between group composition variables and caribou behavioral variables.

high positive correlation ($P \le 0.01$) positive correlation ($P \le 0.05$) ++

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negative correlation (P<0.05) high negative correlation (P<0.01) .

These correlations were apparently a result of more frequent movements within and between feeding areas by larger groups. These larger groups tended to be more clumped than small groups. The higher incidence of walking and lower incidence of feeding in large groups was probably partly a consequence of higher rates of social interactions, such as displacement of subordinates from feeding craters and beds by dominant group members. Social interactions appeared to be less frequent in small, more dispersed groups.

In late winter, group movement rate ($P \le 0.01$) and the incidence of walking ($P \le 0.05$) were positively correlated with group size. Higher movement rates in large groups were probably a response to limited snow-free areas where feeding was possible, in addition to higher rates of social displacements as in midwinter. Large groups probably exhausted the available lichen forage in these restricted feeding areas more rapidly than small groups.

The relationship of group size to winter activity budgets was investigated in greater depth by dividing all winter activity observations (November 11-April 28) into the following classes based on the number of individuals within the group:

1-5, 6-10, 11-15, 16-20, 21-25, 26+.

It can be seen from Table 13 that groups larger than 15 had a higher incidence of lying and a lower incidence of feeding. Also mean group movement rate tended to be lower in groups larger than 20. The correlation between percentage of bulls in the group and group size

			Cman			
				ip 512e		
	1-5	5-10	10-15	15-20	20-25	26+
Percent feeding	55.0	50.8	59.4	49.9	42.7	43.8
	(2.0)	(1.5)	(1.5)	(1.9)	(3.2)	(2.9)
Percent lying	33.0	34.6	30.5	40.1	49.2	45.7
	(1.9)	(1.6)	(1.6)	(2.1)	(3.6)	(3.3)
Percent standing	2.9	3.6	2.3	4.4	2.1	2.6
	(0.6)	(0.5)	(0.3)	(0.6)	(0.4)	(0.6)
Percent walking	7.8	10.0	7.0	4.9	4.8	7.1
	(1.0)	(0.9)	(0.7)	(0.6)	(0.6)	(1.2)
Group movement rate	171	201	119	58	92	117
(meters/hour)	(21.2)	(17.4)	(15.1)	(11.6)	(20.5)	(25.5)
Average individual	8.9	8.8	7.7	9.9	6.3	4.3
distance (meters)	(0.5)	(0.3)	(0.3)	(0.7)	(0.6)	(0.1)
Sample size	482	726	426	254	117	164

Table 13. Caribou activity in groups of different sizes during winter.

Standard error of the mean appears in parentheses beneath each activity mean.

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makes these results difficult to interpret. The lower incidence of feeding and higher incidence of lying in larger groups in the CAH during winter contrasts with results from the Fortymile herd (Curatolo 1975). Lower movement rates of larger groups in winter is also markedly different from Curatolo's observations. I suspect that increased group size is not responsible for lower movement rates in the CAH during winter. (In late winter, group movement rate was positively correlated with group size.) The decrease in group movement as group size increases was probably a result of sexual differences in mean group size and mean group movement rate. In early and midwinter most groups larger than 15 were dominated by cows. Additional correlations between the composition of groups and group behavior are discussed below.

Changes in summer caribou behavior associated with changes in group size were examined by dividing all summer activity observations (May 15-September 28) into the following classes based on group size:

1-5, 6-10, 11-15, 16-20, 21-30, 31-45, 46-70, 71-150, 151+. Table 14 shows that in summer the incidence of feeding increased and the incidence of lying decreased in groups larger than 150. This result can be attributed to the effects of mosquitos on activity (see also the previous section). Few groups larger than 150 were observed except during periods of severe mosquito harassment. The incidence of feeding and walking was low while the incidence of standing was high in groups smaller than 5 during summer. This is probably due to oestrid fly harassment which appears to be related to group fragmentation. Conse-

	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,			G	roup si	ze			
	1-5	6-10	<u>11-15</u>	16-20	21-30	31-45	46-70	71-150	151+
Percent feeding	30.4	45.3	38.0	48.2	39.2	39.7	34.8	41.5	47.8
	(1.7)	(1.7)	(2.5)	(1.8)	(2.0)	(2.9)	(2.6)	(2.4)	(2.3)
Percent lying	33.7	34.3	38.9	37.2	37.3	40.9	38.3	38.0	23.5
	(1.9)	(1.9)	(3.1)	(2.0)	(2.4)	(3.7)	(3.3)	(2.9)	(2.1)
Percent standing	23.0	4.9	7.3	2.9	11.4	2.1	6.5	5.5	6.2
	(1.8)	(0.8)	(1.5)	(0.4)	(1.6)	(0.4)	(1.1)	(1.0)	(1.0)
Percent walking .	6.7	12.7	14.1	10.4	9.7	16.3	12.8	10.1	14.3
	(0.9)	(1.0)	(1.6)	(0.9)	(0.9)	(2.0)	(1.5)	(0.9)	(1.4)
Average individual	42.1	11.5	6.1	6.2	6.7	5.0	5.1	4.6	5.8
distance (meters)	(2.0)	(0.6)	(0.4)	(0.3)	(0.2)	(0.2)	(0.3)	(0.1)	(0.4)
Group movement rate	376	391	367	327	293	541	408	314	455
meters/hour	(44.5)	(29.4)	(39.5)	(27.3)	(31.0)	(74.6)	(50.9)	(42.2)	(103.2)
Sample size	499	469	193	359	233	121	122	102	76

Table 14. Caribou activity in groups of different sizes during summer.

Standard error of the mean appears in parentheses beneath each activity mean.

quently, differences in caribou activity budgets during summer could not be directly attributed to difference in group size.

Curatolo (1975) observed that as group size increased, group movement rate and the incidence of feeding increased while the incidence of lying decreased. However, the present study indicated no correlation between group size and the incidence of lying in the CAH. Only during August dispersal was there a positive correlation between group size and the incidence of feeding. This correlation was clearly a result of oestrid fly harassment which disrupted feeding activity. In the evening when oestrid fly activity subsided, caribou again coalesced into groups and resumed feeding.

Aggregation during post-calving apparently occurred independently of mosquito harassment in the Fortymile herd during 1973 (Curatolo 1975). Newfoundland caribou also aggregate after calving and prior to the emergence of insects (Bergerud 1974). Similar aggregations in the Western Arctic herd had a restless appearance as if the groups were driven but for no apparent reason (pers. observation). The same behavior was observed in post-calving aggregations of wild reindeer in Norway (Thomson 1971) and in the Soviet Union (Baskin 1970). This behavior must have a marked effect on energy expenditure at a time when cows are lactating and the rapid growth of calves is critical for their survival. In addition, extensive post-calving movements would be expected to increase the frequency of cow-calf separation and desertion. It is difficult to explain why this behavior is so

frequently observed in the absence of obvious environmental conditions favoring aggregation. Rapidly moving aggregations of CAH caribou were not observed in the absence of mosquito harassment. It is possible that the lack of these aggregations during insect-free periods reflects favorable forage conditions and a paucity of predators on the summer range. Low stocking rates, rarity of wolves, and very low summer calf mortality (Cameron and Whitten 1977) support this interpretation. In the absence of mosquitos, small average group size in the CAH is perhaps partly a function of the small size of the herd.

The relationship of group composition to caribou behavior was first explored by examining the data for correlations between the percentage of cows or bulls in the group and group behavior (Table 12).

The percentage of cows in the group was positively correlated with group size during midwinter ($P \le 0.01$). Large (20-40) cow-dominated groups frequently included young bulls which retained their antlers as late as early May. Older bulls usually dropped their antlers in early winter and were commonly associated in small, unantlered bull groups for the remainder of the winter. Unantlered bulls which remained in groups of primarily antlered animals usually fed and ruminated at the periphery of the group, probably due to their low social status. Antlered caribou easily displaced these bulls from feeding craters and beds. It appears to be to the advantage of unantlered bulls to segretate from cows and young bulls. Groups composed entirely of unantlered bulls were commonly observed along the haul road during winter.

The ratio of cows in a group was positively correlated with the incidence of lying ($P \le 0.01$) in both early and mid-winter. The ratio of bulls was negatively correlated with the incidence of lying during these two periods ($P \le 0.01$). These correlations agree with the previously discussed sexual differences in activity budgets calculated for early and mid-winter (see the section on the annual cycle and Appendix B). By late winter, this sexual difference had changed and cow-calf groups tended to spend more time feeding and less time lying than bull groups. This increased feeding rate may be in preparation for higher energy demands of the late term fetus as well as northward spring movements.

The percentage of bulls in a group was positively correlated with topography and elevation during most of the year. There was a negative correlation ($P \le 0.01$) between percentage of bulls and distance north of Happy Valley on the haul road in all seasons except pre-rut and midwinter. This agrees with the results of aerial surveys which indicate that bulls tend to have a center of occupancy which is further south than that of cow-calf groups (Cameron and Whitten 1976). Topographic variability and elevation both increase south toward Happy Valley.

The percentage of bulls in a group was negatively correlated with distance from the haul road ($P \le 0.01$) in all seasons except pre-rut, rut, and mid-winter. This suggests that bull groups are more tolerant of haul road traffic than cow groups (see the following section for more about group tolerance of traffic). This is supported by the results

of area-wide aerial surveys which record higher percentages of cows and calves than surveys taken along the haul road (Cameron and Whitten 1976).

Group size was positively correlated with percent cows during post-calving and mid-winter ($P \le 0.01$) but negatively correlated during spring, August dispersal, and pre-rut. The high vulnerability of calves to predation relative to adults suggests that calf survival would benefit from larger group size. However, roadside data did not indicate that cows were consistently more gregarious than bulls.

Bergerud (1974) reported that as the number of males in the Newfoundland caribou population decreased, the size of aggregations during rut increased. There is a very high bull:cow ratio in the CAH as indicated by fall composition counts (Cameron and Whitten 1977). This could account for the low mean group size during rut. It was common to observe isolated bull-cow pairs at that time. Average size of cow groups during calving was also low. Lone cows accompanied by new-born calves were widely scattered over the calving grounds. This appears to be related to the extreme vulnerability of neonates to predation since concealment rather than flight is the principal means of escape for the first two days after birth (Lent 1966b). Dispersal is the best means of concealment in the open habitat of the coastal plain. In addition, the establishment of a strong cow-calf bond is important for the survival of the neonate. Isolation from other adults at the time of calving permits bond formation without interference.

The relationship between the sexual composition of groups and their behavior during summer and winter was further explored by dividing all groups into three categories: 1) 0-5% cows, 2) 5-50% cows, 3) 50-100% cows. Analysis of variance disclosed significant seasonal differences in behavior between these classes (Table 15). The incidence of feeding is not significantly different between group types during summer. In winter, percent feeding increases with increasing percentage of bulls (P<0.001). During both summer and winter, the incidence of lying increases with increasing percentage of cows (P<0.025, P<0.001). Higher incidence of lying in cow groups during summer may be caused by several factors, including more frequent lying by calves, longer rumination times due to poorer quality forage, and less selective pressure on cows for rapid antler growth, body growth, and fat deposition. Differences in winter may be a result of the better physical condition of cows.

Both percentage standing and percentage walking are significantly different between group types only during summer. The incidence of standing in bull groups was higher than in cow groups but mixed groups had the lowest standing values ($P \le 0.001$). Walking was highest in mixed groups ($P \le 0.001$). No significant differences in percentage running were present between the three classes.

During winter, groups that were only 0-5% cows had significantly higher movement rates ($P \le 0.01$) and average individual distance ($P \le 0.001$). This is consistent with the higher incidence of feeding and the lower

	Percentage	of Cows	in Group	Significance
	0-5	5-50	50+ 	level of <u>F ratio</u>
summer	41.0	42.0	41.9	N.S.
winter	55.0	40.4	40.9	<0.001
summer	34.6	38.8	41.1	<0.025
winter	32.2	39.4	41.9	<0.001
summer	10.6	2.5	5.1	<0.001
winter	3.4	2.6	3.7	N.S.
summer	10.1	14.3	8.9	<0.001
winter	7.8	8.5	6.2	N.S.
summer	2.8	1.8	1.8	N. S.
winter	0.7	0.6	1.1	N.S.
CUMMON	81 8	108 0	73 /	<0.001
winter	40.1	35.3	17.7	<0.01
summer	13.6	6.8	14.3	- <0.001
winter	9.1	6.6	7.6	<0.001
summer	17.3	75.0	21.5	<0.001
winter	8.9	18.3	7.9	<0.001
	summer winter summer winter summer winter summer winter summer winter summer winter summer winter	Percentage0-5summer41.0winter55.8summer34.6winter32.2summer10.6winter3.4summer10.1winter7.8summer0.1winter0.7summer81.8winter40.1summer13.6winter9.1summer17.3winter8.9	Percentage of Cows 0-5 5-50 summer 41.0 42.0 winter 55.8 48.4 summer 34.6 38.8 winter 32.2 39.4 summer 10.6 2.5 winter 3.4 2.6 summer 10.1 14.3 winter 7.8 8.5 summer 0.7 0.6 summer 81.8 108.0 winter 9.1 6.6 summer 13.6 6.8 winter 9.1 6.6 summer 17.3 75.0 winter 8.9 18.3	Percentage of Cows in Group $0-5$ $5-50$ $50+$ summer 41.0 42.0 41.9 winter 55.8 48.4 46.9 summer 34.6 38.8 41.1 winter 32.2 39.4 41.9 summer 10.6 2.5 5.1 winter 3.4 2.6 3.7 summer 10.1 14.3 8.9 winter 7.8 8.5 6.2 summer 0.7 0.6 1.1 summer 81.8 108.0 73.4 winter 40.1 35.3 17.7 summer 13.6 6.8 14.3 winter 9.1 6.6 7.6 summer 17.3 75.0 21.5 winter 8.9 18.3 7.9

Table 15. Relationship of group composition to caribou behavior (means).

^ameters/15 minutes.

incidence of lying in bull groups since feeding groups maintain greater individual distances and move more frequently.

Curatolo (1975) found that during post-calving, cow-calf groups maintained smaller average individual distances than other groups and that cow-calf pairs tended to form larger groups. This spacing has adaptive significance when predation is an important source of mortality during post-calving. In the CAH group size is positively correlated with percentage of cows present during the post-calving period but cow-calf groups maintained greater average individual distance than bull groups. This may be another behavioral ramification of low predation pressure during post-calving.

Some activities were correlated with each other and with parameters of social structure, indicating a degree of behavioral synchrony and social facilitation within groups (Table 16). As expected, the percentage feeding was negatively correlated with the percentage lying throughout the year, reflecting the cyclic nature of feeding and lying activities. The percentage feeding was also negatively correlated with the incidence of standing during the post-calving, August dispersal, and midwinter periods ($P \le 0.01$). During the two former periods standing was a common response to insect attack and effectively replaced feeding. In midwinter standing was rare during a feeding bout and most frequent during periods of resting or while moving between feeding areas. The relationship between the incidence of feeding and the incidence of walking changes seasonally. During spring and post-calving the

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Novement rate	++ -	++		+				+	+	-	•	-	•	•	•			•			-		++	++	++	++	++	++	- ++	+	• +	÷ •	••	++	++	++	++	++	٠		**	++
Average individual distance	** ·	••	•	++		44	• •	•	•	-		•		-	•	•	•			•	++						++	-	•				+				-	++				
Percent sparring					++	•																																				
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Table 16. Correlations between caribou activity and behavioral variables.

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S = spring and calving

= post-calving A + August dispersal

- F = fall migration and pre-rut
- R = rut
- E = early vinter M . mid-winter
- L = late winter

++ high positive correlation (P<0.01)
+ positive correlation (P<0.05)
- negative correlation (P<0.05)
- high negative correlation (P<0.01)

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incidences of feeding and walking were positively correlated because caribou usually fed while on the move. However, during pre-rut, rut, early winter, and midwinter feeding and walking percentages were negatively correlated since periods of feeding were generally alternated with movements between feeding areas reflecting the reduced availability of forage. The incidence of feeding was negatively correlated with the incidence of trotting/running except during the rut when chasing of cows and rival bulls by dominant bulls occurs during periods of feeding.

The incidence of standing was negatively correlated with the incidence of walking during August dispersal ($P \le 0.01$). Oestrid fly harassment increases the time spent standing and reduces the time spent walking. During rut and in early and midwinter the incidence of standing was positively correlated with the incidence of walking ($P \le 0.01$). Most standing occurs while groups are moving between cratering areas. Percent walking was positively correlated with percent running only during post-calving when groups harassed by mosquitos, walked and trotted into the wind. The percentage sparring was correlated only with feeding during rut. Sparring between subordinate males occurred mostly during feeding periods.

In general, there was a positive correlation between the percentage of a group feeding and average individual distance. There was also a negative correlation between percent lying and average individual distance. This indicates a tendency for greater spacing within groups

during feeding periods which reduces competition between members of the group for preferred forage. Shorter distances between individuals during lying periods would increase the synchrony of response in the event of predator attack.

Movement rate was positively correlated with the incidence of running except during rut when considerable chasing of cows by mature bulls occurred without any overall group movement. The percentage standing was positively correlated with group movement rate during the four winter periods as suggested by the correlation between percentage standing and percentage walking. The percentage feeding was positively correlated with movement rate during those periods when snow-free areas were available, except during August dispersal. Oestrid fly harassment during August dispersal caused considerable rapid movement and deterred feeding.

In summary, few direct effects on caribou behavior and activity from changes in group size were found in observations from the CAH. Correlations between group size and various behavioral parameters are in most cases easily attributed to environmental variables which are apparently important in determining group structure. The environmental variable which has the greatest influence on group structure in the CAH during summer is insect harassment. Predation is seemingly a secondary factor. During winter the distribution and abundance of forage plus the availability of forage as determined by snow conditions
are apparently the most important environmental factors influencing group structure.

The sexual composition of groups has a more significant bearing on caribou activity than group size. These sexual differences in behavior result from different selective pressures related to breeding and care of young which operate on caribou as well as most northern ungulates. The incidences of various activities in caribou groups are closely interrelated as indicated by correlations between activities. However, these interrelationships change with the changing seasonal environment. Synchrony of activity within groups as well as group adherence to circadian patterns of activity are responsible for these correlations.

The pipeline and haul road

Several quantitative variables were recorded which are relevant to the impact of the pipeline haul road on caribou behavior and movements. These include:

- 1) Distance of the caribou from the haul road.
- 2) Vehicle rate on the haul road or pipe pad.
- Adjusted vehicle rate considering differences in vehicle size.
- 4) Level of alarm/avoidance reaction of caribou to the road.

5) Number of times caribou were observed crossing the road. Certain consistent correlations were found among these five variables (Table 17). Distance of groups from the haul road was negatively correlated with vehicle rate on the road in all seasons; i.e. the higher the vehicle rate the closer groups tended to be to the haul road. Two factors appear to effect this unexpected relationship. The greater the rate that vehicles pass on the haul road the less startling the stimulus becomes and habituation is facilitated. An occasional vehicle would be expected to elicit a stronger response than vehicles passing in rapid succession (Geist 1975). Also, frequent traffic prevented crossing of the road because caribou were repeatedly frightened while approaching. This suggests an obstruction of caribou movements and a local effect on distribution.

The level of avoidance reaction to the haul road was negatively correlated with distance from the road in all seasons ($P \le 0.01$) except

	Number of Crossings of Haul Road				Distance from Haul Road			Vehicle Rate of Haul Road				Weighted Vehicle Rate on Haul Road						Avoldance																						
	· <u>s</u>	2	¥	<u>r</u>	R	Ľ	Ħ	Ŀ	5	<u>P</u>	<u>^</u>	<u>*</u>	R	Ľ	Ħ	Ŀ	<u>s</u>	7	<u>^</u>	<u>!</u>	R	2	Ħ	L	5	<u>P</u>	<u>^</u>	2	<u> </u>	Ľ	M	Ľ	5	1	<u>^</u>	ľ	Ľ	Ľ	M	Ŀ
Fercent feeding		•		-			++	++			++						++	++	++					•	++	++	++	•				•	++	+		-				-
Percent lying			++	++				-	+		++	-	•				-			+				++	-			++				++	-	•	-		-	-		-
Percent standing	•	+	•	-			+			-	-		-					++	-							+	-				+		++				++		++	++
Percent walking					-				-			++	++						+					-			++						++	++	++	++		++	٠	++
Percent running	+ +	+									-							-	•							-							++	•		++			++	++
Movement rate	++ +	+		++			++	+	•		-	++		+			+		-	-		+						-	•				++	++	++	++	++	++	++	++
Slope movement					۰	-	+											++	•	-			-		+	++		-	•			,						++		
Average individual		-	•	-			++	-		-	•				++		•		-			++	•		-		-				-	ı.	-		-	-				
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Table 17. Correlations between pipeline haul road disturbance variables and caribou behavioral variables.

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- S = spring and calving
- P = post-calving
- A = August dispersal
- F = fall migration and pre-rut
- R = rut
- E = early winter
- H = mid-winter
- L = late winter

- ++ high positive correlation (P<0.01)
- positive correlation $(P \le 0.05)$ +
- -
- negative correlation ($P \le 0.05$) high negative correlation ($P \le 0.01$) -

pre-rut; i.e. the observed behavioral reaction was stronger the closer caribou were to the road. Level of reaction was positively correlated with vehicle rate on the road during all seasons except August dispersal, pre-rut, and midwinter. This indicates that although caribou may approach closer to the road when traffic is frequent they are also more likely to display alarm reactions.

Level of alarm reaction was positively correlated with rate of group movements in all seasons ($P \le 0.01$) and negatively correlated with mean individual distance, except during rut, early, and midwinter. This indicates that caribou groups tend to bunch up and move more rapidly after being disturbed by traffic on the haul road. Avoidance behavior was associated with an increase in the incidence of standing, walking, and trotting/running and a decrease in the incidence of lying during most seasons.

During August dispersal, the incidence of feeding and lying was positively correlated with distance from the haul road ($P \le 0.01$). This probably reflects increased tolerance by caribou for nearby human activity during periods of oestrid fly harassment when feeding and lying occur infrequently. This increased tolerance is also suggested by the reduced incidence of standing and trotting/running as well as lower movement rates as distance from the road increased. However, during spring, percent lying was positively correlated with distance from the haul road ($P \le 0.05$) and percent walking and movement rate were negatively correlated with distance from the haul road (P < 0.01). This suggests

that traffic on the haul road was affecting caribou behavior during this period by reducing the incidence of lying and stimulating increased movement.

The effects of the haul road and pipeline construction on seasonal caribou activity budgets were investigated by dividing all data into intervals according to distance from the haul road:

- 1) 0-100 meters
- 2) 100-200 meters
- 3) 200-300 meters
- 4) 300+ meters .

Mean values for percent feeding, lying, standing, walking and trotting/ running were calculated for each interval (Table 18). The means from the three distance intervals closest to the road were compared with the means at 300+ meters from the road using Student's t Test (Table 19). At 0-100 meters and 100-200 meters from the haul road most activity means were significantly different ($P \le 0.05$) from those 300+ meters from the road, regardless of the group type or season. The results indicate few significant differences in activity budgets between groups that were 200-300 meters from the haul road and those that were 300+ meters from the road. The two exceptions were: 1) the incidence of feeding was higher and the incidence of lying was lower in groups with calves during summer and 2) the incidence of walking was greater in groups without calves during winter. This suggests that groups with calves during summer were most sensitive to the haul road as reflected by altered

	Distance	Wi	nter	Summer				
	(from road)	Grou	Ip Type	Group Type				
Activity	(110m 10au) (m)	With Calves	Without Calves	With Calves	Without Calves			
Feeding	0-100	26.1	53.8	60.3	36.7			
	100-200	25.3	66.0	40.2	54.6			
	200-300	53.8	54.7	59.6	37.5			
	300+	52.1	55.3	41.2	36.7			
Lying	200- 300	32.0	29.6	21.1	40.1			
	300+	34.6	34.3	42.4	35.3			
Standing	0-100	0.5	11.6	11.8	21.2			
	100-200	2.1	4.6	20.4	16.4			
	200-300	4.2	4.1	3.9	9.5			
	300+	3.1	2.8	3.3	13.6			
Walking	0-100	4.8	12.7	19.1	10.0			
	100-200	3.9	12.1	24.6	12.4			
	200-300	10.0	10.6	15.4	9.2			
	300+	8.8	7.0	10.3	10.2			
Trotting/running	0-100	5.7	0.2	0.0	7.4			
	100-200	0.8	2.6	7.4	2.6			
	200-300	0.0	1.1	0.0	3.0			
	300+	0.7	0.4	1.9	3.5			

Table 18.	Seasonal	mean	caribou	activity	percentages	in	relation	to	distances	from	the
	pipeline	haul	road.								

Activity		Distance 0-100	Summer from road 100-200	or pipe 200-30	(m) Distance 00 0-100	Winter from road (100-200	or pipe (m) 200-300
-	w/ca ^a	0.01	N.S.	0.02	5 0.001	0.001	N.S.
Feeding	w/o ca ^b	N.S.	0.0005	N.S.	N.S.	0.025	N.S.
1	w/ca	0.0005	0.0005	0.02	0.0005	0.0005	N.S.
lying	w/o ca	0.005	0.0005	N.S.	0.025	0.0005	N.S.
ctanding	w/ca	0.0005	0.0005	N.S.	0.05	N.S.	N.S.
standing	w/o ca	0.01	N.S.	N.S.	0.0005	N.S.	N.S.
valking	w/ca	0.025	0.005	N.S.	N.S.	0.005	N.S.
walking	w/o ca	N.S.	N.S.	N.S.	0.05	0.025	0.05
trot/runn	w/ca	N.S.	0.025	. N.S.	0.0005	N.S.	N.S.
	w/o ca	0.01	N.S.	N.S.	N.S.	0.005	N.S.

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Table 19.	t test comparison of mean caribou activity percentages between groups	
	greater than 300 meters from the haul road and groups at closer distar	nces.

a groups with calves

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b groups without calves

activity budgets. There was no significant difference in calculated activity budgets at intervals greater than 300 meters from the road. An approximate "critical distance" from the haul road, in terms of caribou activity budgets, was 300 meters for groups with calves during summer and 200 meters for bull groups in summer and all groups during winter.

The effect of proximity to the haul road on normal circadian cycles of feeding and lying was investigated by dividing the data into two groups:

1) less than 400 m. from the haul road*

2) greater than or equal to 400 m. from the road

Few significant differences were found between the circadian pattern of feeding and lying at the two distance intervals during winter. This suggests that in general groups which approach closer than 400 m. from the haul road are able to maintain the general pattern of daily activity regardless of occasional alarming stimuli. However, a striking difference occurred in the summer diel pattern of lying. Closer examination revealed that the circadian incidence of lying in all groups less than 400 m. from the haul road was very similar to the diel pattern for bull groups during summer (Fig. 22). The pattern of lying in groups 400 m. or more from the haul road was similar to the diel pattern of lying determined previously for combined bull and cow groups

*Four hundred meters was used as a cutoff distance because mean levels of alarm reaction at all seasons were low (< 0.5) beyond 400 meters from the road. See Fig. 23.



Fig. 22. Comparison of summer diel pattern of lying between caribou groups less than 400 m and groups greater than 400 m from the pipeline haul road.

during summer (see Fig. 8). This is understandable because bull groups, which were generally more tolerant of haul road traffic, constituted most of the groups within 400 m. of the haul road while few cow-calf groups ventured within 400 m. of the road.

Figure 23 demonstrates the importance of distance from the haul road to alarm reactions. It also indicates the importance of season and composition of caribou groups in determining the mean level of alarm reaction (see page 25 of Methods). For instance, at 0-100 meters from the haul road the "mean reaction" of cow-calf groups in summer was a little over 3 ("trotting away from the haul road"). For bull groups in summer the "mean reaction" was about 1.6 (between "raising the head to the alert position" and "walking away from the haul road"). In winter, both cow-calf groups and bull groups had much lower mean alarm reactions to the haul road at a given distance. In general, groups in summer are more easily alarmed by the haul road than groups in winter. Groups with calves during summer are by far the most reactive, even out to distances of 700 meters from the road.

Avoidance reactions had pronounced immediate effects on caribou activity. Table 20 summarizes the longer term effects of avoidance on activity budgets. The level of avoidance reaction was classified on the basis of the strongest reaction of any member of the groups in those cases where not all members reacted the same. The three activity scans following an observed avoidance reaction were recorded with that level of reaction. Mean movement rate when there was no observable reaction



Fig. 23. Mean level of alarm reaction in groups of caribou as a function of distance from the pipeline haul road.

	-	Level o	f Avoidance Reac	tion	
	No Observable Reaction	Head Raised to Alert Position	Movement Away at Valk	Hovement Away at Trot	Novement Away at Run
Novement rate					
SUMPER	82.9	66.7	227.7	189.0	221.8
winter	30.1	51.0	64.1	177.8	281.8
Average individual distance	c				
Rummer	14.8	7.7	14.4	4.9	11.6
winter	8.3	7.0	5.6	5.0	4.3
Percent feeding					<i>v</i> .
Rumme F	38.5	48.9	40.5	52.1	42.3
vinter	52.3	55.5	52.8	40.7	42.6
Percent lying					
sumer'	39.6	28.7	32.3	10.7	3.3
vinter	37.5	25.9	17.6	9.8	3.5
Fercent standing					
sumer"	9.4	11.0	19.2	7.1	17.4
winter	2.3	10.6	9.5	14.7	14.3
Percent walking					
summer	9.3	10.0	6.1	24.7	25.3
vinter	7.2	7.5	20.0	20.8	31.8
Percent trotting/running					
AN LEARCH C. E.	2.3	0.2	1.3	5.0	11.4
winter	0.4	0.4	-	13.8	8.0

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Table 20. Caribou behavior and activity following different levels of avoidance reaction to the pipeline haul road.

^aSee Methods section for a description of this parameter.

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to the haul road was 83 meters during summer and 30 meters in winter. At the most pronounced level of alarm reaction these rates increased to 222 meters and 281 meters, respectively. When alarm reaction was high, in winter, mean individual distance decreased to almost half the undisturbed individual distance. Alarm reactions were not associated with pronounced changes in the incidence of feeding. Apparently caribou can quickly return to feeding after being disturbed. However, a lower incidence of lying was associated with avoidance behavior in both summer and winter. The incidence of walking, standing, and trotting/running all increased markedly after an avoidance reaction.

An important component of the alarm reaction in caribou is the reduction of space between individuals within a group. A group taking flight from a potential predator frequently appears more like a single large organism than a group of individuals. This social synchrony improves the chances of survival for each individual (Treisman 1976). Figure 24 depicts mean individual distance within groups as a function of distance from the haul road during winter. In general, unalarmed groups without calves are less clustered than groups with calves, as discussed in the previous section. A significant decrease in mean individual distance occurred at distances closer than 300 m. to the haul road in bull groups. In cow-calf groups a significant reduction in mean individual distance did not occur until groups were within 200 m. of the road but the mean individual distance was considerably lower than for groups of bulls which were less than 200 m. from the road.



Fig. 24. Mean individual distance in caribou groups at different distances from the pipeline haul road.

Installation of elevated pipe on the north slope commenced in early August 1975. Fifty-one percent of the total pipe length on the north slope is elevated (four sections ranging from 11 to 65 km. long) (Fig. 1). Between August 1975 and October 1976 41 group crossings beneath elevated pipe were recorded (see Appendix G). Nineteen of these crossings were observed and the others were inferred from the track record. Eight attempted crossings were observed which resulted in failure to gain access to the other side of the pipe. Eleven crossing attempts were inferred from the track record. These crossing attempts did not occur in areas where the pipe was unusually low.

Ten of the 19 observed successful crossings involved single bulls. No crossings by predominately cow-calf groups were observed. However, of the 22 successful crossings inferred from the track record, 3 involved groups which included at least one calf. All three of these observations were recorded during rut. Two nonparous cows were involved in two crossings by bull-dominated groups. In both cases the bulls initiated the crossings. The largest group recorded crossing beneath the pipe was 29: 26 bulls, 2 non-parous cows, and 1 short yearling. The pipe height above the ground at sites of successful crossings ranged from 1.1 meters to 5.1 meters (Appendix G).

Seven of the 19 observed crossings occurred during periods of severe oestrid fly harassment in mid-August. Adult bull caribou were observed standing in the shade of the pipe and repeatedly crossed beneath sections elevated as low as 1.1 m. Temperatures up to 25°C and

low wind velocities were noted, suggesting that thermal stress was an influencing factor. In addition to exhibiting little aversion to the elevated pipe, these bulls appeared tolerant of nearby heavy equipment. Such behavior was not observed during any other season of the year and therefore may be associated with weather conditions which encourage high oestrid fly activity. Other crossings observed were usually preceded by several crossing attempts and accompanied by behavior indicative of stressful conditions. The track record indicated that nearly all crossing involved some milling, running and/or group separation on the approach side of the pipe.

One situation which apparently facilitated the crossing of elevated pipe was observed in May 1976. A section of the Sagavanirktok River floodplain which supported particularly dense stands of horsetail (<u>Equisetum variegatum</u>) was bisected by elevated pipe during the previous winter. Groups of bulls moved into the area to feed following snow melt and remained in the area for about two weeks. They crossed beneath the pipeline repeatedly to gain access to new stands of horsetail. Some bulls became so accustomed to crossing beneath the pipe that they no longer lowered their heads and trotted while beneath the pipe. This suggests that with repeated experience bulls can adapt to the elevated pipe and cross freely beneath it.

It is possible that cows will also adapt to elevated pipe over an extended period of time. Traffic along the pipe pad and adjacent haul road may have disturbed females enough to result in avoidance of the

pipeline area. Unfortunately, data on the reactions of cows to elevated pipe are too scanty to permit generalizations.

The adaptability of caribou to haul road traffic in winter was occasionally striking. Groups of bulls were observed feeding and ruminating as close as 70 m. to the road while heavy construction vehicles were passing at a rate of 1/min. Small cow-calf groups were able to feed quietly while only 140 m. from the road. These observations are the extreme examples and most other groups did not completely habituate to road traffic. Larger groups of cows, calves and young bulls usually maintained greater distances from the haul road than small groups of bulls. The extent of the individual's experience with the haul road is likely an important factor in determining sensitivity.

There was a surprising lack of disruption of diel activity patterns in groups closer than 400 m. from the haul road despite occasional alarm responses to traffic. In addition, activity budgets were not significantly altered in groups beyond 200 m. fom the haul road except for cows accompanied by calves during summer. Groups which were disturbed by the haul road or pipe apparently moved to a distance where the stimulus was no longer alarming rather than remain in the vicinity of the road and behave abnormally as a result of stress. Consequently, behavioral sampling near the road was primarily on those groups of caribou which habituated to the road. For this reason the distribution of caribou in relation to the haul road and pipeline is a better indication of the impact of these features on the CAH. The composition of groups observed

near the road makes it apparent that bull groups more easily habituate to traffic and human activity than groups of cows with calves. This is particularly true during summer when more than 90 percent of all caribou observed from the haul road were bulls (Cameron and Whitten 1976).

Geist (1975) pointed out that "behavioral response is not always an indicator of harassment." The stress of disturbance can be obscured by active inhibition of the flight response. This stress may be expressed in a raised tonus of the muscles, increased metabolism, and hormonal changes which if chronic can have serious consequences for health. Although vehicles passing on the road may elicit little response, other types of disturbance which do cause alarm are also frequent near the road. Low-flying helicopters and fixed-wing aircraft frequently follow the road and occasionally fly over groups of caribou. Humans outside their vehicles (especially when attempting to photograph caribou near the road) usually elicit a strong flight response. Hence occupancy of areas near the road is potentially harmful despite habituation to haul road vehicles. Caribou apparently did not have an innate aversion to the haul road when traffic was absent on the road. In winter, if no traffic passed, groups sometimes walked on the bare road surface for several hundred m. before crossing. When traffic was present caribou apparently associated the road with the alarming stimulus of passing vehicles. When groups approached the road to cross during a break in traffic the caribou usually trotted on either side of the road for about 50 m.

Occasionally short sections of steep road berm were avoided by caribou attempting to cross the road. In most cases the caribou detoured their movements to a spot where the berm was lower (see also Cameron and Whitten 1976). Snow accumulations next to the road berm rarely posed a problem since the redistribution of snow by wind usually resulted in hard-packed conditions. No evidence was obtained to suggest that snow conditions prevented crossing of the haul road.

The haul road, pipeline, and associated constructs attract bulls for several apparent reasons. Use of the bare road surface for travel in winter was infrequent, and no groups were observed traveling on the road surface for more than 0.5 km. In spring, certain road materials offer a source of minerals which bulls apparently craved. Specific locations along the road were visited repeatedly by bull groups during the latter half of May and early June. The bulls were frequently frightened by passing vehicles and trotted off a short distance but usually quickly returned. No cows were observed utilizing roadside areas as mineral licks. One non-parous cow in a group with 20 bulls refused to follow the bulls to a frequently-used lick. The cow exhibited alarm behavior and trotted away from the rest of the group when a vehicle passed.

Another characteristic of the haul road which attracts caribou is the early snow melt near the road. Dust stirred up by passing vehicles settles out on the snow and decreases the albedo, particularly on the lee side of the road. This promotes early snow melt in a strip along

the road. In late April, before the emergence of new growth, caribou were observed feeding on lichen in bare patches of ground near the road. In May the flowers of cottongrass <u>(Eriophorum vaginatum</u>) appeared along the road earlier than surrounding areas and attracted bulls which fed adjacent to the road.

During the oestrid fly season caribou seek raised, unvegetated areas where they stand with their backs to the wind. Gravel pads, piles of road material, and even the haul road itself were sought when the animals were under severe harassment from oestrid flies. Shade is also an apparent deterrant for ocstrid flies, and on a treeless landscape animals seek terrain features that offer relief. Bulls were observed standing in the shade of buildings, machinery, and even the elevated pipeline. Cows, however, were never observed taking advantage of human constructs for shade. Bulls are apparently so distracted by oestrid flies during warm, sunny days in August that their tolerance for other types of disturbance is extremely high. Unfortunately others observing this behavior frequently do not recognize the stressful circumstances and consider the animals docile and attracted to areas of human activity (Gavin 1972). This is the source of many claims that the pipeline has no impact on caribou.

A fifth attraction for caribou near areas of construction is related to the delayed senescence of forage in late summer. Road berms and gravel pads impound water and maintain marshy conditions longer than normal. These areas remain green later in the season than surrounding

In summary, behavioral observations indicate that caribou, particularly bulls, have a potential for adaptation to the pipeline and associated human activity. The behavior of groups near the road suggests disruption of normal activity rarely occurs for extended periods of time. Instead, the principal danger to the well-being of the CAH may result from progressive avoidance of the pipeline corridor, particularly by groups of cows and calves. This potential for the disruption of free movement could result in inefficient utilization of the available range and subsequent reduction in carrying capacity of the range. Other possibilities include fragmentation of the herd and reduced access to insect relief habitat. In addition, the productivity of cows and survival of neonates appears to be particularly susceptible to disturbance associated with petroleum development. Low forage quality and reduced availability on the calving grounds places calves in a tenous position during the first two weeks of life. This is reflected in low calf-cow ratios during post-calving relative to other caribou herds in Alaska (less than 50:100) (Cameron and Whitten 1977). Continuing studies of the CAH are designed to monitor the effects of the pipeline on . productivity and movements subsequent to calving. The results of these studies should reveal the long range impact of the pipeline on the wellbeing of the CAH.

SYNOPSIS AND CONCLUSIONS

Movements of the Central Arctic caribou herd within the study area were apparently a behavioral adaptation to several features of the arctic slope environment. The northward spring migration of parturient cows is apparently timed to minimize predation on neonates rather than maximize the quality of available forage during the nutritionally stressful period of lactation. In contrast, the delayed northward movement of bulls seemingly follows the northward shift of the peak in forage quality and takes bulls to the coast at the time of mosquito emergence. The availability of mosquito relief habitat on river deltas and relatively low densities of predators (specifically wolves) favor coastal areas as summer range. Movements, distribution, and the extent of aggregation of the herd during the post-calving period were primarily dictated by the degree of mosquito harassment. Mosquitos and oestrid flies also had an important influence on caribou activity and consequently on fattening and growth rates during summer. Parasitic insect activity was in turn closely related to weather.

Higher standing crops of preferred winter forage (fruticose lichen and evergreen horsetail) and generally softer, less wind-packed snow conditions favored the foothills of the Brooks Range over the coastal plain as winter range. However, lower forage standing crops and localized distribution of winter forage relative to wintering areas of other herds in Alaska make these rangelands unsuitable for grazing by large groups. On the other hand, wolf predation, which was the major source of winter mortality, appeared to exert selective pressure for gregariousness in the absence of forage conditions which would otherwise encourage large group size. The mean size of winter groups (10) appeared to be primarily a function of these two environmental conditions. Winter distribution and the frequency of local movements was evidently dictated by snow conditions as they affected the availability of stands of preferred forage. Winter weather had some influence on the timing of movements as well as the intensity of feeding activity.

Diurnal cycles of feeding and lying/ruminating were identified for both summer and winter. These cycles are primarily synchronized within the social unit but are additionally synchronized to the diel cycle. However, these activity cycles were responsive to environmental factors and consequently varied considerably from the predicted pattern. The cyclic frequency of activity during summer was about twice the frequency during winter, ostensibly because of higher forage quality and availability and/or higher metabolic demands during summer. Feeding-lying cycles in winter were apparently synchronized to the timing of dawn and dusk. Some sexual differences in the period of activity cycles were noted, particularly during summer. This difference may have been partly a result of sexual differences in habitat preference which affect the availability of forage.

Activity budgets varied widely between seasons primarily as a result of the presence or absence of parasitic insects and secondarily as forage quality and availability changed. In general, activity budgets suggest favorable grazing conditions during summer in the absence of severe insect harassment. Winter activity budgets indicate less favorable grazing conditions which agree with the observed low biomass of winter forage.

Activity budgets of caribou groups greater than 300 m. from the pipeline haul road were not significantly different from activity budgets of undisturbed groups. Proximity to the haul road did not appear to significantly disrupt normal activity cycles and their synchronization to the diel cycle. Instead, the impact of haul road activity on caribou behavior was distributional. Disturbed caribou, particularly cows with calves during summer, avoided the pipeline corridor as evidenced by skewed sex ratios. This was supported by observations of greatly increased sensitivity of cow-calf groups to human activity during summer. Limited observations of caribou interacting with elevated sections of pipeline suggest that bulls may be able to adapt to these features. Avoidance of the pipeline corridor by cows with calves will greatly deter the accommodation of these cohorts to elevated pipe.

A major attribute of caribou life history which is difficult for us (as a species poorly adapted to arctic conditions) to fully appreciate is the pronounced seasonality of behavior. The magnitude of the

difference in caribou behavior between summer and winter is comparable to the behavioral differences between various temperate or tropical species of cervids. The ability of Rangifer to change both physiologically and behaviorally with the contrasting seasonal climate and nutritional circumstances reflects a high degree of environmental adaptation. During summer caribou experience continuous sunlight, abundant forage of the highest quality, and occasionally oppressive heat accompanied by severe attack from parasitic insects. During winter they are exposed to nearly continuous darkness, forage meager in both quality and quantity which must be obtained from beneath the snow, and very low temperatures frequently accompanied by severe windchill. As a result caribou markedly change in their sensitivity and reactivity to environmental stimuli during the annual cycle. This is demonstrated by observed differences in seasonal metabolic rates (Segal 1962, McEwan and Whitehead 1970), activity patterns, movement rates, forage preference, social structure (i.e. group size, composition, and individual distance), and reaction to human constructs and activity.

Another characteristic of caribou (and most other northern cervids and bovids) which has important implications for ethological research is the distinct sexual dimorphism associated with behavior. For bulls there is strong selective pressure for large body and antler size because of the importance of these attributes for successful breeding. The extent to which an adult male transmits its genetic material to succeeding generations is primarily determined in a short two weeks

period of intense activity during rut. A short period of reproductive maturity and keen competition among bulls for estrous cows (particularly in the Central Arctic herd because of high bull-cow ratios) severely limits a bull's chances to breed. The short summer must be spent in a manner that prepares bulls for the rigors of rut when all stored energy reserves may be expended. Survival through winter may have little value in a selective sense if success during the breeding season is the trade-off.

In contrast, cows are able to enhance their chances of reproductive success through behavior which assists the survival of the calf through its first year. Hence cows are warier of predators, less inquisitive, more gregarious, less adaptable in their behavior; in general the more conservative (personal observation). Cows with calves maintain larger group size than bulls. Cow-calf groups tend to avoid riparian willow thickets in summer because of the possibility of ambush by predators. The return of parturient cows to traditional calving grounds in the spring may be the only predictable movements in a herd's annual wanderings (Skoog 1968). Cows with calves may flee from a person on foot at a distance of 800 m., while bull groups may be approached to within 50 m. (personal observation). All of these behavioral attributes of cows improve the chances of calf survival. In light of these important sexual differences in behavior it is easily understood why caribou remain sexually segregated during most of the annual cycle.

Studies of the impact of northern development on movements and behavior of caribou are particularly complex because of the seasonal and sexual differences in caribou behavior. It is not justifiable to generalize on the reaction of caribou to human disturbance based on observations of a particular cohort during a particular season. It is also apparent that environmental factors can have an important influence on the sensitivity of caribou to human activity. Parasitic insects and severe winter weather decrease sensitivity. The presence of potential predators increases sensitivity. Very large (500+) or small (less than 10) groups are less sensitive than groups of intermediate size.

The variability and instability of arctic ecosystems dictates that caribou maintain the ability to adapt behaviorally to environmental changes. Consequently, repeated exposure to a strange stimulus such as the pipeline or haul road should lead to habituation and provide opportunities for caribou to learn ways in which to exploit these new features of their environment. Bulls in the Central Arctic herd have demonstrated this ability. However, exceptions to this rule should occur when strange stimuli are innate releasers of genetically programmed avoidance responses (Bergerud 1974). In such cases the avoidance or flight response may be so strongly bound to a generalized stimulus that adaptation to the stimulus is slow or impossible. This is apparently the mechanism which prevents cows with calves from accommodating to the environmental changes associated with construction

of the Trans-Alaska Pipeline. Only long-term research into the impact of Prudhoe Bay petroleum development on cow-calf groups of the Central Arctic herd will reveal the consequences for productivity, recruitment, and general well-being.

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	Nean Percentage											
Season	Sample Size	Feeding	Lying	Standing	Walking	Trot/running	Sparring	Nursing	Other			
Spring migration and calving	866	36.8	49.3	1.7	10.8	0.6	0.01	0.32	0.47			
Post-calving	419	39.4	39.8	4.8	11.2	4.1	-	0.17	0.57			
August dispersal	244	40.2	33.7	17.4	5.1	3.1	-	0.20	0.33			
Fall migration and pre-rut	250	57.0	24.2	2.4	14.0	0.8	1.3	0.06	0.48			
Rut	338	39.7	33.8	7.3	14.6	3.4	1.1	-	0.08			
Early winter	312	51.7	30.9	2.8	12.1	0.7	0.2	-	0,14			
Midwinter	912	60.7	27.5	3.2	7.9	0.6	0.1	-	0.12			
Late winter	839	45.9	43.9	2.9	6.5	0.4	0.4	-	0.14			

Appendix A. Seasonal changes in the percentage of individual caribou within groups engaged in various activities. Only groups at a distance greater than 200 meters from the haul road are included.

•	_									
Seann	Group Type	Sample Size	Feeding	Lying	Standing	Walking	Trot/Running	Sparring	Nursing	Other
Spring migration	Cov+	384	33.7	52.8	2.3	9.5	0.8	-	0.72	0.24
and calving	Bull	482	39.2	46. 6	1.3	11.8	0.5	0.02	-	0.65
Post-calving	Cov+	212	41.8	37.4	3.7	12.6	3.8	-	0.33	0.43
	Bull	207	36.8	42.3	5.9	9.7	4.4	-	0.01	0.72
August dispersal	Cov+	102	46.5	38.5	6.5	4.5	3.2	-	0.49	0.35
	Bull	142	35.6	30.3	25.2	5.6	3.0	-	-	0.32
Pre-rut	Cov+	150	62.0	16.1	2.6	17.0	1.2	1.15	0.09	0.36
	Bull	100	49.6	36.4	2.2	9.6	0.2	1.44	-	0.67
Rut*	Both	338	39.7	33.8	7.3	14.6	3.4	1.08	-	0.08
Eirly vinter	Cow	182	36.1	46.8	3.1	12.6	1.0	0.06	-	0.24
	Bull	1 30	73.5	12.2	2.1	11.4	0.4	0.45	•	-
Mid-winter	Cav	300	56.8	30.7	3.5	8.1	0.3	0.35	-	0.23
	Bull	612	62.6	25.9	3.0	7.8	0.7	0.02	-	0.07
Late winter	Cov	405	49.3	39.2	2.9	7.5	0.6	0.45	-	0.17
	Bull	434	42.8	48.3	2.8	5.5	0.2	0.31	-	0.10

Appendix B. Seamonal changes in the percentage of individual caribou within groups engaged in various activities. Only groups greater than 200 meters from the haul road are included and groups are divided by sex.

almost all groups with sexes mixed

only groups greater than 300 meters from the haul road are included

Appendix C

Description of Vegetation Types

1 - Eriophorum tussock tundra - Spetzman (1959) referred to this community type (in unfortunate terms) as "niggerhead meadow" and Hanson (1953) labeled it "cottongrass-sedge-dwarf heath shrub complex." This type is dominated by tussocks of Eriophorum vaginatum.

2 - <u>Tussock-heath tundra</u> - similar in appearance to the above type but dominated by various dwarf shrubs and herbs like <u>Vaccinium</u>, <u>Ledum</u>, <u>Empetrum</u>, <u>Arctostaphylos</u>, <u>Betula</u> and <u>Rubus</u>. Usually a relatively high percentage of lichen cover such as <u>Cladonia</u> spp. and <u>Cetraria</u> spp. Analogous to Hanson's dwarf birch-heath - lichens and blueberry-heath lichens vegetation types. Pegau (1968) referred to this as the "dwarf shrub-lichen type."

3 - <u>Upland Dryas meadow</u> - analogous to Spetzman's dry upland meadow and Hanson's alpine <u>Dryas</u> vegetation type. Limited to well-drained ridges, slopes, and fell-fields. <u>Dryas octopetala</u> usually dominant. <u>Eriophorum vaginatum</u> either largely absent or scattered with poor tussock formation.

4 - Wet sedge meadow - flat, poorly-drained terrain not on a river floodplain. Frequently low-center polygonal ground. Varies considerably in wetness and hence in species composition but always dominated by sedges, mostly Carex spp. and Eriophorum angustifolium.

5 - <u>Birch-willow shrub</u> - dominated by dwarf birch (<u>Betula nana</u>) and/or low willow (<u>Salix spp.</u>) and usually in association with <u>Eriophorum</u> <u>vaginatum</u>. Analogous to Hanson's type of the same name.

6 - <u>Riparian willow</u> - shrub stands of <u>Salix</u> spp. on active river floodplains and river terraces. Pegau (1968) labeled this the willowherb type.

7 - Well-drained alluvial - river terraces dominated by herbaceous plants such as Dryas, Pedicularis, Hedysarum, Epilobium, Lupinus, Oxytropis, and Astragalus.

8 - <u>Poorly-drained alluvial</u> - river terraces dominated by sedges, mosses and horsetail (Equisetum variegatum).

9 - <u>Raised-center polygons</u> - most common near the Arctic coast and along lake shores on the coastal plain. Better drained but peaty conditions lead to a flora distinct from the surrounding wet sedge meadows. Usually <u>Dryas integrifolia</u>, <u>Carex scirpoidea</u>, and <u>Salix</u> <u>rotundifolia</u> are important. Analogous to the "<u>Dryas integrifolia</u> heath" described by White et al. (1975). 10 - Artificially revegetated - gravel borrow pits reseeded with annual rye (Lolium sp.) and red fescue (Festuca rubra).

and the second s

11 - <u>Unvegetated</u> - bare river gravel bars and river deltas as well as gravel borrow pits and pads.

Appendix D

Forage Species List

Winter (September 20-May 6)

<u>Cladonia rangiferina</u> "reindeer lichen"
 Period of use: September 26-May 6

Niche: This species did not form dense mats (characteristic of taiga winter range) in any of the feeding areas examined. The habitat classification "tussock-heath tundra" supported the highest standing crops of this lichen. Poor soil conditions (acidic, peaty) which are unfavorable for <u>Eriophorum vaginatum</u> and suitable for various e.icaceous species also favor this fruticose lichen. When protected by dwarf shrubs this species can be important where soils are stony and well drained on glacial moraines. <u>C. rangiferina</u> was never abundant but frequently present in small amounts in <u>Eriophorum</u> tussock tundra. Competition with moisture-loving mosses appears to be a major limiting factor.

Comments: Probably the most important winter forage species for the CAH in terms of amount consumed. Other species of <u>Cladionia</u> may have been mistakenly lumped with this species but <u>C. rangiferina</u> was the dominant.

2) Cetraria cucullata

Period of use: September 20-May 6

Niche: Frequently occurs in association with the above species but is more widespread because of its ability to tolerate wetter soil conditions and hence is better at competing with moss. Like <u>C</u>. <u>rangiferina</u> it was never found in dense mats but is scattered on the sides of tussocks in <u>Eriophorum</u> tussock tundra and grows on the tops of microrelief features in wet sedge habitats.

Comments: A very important winter forage species, perhaps consumed as much as the preceding species because of its broader niche. In areas of deep snow cover it was mostly unavailable because of consistently low standing crop.

3) Equisetum variegatum "evergreen horsetail"

Period of use: September 20-May 6

Niche: Restricted on the winter range of the CAH to moist areas on river floodplains. Can form a fairly dense mat among scattered willows or among sedges and mosses. It is present in moist areas throughout the coastal plain but in small quantities. Apparently this species does best in wet alluvial silt with a thin peat cover.

Comments: A very important winter forage as a supplement to protein and mineral-poor lichen diets because of its evergreen condition. Frequently it was intensively utilized where it grows in mats along rivers even when snow cover was relatively deep. Feeding on this species was usually alternated with periods of feeding on lichen, hence it does not appear to satisfy all of the winter dietary requirements of caribou.

4) <u>Dryas octopetala</u> mountain avens"

Period of use: April 3-May 6

Niche: Restricted to well-drained slopes and ridge tops. Uncommon in the northern foothills except locally. This is the dominant species on much of the alpine tundra of the southern foothills and Brooks Range.

Comments: Most of the evidence for utilization of this species was indirect because of the difficulty of detecting clipped stems. It may have been a more important forage on windblown ridge tops in late winter than I suspected. Lipid content of the brown leaves is reportedly high (R. White, pers. comm.), hence it could have been an important late winter supplement to sparse lichens.

5) Vaccinium vitis-idaea lowbush cranberry"

Period of use: November 2

Niche: Widespread on mesic sites; particularly common on "tussockheath tundra" habitat. It is usually an important species in areas of good lichen standing crop.

Comments: Because of its evergreen leaves and close association with good lichen stands this species was probably consumed frequently while cratering for lichen. However, I only identified this species as the main forage consumed in one small feeding area. Consequently, it does not appear to be an important forage species.

6) Astragalus umbellatus

Period of use: November 2

Niche: Common on well-drained alluvial deposits and locally on other well-drained sites.

Comments: This species remains green so late into the growing season that it is frequently frozen in the green state. I was only able to positively identify it as the plant being selected in one case, but it may have been more important during early winter than my observations indicate.

7) Artemesia arctica "arctic wormwood"

Period of use: November 16

Niche: Scattered plants grow on recently disturbed gravel bars along rivers; a pioneer in most well-drained, disturbed habitats.

Comments: I only observed this species being selected on one occasion. The caribou fed on the green hearts at the base of the previous year's growth. The animals were apparently visually cueing on the dead stalks which protruded from the snow since they walked directly from one plant to the next. <u>Festuca rubra</u> and <u>Lolium</u> sp. "red fescue" and "annual rye"
 Period of use: September 20-October 18, April 9

Niche: Used to revegetate abandoned material mining sites. These two species are not native to the arctic slope.

Comments: Both of these grasses were frozen in the green state after the sites were revegetated midway through the growing season. One site in particular received intensive use during fall and some use again in late winter.

9) Salix sp. "riparian willow"

Period of use: February 16

Niche: Along major drainages on river floodplains.

Comments: I only observed winter browsing on willow once by several bulls for a short period of time. Apparently rarely occurs in the winter diet.

Summer (May 14-September 20).

1) Eriophorum vaginatum cottongrass"

Period of use: May 16-June 15

Niche: This is the dominant species over most of the foothills region.. It also occurs in scattered mesic sites on the coastal plain.

Comments: The flowers of this species are the first new growth to appear in the foothills (observed as early as April 28) and consequently

it was the most important forage during the first part of the growing season. Use by caribou in the foothills tapered off during the second week in June, but the flowers continued to be selected on the coastal plain for at least another week.

2) Equisetum variegatum "evergreen horsetail"

Period of use: May 14-June 19

September 12-September 20

Niche: See the description in the section on winter forage.

Comments: This is an important forage as snow melt occurs on the river floodplains since little other green forage may be available. It is apparently a substitute for <u>Eriophorum vaginatum</u> flowers when the latter are scarce. At times groups of up to 50 animals gathered at good stands of this species and grazed intensively. This contrasts with feeding behavior while selecting <u>Eriophorum</u> flowers where the animals feed on the move in smaller, more dispersed groups.

3) Thamnolia vermicularis

Period of use: June 5-June 15

Niche: This species was frequently the dominant lichen on raised tundra near the coast ("raised-center polygonal habitat"). <u>Dryas</u> integrifolia was usually the dominant dicot in such areas.

Comments: This species appeared to be of major significance to **parturient cows on the calving grounds near the coast before any new** growth appeared. Despite very low standing crops there was little else in the way of adequate forage during this period of physiological stress for cows.

4) Cetraria sp.

Period of use: June 5-June 15

Niche: Similar to the preceding species but usually not as prevalent.

Comments: May be a significant supplement to the preceding species for a limited period.

5) Cochlearia officianalis "scurvy grass"

Period of use: around June 15

Niche: A pioneer species on disturbed soil near the coast.

Comments: This was one of the first species of new growth to appear near the coast and consequently was significant for cows on the calving grounds.

6) Salix spp. "shrub willows"

Period of use: June 22-September 6

Niche: Some species are mostly restricted to riparian habitats (S. alaxensis, S. glauca) while others occur scattered throughout tussock tundra and wet sedge meadows (S. planifolia, S. lanata).

Comments: These species appeared to constitute the most important summer forage for the CAH. Riparian willows were preferred by bulls during most of the summer. Cows also seemed to prefer <u>Salix planifolia</u>, a willow which is fairly widespread on the coastal plain summer range. Caribou fed on willow leaves with an upward jerk of the head which was easily recognized even at considerable distance.

7) Pedicularis Kanei lousewort"

Period of use: June 17-July 6

Niche: Most abundant on well-drained alluvial terraces in the foothills and coastal plain.

Comments: Caribou seemed to have a real affinity for this species, as they did for most other members of this genus. <u>P. Kanei</u> was the first of a series of pink louseworts to emerge on the arctic slope. In areas where it was abundant caribou walked from one plant to the next clipping off floral parts as well as most of the leaves. The northward movement of bulls in spring appeared to coincide with the northward progression of emergence of this species and the leaves of <u>Salix</u>. By the first week in July the floral parts of <u>P. Kanei</u> were brown and wilted in the foothills but at their peak near the coast.

8) Pedicularis Langsdorffii lousewort"

Period of use: around July 4

Niche: Found in somewhat wetter habitat than the preceding species. Comments: This was the second species of <u>Pedicularis</u> to emerge in the foothills on the Sagavanirktok River floodplain. It was not as abundant as the preceding species.

10) Pedicularis sudetica "lousewort"

Period of use: around July 12

Niche: Occurs in wetter areas than the preceding species. It grows scattered in amongst monocots in wet sedge meadows on the coastal plain.

Comments: The third <u>Pedicularis</u> to flower, it was sometimes common on the coastal plain and apparently grazed whenever encountered.

11) Pedicularis parviflora "lousewort"

Period of use: around July 16-17

Niche: Similar to the preceding species.

Comments: Not as common as the preceding species but appeared right after P. sudetica.

12) Pedicularis verticillata "lousewort"

Period of use: around July 27

Niche: Well-drained alluvial deposits.

Comments: The last member of this genus to flower; it may have been relatively unimportant as caribou forage since it was only observed being selected once.

13) <u>Saxifraga oppositifolia</u> "purple mountain saxifrage"

Period of use: June 24

Niche: On the coastal plain it was common on frost boils and other disturbed areas.

Comments: I observed one bull eating the flowers of this species from a frost boil. Because of its very small size it was probably a minor component in the summer diet.

14) Saxifraga hieraciflora

Period of use: July 4

Niche: Moist areas on river floodplains.

Comments: I observed it being selected several times by a group of bulls feeding mostly on willow leaves on the floodplain south of Sagwon.

15) Oxytropis nigrescens black vetch"

Period of use: July 6-15

Niche: Can grow in fairly dense mats on well-drained, sandy river terraces.

Comments: The importance of this species as forage was probably enhanced by its proximity to mosquito relief habitat on river deltas.

16) Betula nana dwarf birch"

Period of use: June 23-August 3

Niche: Common throughout the foothills but uncommon on coastal plain summer range.

Comments: This species did not appear to be an important forage species for the CAN. It was largely unavailable in those areas where most of the herd remains during the growing season.

17) Astragalus umbellatus

Period of use: July 15-September 12

Niche: Well-drained areas, particularly river terraces.

Comments: This species was observed being grazed on three occasions. It was apparently a preferred dicot in late summer when most other dicots had declined in quality.

18) Hedysarum Mackenzii

Period of use: August 2-14

Niche: Well-drained alluvial deposits.

Comments: I observed bull groups feeding on this species twice on river terraces. It is a relatively late flowering legume.

19) Polygonum bistorta "bistort"

Period of use: around July 29

Niche: Tussock tundra

Comments: I observed this species being selected once by bulls in the foothills near Toolik camp.

20) Eriophorum angustifolium cottongrass"

Period of use: August 16

Niche: Frequently a dominant monocot in wet sedge meadows. Comments: This species was probably much more important than my one observation indicates (White et al. 1975). It was difficult to identify what plants were being consumed when caribou were feeding in wet sedge meadows. Cow-calf groups in particular frequently fed in this habitat and their long flight distance made observations of forage selection difficult. However, the characteristic head movement of caribou stripping willow leaves indicated that these groups were frequently feeding on <u>Salix</u> instead of the abundant monocots.

21) Arctagrostis latifolia

Period of use: September 3, 4

Niche: Wet sedge meadows

Comments: I observed groups of bulls feeding on this species where it grew in lush patches next to the sewage treatment lagoon at Franklin Bluffs Camp. In wet areas this species senesces late in the season, so it was perhaps an important early fall forage.

22) Festuca rubra red fescue"

Period of use: August 12

Niche: This species was planted on disturbed soil at the Arctic Gas research facility at Prudhoe Bay and at several other sites in the area. Comments: Several bulls were observed feeding in these revegetated areas near Prudhoe Bay after other native vegetation near the coast had yellowed noticeably.

23) Lolium sp. "annual rye"

Perod of use: September 1-20

Niche: Revegetated material mining sites.

Comments: The material site in the Sagwon hills was used repeatedly by groups of bulls during the pre-rut period after other vegetation had begun to senesce.

Appendix E

Description of winter feeding areas

<u>Equisetum</u> feeding area - intensively cratered during the first
 week of April 1975. Area is on the Sagavanirktok River floodplain
 on the east side of the river about four miles north of Pump Station #3.
 Cratered area was 66 m by 15 m.

Percent cover estimates (average of 4 random meter² plots)

Mosses	-	90%
Equisetum variegatum	-	30%
Carex sp.	-	15%
Salix reticulata	-	6%
<u>Salix</u> sp.	-	3%
Arctostaphylos sp.	-	3%
Eriophorum angustifolium	-	2.5%
<u>Hedysarum</u> sp.	-	1%
Vaccinium uliginosum	-	1%

2) <u>Equisetum</u> feeding area - intensively cratered during the second week in April 1975. Area is on the Sagavanirktok River floodplain on west side of the river about 4 miles north of Happy Valley camp.

Percent cover estimate (average of 4 random meter² plots) Mosses - 70% Equisetum variegatum - 35%

bare ground	-	15%
Carex sp.	-	9.5%
<u>Salix</u> sp.	-	9.5%
Eriophorum angustifolium	—	6%
Salix reticulata		5.5%
Arctostaphylos sp.	-	2%
Equisetum arvense	-	17
Hedysarum sp.	-	1%
Polygonum viviparum	-	1%

3) Lichen feeding area heath area on receding lake bed about 3.5 miles south of Happy Valley camp area was intensively cratered during the second week of March 1975.

•	Percent cover estimate	(avera	ge of	5	random	meter ²	plots)
	Mosses	-	44%				
	Lichens	-	19%				
	(mostly <u>Cladonia</u> rangiferina	<u>L</u>					
	bare ground and litter	-	16%				
	Ledum sp.	-	137				
	<u>Vaccinium</u> <u>vitis-idaea</u>	-	11%		•		
	<u>Betula</u> <u>nana</u>	-	8%				
	Eriophorum vaginatum	-	7%				
	Rubus chamaemorus	-	27				
	Empetrum nigrum	-	17				
	Vaccinium uliginosum	-	17				

Rubus chamaemorus	-	7.5%
Arctostaphylos sp.	- .	7.5%
Eriophorum vaginatum	-	6.5%
Lichens		
(mostly <u>Cladonia</u> rangiferina)	
miscellaneous monocots	-	4Z

Petacites frigidus	-	47	
<u>Betula nana</u>	-	17	
Polygonum bistorta		-	17
Cassiope tetragona		-	1%

Appendix F

Wolf kills near the haul road

- adult cow 11/23/74, killed 12 meters from the road near Slope Mountain. Three wolves were seen feeding on the carcass.
- 2-3 year-old bull 3/7/75, killed about 400 meters from the road and about 3 kilometers east of Toolik Camp. One wolf seen feeding on carcass.
- calf 3/7/75, killed about 200 meters from the road on the Kuparuk River floodplain. Carcass was completely utilized.
- adult bull 4/10/75, killed about 100 meters from the road, four south of Slope Mountain. Four wolves seen near or on the carcass which was cleaned up in two days. Blood trail led from the road to the kill.
- adult bull 10/3/75, killed about 250 meters from the road
 on the coastal plain north of Pump Station 2.
 Carcass was about one week old with a fair
 amount of meat still on it and no fresh wolf
 tracks around it.

adult 10/25/75, killed right next to road berm on the Sagavanirktok River floodplain north of Happy Valley. One wolf was seen feeding on the kill which was only partly utilized. A wolverine visited the carcass.

adult cow (old)

12/5/75, killed on Kakaktlcruch Bluff across the river from Pump Station 3, about a kilometer from the road. Four wolves were seen near the kill.

12/5/75, killed about 100 meters from the road, south of Pet 119-4. Carcass was completely utilized.

1/29/76, killed right next to road berm on the Sagavanirktok River floodplain south of the "ice-cut." Five wolves were seen on the kill.

2/8/76, killed either on the road or right beside it, south of Pump Station 3. Four wolves were 200 meters away where they had dragged the head and rib cage.

5/19/76, killed about 200 meters from Happy Valley Camp pad at about 0130 hours. One wolf fed on the carcass which had the throat torn open and one ham eaten.

calf

unknown (not calf)

adult cow

adult bull

Composition of 11 wolf-killed carcasses near the road: 3 adult bulls, 3 adult cows, 1 young bull, 2 calves, 1 adult, and 1 unknown.

						<u>.</u>	
Observation Number	Date	Location ¹	Observation Type ²	Composition ³	Direction	Pipe Keight (m)	Renarks
1	8/15	47.7 N	v	1 B	E	1.9	Severe warble fly harassment; aberrant running; traffic on pad.
2	8/15	47.8 N	V	1 B	E	2.3	Severe varble fly harrassment; stood in shade beneath pipe.
1	8/15	47.4 X	v	1 B	¥	1.1	Severe warble fly harassment; stood in shade beneath pipe.
4	8/15	47.8 N	V	1 B	NC"	2.0	Severe warble fly harassment; attempted crossing to east but reversed movement after several attempts.
5	8/15	47.5 N	v	1 B	E	2,4	Severe warble fly harassment; disturbed by traffic on pipe pad.
6	8/22	43.5 N	v	1 B	W	1	Possible warble fly harassment.
7	10/3	47.2 N	T	3A, 3U	nc e	1.9 2.1	One large adult deflected 175 m south and crossed 2.1 m; some milling on pipe pad prior to crossing.
8	10/3	44.8 N	T	1 U 2 U 2 U	NC NC NC	1.6 1.7 1.9	All attempted crossing to cast; not clear whether the same or different individuals were involved.
9	10/3	44.3 N	T	1 ca	NC	1.9	Tracks on pipe pad; attempted crossing to east.

Appendix G. Elevated pipe crossings/deflections (1975 and 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

10	10/4	28.0 5	Ŧ	1 A	NC	1	Tracks on pipe pad; attempted crossing to west.
11	10/10	48.0 N	T	1 B -	¥	2.0	Two other bulls failed to cross after acveral attempts and deflected about 2 km to north, but crossed where pipe was buried.
12	10/11	46.4 N	¥	1 ca 1 Y	NC	1	Approached from east to within 20 m of pipe; assumed alarm stance, but didn [*] t cross.
11	10/12	47.2 N	T	1 A	W	2.2	Some milling to east of pipe before crossing.
14	10/17	21.9 5	Ŧ	2 U	NC	0.2	Tracks paralleled pipe to south; pipe was on blocks about 0.1-0.2 m above ground; animals attempted to cross to west but deflected to northeast.
15	10/18	43.2 N	v	1 B	NC	7	Paralleled pipe to south for 1.5 km; approached to within 50 m of pipe; no crossing.
16	10/23	45.1 N	T	3 A 1 cm	W	1.8	Paralleled pipe to the south for about 0.5 km before crossing.
17	10/23	44.8 N	T	1+ U	NC	7	At least one animal milled around on pipe pad to west of pipe; no crossing.
18	10/23	12.5 5	T	3 A	NC	1.5	Crossed road to east and approached to within 30 m of pipe; reversed direction and recrossed road to west.
19	10/23	26.8 S	V	1 B	v	2.2	Attempted to negotiate pipe about 6 times; paralleled pipe to north for at least 1.5 km before crossing; pipe heights at 4 attempted crossings were: 1.9, 2.0, 2.0, and 1.8 m.

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20	1174	10.0 3	1	4 8		1.0	Some milling on pipe pad before crossing.	,
21	11/2	19.2 5	T	1 U	Z	-	Adjacent pipe in place, but absent at crossing site.	
22	11/2	19.8 \$	T	2 A	E	2.5	Approached twice at pipe heights of 1.6 m and 1.8 m above pad; crossed at 2.5 m.	
23	11/2	20.3 5	, : T	<u>1-A</u>	E`	1.95	Caribou approached 3 times before crossing; pipe was 1.7 m high at site of first attempt.	
24	11/7	17.3 \$	T	1 A	W	1.45	20 m north pipe height was 2.0 m above pad; 10 m further south, 1.1 m.	
25	11/7	20.8 5	T	5 U	NC	7	Feeding craters within 16 m of pipe.	
26	11/7	21.6 5	T	10 U	NC	7	Peeding craters within 19 m of pipe; tracks deflected to north.	
27	11/7	18.4 5	T	1 U	NC	1	Caribou approached pipe from west; reversed movement to west.	
28	11/10	19.2 \$	V	1 B	E	-	Attempted to cross 3 times at pipe heights 2.2 m, 2.0 m, and 1.8 m; crossed pad at a gap in the pipe.	4
29	11/10	35.8 S	τ	12 U	E	2.3	Some milling on pipe pad pricr to crossing.	
30	11/24	31.2 S	T	5 U	E	2.1	Some milling and running prior to crossing; one individual crossed under a 2 m gap in the elevated pipe.	
31	12/5	35.2 5	τ	3 U	W I	2.1	No milling.	
32	12/5	35.2 \$	T	15 U	E	2.1	Group fragmented and crossed in several places; probably included at least 1 calf and at least 2 bulls.	
33	12/6	35.2 S	T	4 U	W	2.1	Considerable milling around and on pad prior to crossing; another group had	•

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34 12/6 35.2 S T 6 U W 2.4 Same as above. 35 12/6 35.2 S T 3 U E 1.7 Pipe was higher on either sid crossing site; no apparent set for higher sections. 36 1/26 3.1 S T 6 U E 2.7 Approached and crossed at right of the sections.	de of election ght angles; about 200 m d pipe, not
35 12/6 35.2 S T 3 U E 1.7 Pipe was higher on either sid crossing site; no apparent set for higher sections. 36 1/26 5.1 S T 6 U E 2.7 Approached and crossed at rights	de of election ght angles; about 200 m d pipe, not
36 1/26 5.1 S T 6U E 2.7 Approached and crossed at rig	ght angles; about 200 m d pipe. not
two other caribou deflected a north and crossed over burled	not
37 4/28 67.2 S V 4 ca NC 0.6 Paralleled pipe to NNE, Did approach closely.	•
385/1420.2 ST5 AW1.7Group fragmented and deflected3 AW2.253 times; 5 additional caribou2 AW2.1100 m south where a section of5 AW-missing.	ed at least u crossed of pipe was
39 5/15 19.2 S V 17 B Z/W 17 B crossed under the pipe at 2 B NC 2 B did not cross; worker she 17 B recrossed to the east.	at a run, outing nearby;
40 5/16 17.4 S ♥ 10 B E 3.5-5.1 "Special big game crossing" a 1 C E buils showed no alarma; cow wa cross.	site. Some as last to
41 5/17 17.4 S V 26 B W 1.85-4.0 Near "Special big game cross: 2 C W many crossed at periphery while 1 ca W lower; some milling with hes to 10 min; crossed at a run.	ing" site, but ere pipe was itation for up
425/1719.2 5V9 BE1.959 Bcrossed after considerab17 BNCremainder did not; road trafic copter disturbance present.	le milling, fic and heli-
43 5/19 17.3 5 V 6 B E 2.05 Deflected once before crossi	ng.
44 5/22 17.6 S T 4 U W 2.4 All crossed in exact same lo	cation.
45 5/22 19.8 S T 1 U E 1.65	

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-6	5/22	18.4 5	T	20+ U	¥	1.95	Crossings distributed along several sections of pipe; may have involved more than one group.
- 47	5/25	21.1 5	V.		E	2.4	Deflected once before crossing; jumped 8" gas line on 4" blocks beneath 48" pipe.
48	5/27	11.2 5	v	3 8	v	1.3	One bull deflected twice before crossing to join others.
49	6/23	Prudhoe Bay	۷	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.
50	8/15	128.0 N	v	1 B	E,W	2.1	Severe warble fly harassment; crossed beneath pipe three times, then remained in shade of pipe.
. 51	8/24	85.9 S	V	1 8	NC	•	Bull deflected; 48" pipe on the ground.
52	10/12	27.8 5	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	м УС	2.2	Paralleled pipe at least 0.5 km before crossing beneath pipe just south of incomplete mag bend; only about half of the group crosmed.