A REVIEW OF RESEARCH ON THE EFFECTS OF HUMAN ACTIVITIES ON BARREN-GROUND CARIBOU OF THE BEVERLY AND KAMINURIAK HERDS, NORTHWEST TERRITORIES

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ABSTRACT

In 1978, the Department of Indian and Northern Affairs Canada (INAC) developed and implemented the Caribou Protection Measures which were designed to prevent potentially harmful contact between caribou of the Beverly and Kaminuriak herds and human activity during calving, post-calving and migration periods. The Caribou Protection Measures were developed to take into account the general concerns, opinions and judgements of the biologists advising INAC. At the time, few relevant studies were available to substantiate those concerns. Descriptions of effects of human activities on caribou were mostly anecdotal, and hence untestable and unrepeatable. A workshop was convened in 1979 by the NWT Wildlife Service to assist resource managers in determining the type of research that should be completed. In 1980, the NWT Wildlife Service implemented the research program. The research was designed to: describe the ecological characteristics of the Beverly and Kaminuriak calving grounds; develop a repeatable design to describe caribou behaviour in the absence of land use activities; and, describe the behavioural responses of caribou to experimental land use activities. Emphasis was placed on describing use of the areas by caribou in a quantitative and repeatable manner in order to identify any changes that might result from human contact. This report summarizes the research and briefly reviews the results of the studies on the caribou calving grounds, and the effects of human activities on caribou. The report also draws on the research results of other studies to re-examine some of the original concerns that led to the creation and implementation of the Caribou Protection Measures.

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INTRODUCTION

The people of Baker Lake and other communities in the District of Keewatin were concerned that mineral exploration activities in the 1960's and 1970's caused caribou to change their movement patterns and abandon areas of traditional use. Their concerns were raised with government agencies and eventually culminated in the creation and implementation of the Caribou Protection Measures in 1978 (Mychasiw 1984) after court hearings in Baker Lake and Toronto. Many questions arose from the variety of opinions expressed about the possible effects of human activities on caribou and the lack of data on caribou activity on the calving grounds and at the water crossing sites.

In 1978, the Department of Indian and Northern Affairs Canada (INAC) added a special set of conditions (the Caribou Protection Measures) to Land Use Permits issued for camps and associated activities within the Caribou Protection Areas, located in the Keewatin Region of the NWT. The Caribou Protection Measures were designed and implemented to prevent potentially harmful contact between caribou and human activity during calving, post-calving and migration periods. The Caribou Protection Areas include the calving and post-calving areas of the Beverly and Kaminuriak herds of barren-ground caribou (Rangifer tarandus groenlandicus). In addition, designated water crossing sites are protected. Most of the Land Use Permits affected were those issued to mining companies involved in mineral exploration, particularly for uranium.

The Caribou Protection Measures restrict the operation of camps and associated activities on the known traditional calving grounds and post-calving areas (Caribou Protection Area 1980-1982), as defined by the Government of the Northwest Territories Wildlife Service,by managing the establishment of camps between 15 May and 31 July. INAC's Land Use Inspector can permit the holder of a Land Use Permit to carry out land use activities if caribou cows are not near or expected to be in the area of the camp. When cows and calves leave a Protection Area, controlled land use activities can proceed. If the cows and calves approach a camp outside the Protection Areas, between 15 May and 15 July, the Land Use Inspector can suspend the camp's activities until the caribou have left the vicinity.

Migratory barren-ground caribou cross rivers and lakes at traditional water crossing sites during seasonal migrations. Twenty-seven of the sites traditionally used by Beverly and Kaminuriak caribou to cross lakes and rivers were designated as restricted areas. Specific land use activities within specified distances from water crossing sites were suspended all year in 1978 and 1979, and between 15 May and 1 September in subsequent years.

The Caribou Protection Measures recognize the presumably greater wariness of caribou cows and calves (Murie 1935, de Vos 1960, Lent 1964, Miller and Gunn 1979) by ensuring the separation of most human activities from this sex and age group. The Measures also recognize the increased vulnerability of caribou in large aggregations to human disturbance during the post-calving period and at natural obstacles such as water crossing sites. Although caribou

in large aggregations are usually less wary (Harper 1955, Lent 1964), the contagious aversion behaviour of all the caribou can cause panic and the chances of calf injuries or death from trampling and irreversible separation of cow-calf pairs is greatly increased (Bergerud 1978).

The Caribou Protection Measures were based on the general concerns, opinions, and judgements of the biologists advising INAC. However, there were few relevant studies available to substantiate those opinions. Descriptions of effects of human activities on caribou were mostly anecdotal, which is not to say that they were false, but simply untestable and unrepeatable, and therefore, disputable.

A workshop to address the effects of human activity on caribou was held in 1979 to assist the Canada-NWT Wildlife Research Co-ordinating Committee in determining the type of research that should be completed. Some of the problems inherent in disturbance research were recognized at the workshop, which concluded with recommendations to guide a research program on human activity and caribou (Anonymous 1980). INAC's specific research requirements were to evaluate the times of protection and the effects that land-use contacts might have on caribou during the critical calving and post-calving periods and at the places identified to be important to caribou.

A major objective of the research completed by the NWT Wildlife Service was to describe caribou use of the calving grounds

and water crossing sites. Once completed, these baseline data could be used as a guide in measuring the significance of the responses of caribou to human activities. Emphasis was placed on describing caribou use of the areas in a quantitative and repeatable manner, in order to identify any changes that might result from human contact. Baseline data were required before the Caribou Protection Measures could be evaluated. Any evaluation of the Measures would necessitate description of caribou responses to land-use activities, and interpretation of the significance of those responses to the individual and to the population over short- and long-term periods.

During the first year of study (1980), we designed the project to describe the ecological characteristics of the Bathurst, Beverly and Kaminuriak calving grounds. During the second and third years of study, emphasis was placed on developing a repeatable design to describe caribou behaviour in the absence of land-use activities. In addition, work was completed to describe the behavioural responses of caribou to experimental land-use activities.

We used behavioural responses to document the effects of human activities on caribou for three reasons. Firstly, overt behaviour can be used as an indicator of an animal's response to a change in its environment. Behavioural changes are relatively practical to measure and compare. Secondly, the state of the art for describing physiological responses was not advanced enough for field application to barren-ground caribou. In addition, the local community would not support the handling and marking of caribou. The inability to monitor marked individuals prevented us from

establishing a study designed to address potential long-term effects of human activities on the survival and productivity of caribou. Thirdly, there are practical and theoretical limitations to measuring and interpreting responses at the population level (e.g., survival, productivity and movements). The apparent failure to observe and describe these changes, which is currently a major criticism of research on the effects of human activities on northern mammals, is addressed in the summary discussion.

This report summarizes the research, and briefly reviews the results, of other recent studies on caribou calving grounds and the effects of human activities on caribou. The report also draws on the research results and other studies to re-examine some of the original concerns that led to the creation and implementation of the Caribou Protection Measures. It is recommended that reports completed by Fleck and Gunn (1982), Jingfors et al. (1982), Williams and Gunn (1982), Gunn et al. (1983), and Mychasiw (1984) be reviewed prior to reading this report.

Definitions of Terms Used

Calving Ground

The calving ground of a caribou herd in any one year is the area which pregnant cows occupy during the calving period. Although caribou traditionally calve in the same general area, the location of the calving ground can vary from year to year. Therefore, the term calving grounds indicates all areas where pregnant cows of a

herd have been known to calve (Fleck and Gunn 1982).

Pre-calving Period

The pre-calving period is defined as the last trimester of pregnancy. It is the period of the year when the cows often are in their poorest physical condition; a result of winter and the demands placed on the cow by the fetus. The pre-calving period extends from 10 weeks before the first expected dates of calving to the first dates of calving (i.e., 15 March to 25 May for the Beverly herd).

Calving Period

The calving period is the time between the earliest and latest births within a herd and for the Beverly herd is 25 May-25 June. Within the calving period, most cows calve during a 5-7 day peak (Fleck and Gunn 1982).

Post-Calving Period

The post-calving period extends from the last expected date of calving to the latest likely date of dispersal of the cows and calves from post-calving aggregations (i.e., 25 June to 15 August). It is important to note that because of the 507 day peak of calving, caribou can begin post-calving behavious prior to 25 June. Post-

calving is the period when calves are especially vulnerable because of their age, and degree of nutritional and behavioural dependance on the maternal cow.

Water Crossing Site

A water crossing site is an area of shoreline along a lake or river that caribou use to approach and depart from the water body before and after crossing during migration.

Designated Water Crossing Site

A designated water crossing site is the area of a water body and its opposing banks identified as being used by caribou of the Beverly and Kaminuriak herds. Designated water crossing sites are listed in the Caribou Protection Measures.

Disturbance

In the context of wildlife and land management, disturbing stimuli are those which result from human activity. "Disturbance" is more convenient to use as an adjective because it is less clumsy than "human activities". In many cases, however, "human activities" is a more descriptive term than "disturbance", and can be further specified when the source (agent) and/or the resulting stimuli are provided (e.g., "responses to pipeline activities" or "aircraft

noise"). Frequently an agent or source emits several stimuli. For example, a caribou can hear, see and smell a walking person.

Although an observer cannot always isolate the stimuli the animal is responding to, the source or agent is usually detectable.

Harassment

In this paper, harassment implies deliberate and persistent exposure of an animal to human activity. The term carries the connotation of an extreme response by caribou. In the Yukon Territory and the Northwest Territories harassment of game is prohibited through legislation.

Any attempt to define the terms "disturbance" and "harassment" in the context of all of the possible contingencies results in a great deal of confusion. Common sense and an appreciation of whether agent, stimulus, response or state can be specifically identified can reduce much of the confusion.

Response

Response to a stimulus is a change in behaviour which can be correlated with that stimulus. The synonyms for "Effect" are consequence and outcome, which suggest that as stimulus and response are "paired", so should "cause" and "effect". That is, "effect" is the generalized result of human activity and can be qualified. For

example, distributional effects or behavioural effects would imply changes in distribution or behaviour as a consequence of human activity.

Pathological and physiological responses of caribou to human activities have been predicted (e.g., lung damage after panting during periods of extreme cold weather). This pathological condition is caused by the behavioural response of galloping away. Low altitude helicopter flights over a nursery band of caribou cows and calves could cause injury or death of calves by trampling and calf abandonment, again a result of behavioural responses (panic, stumbling, galloping).

METHODS

Characteristics of Three Barren-ground Caribou Calving Grounds in the Northwest Territories

In 1980 the primary objective was to conduct a literature review of the environmental characteristics of the calving grounds of the Bathurst, Beverly and Kaminuriak caribou herds, and to conduct field studies to describe the vegetation of the Beverly calving grounds (Fleck and Gunn 1982). The objective of this study was to test various hypotheses as to why caribou use these specific areas for calving.

Information on the geology, glacial landforms and marine inundation of the calving grounds was obtained from bedrock geology and surficial geology maps, supplemented by accounts from the literature. Data on snowcover patterns and snowmelt regimes were mostly obtained from satellite images.

We referred to previous studies of vegetation on the Beverly and Kaminuriak calving grounds, however, detailed surveys of the vegetation on the Bathurst calving grounds had not been completed. Information on predators was obtained from published material and field notes provided by NWT Wildlife Service personnel.

Behaviour and Range Use Patterns of Caribou on the Beverly Calving Ground, NWT, 1981

Jingfors et al. (1982) developed a sampling technique for describing the responses of caribou to some human activities on the calving grounds. An important criterion in developing the technique was to ensure that the design was repeatable during periods of controlled exposure of caribou to human activity. This enabled comparisons between the observed and expected results. The objective was to quantify and qualify baseline information on caribou behaviour.

We sampled caribou behaviour using two-person ground teams who, at regular time intervals, scanned a group of caribou and recorded the activity and age/sex class of each individual animal (Jingfors et al. 1982). We also recorded various environmental parameters during each activity scan. In addition, the observers selected a cow-calf pair and recorded all bouts of nursing and aggressive or alert behaviour during 10-minute intervals.

We recorded patterns of range use by caribou and examined range use as it related to the availability of the range types on the northern portion of the Beverly calving grounds. Availability of the range types was determined by estimating proportional coverage determined from aerial photography and ground truthing (Jingfors et al. 1982).

Behaviour and Range Use Patterns of Caribou on the Beverly Calving Ground, NWT, 1982

In 1982, we continued to describe caribou use of the calving grounds (Gunn et al. 1983); however, the environmental conditions were different from 1980 and 1981 (snowmelt and calving were slightly later in 1982). In addition, we used helicopter landings as a form of controlled disturbance on caribou. We used a helicopter as a disturbance source because we required a mobile source which could be moved to the caribou already under observation to facilitate comparisons of pre- and post-disturbance behaviour. Emphasis was placed on testing a simulated activity that was realistic and that could potentially occur during land-use activities. However, we did not want to cause extreme levels of disturbance during the calving period. In addition, we wanted to document important but less conspicuous responses, such as changes in foraging patterns. Although we did not simulate any of the key aspects associated with the development of an ore body, our helicopter simulation was relevant, as helicopters are used during many stages of exploration and development of mineral resources.

Descriptions of Water Crossing Sites and Their Use by Migratory Barren-ground Caribou in the Districts of Keewatin and Mackenzie, NWT

The designation of the water crossing sites was primarily based on information collected from the residents of Baker Lake, NWT, a literature review by Interdisciplinary Systems Ltd. (1978), and consultations with personnel from the CWS and the NWT Wildlife Service. The information used to designate the 27 water crossing sites spanned several decades. Use was determined by examining the trail systems.

In 1980-81, we conducted a literature review of activities of caribou at water crossing sites. In addition, we completed field checks of the designated water crossing sites to confirm their locations and describe their topographic features in order to determine whether the topographic features were influencing how caribou approached the sites. At each site, trails were examined and mapped from a fixed-wing aircraft or a helicopter. In spring 1981, we attempted to document the use of some water crossing sites (e.g., central Thelon River) while the river was still frozen. We also attempted to describe the undisturbed behaviour of caribou approaching some water crossing sites on the Thelon River during the open water season.

Patterns of trail systems at 26 of the 27 designated water crossing sites were drawn onto aerial photographs (scale, 1:60,000); Water Crossing Site 12 was examined in 1982.

RESULTS AND DISCUSSION

Characteristics of the Bathurst, Beverly, and Kaminuriak Calving Grounds

Varied topography is characteristic of the three calving grounds, whereas the surrounding areas are characterized by a more uniform topography due to a decrease in the variety of glacial landforms. Marine silts are uncommon on the tundra ranges including the calving grounds of the three herds. Some marine silt deposits are found on the coastal zone of the Kaminuriak range (Fleck and Gunn 1982).

The Kaminuriak and the southern Beverly calving grounds were consistently snow-free earlier than the Bathurst and northern Beverly calving grounds. The end of snowmelt frequently coincided with the onset of calving (1-7 June) on the Kaminuriak and southern Beverly calving grounds, but snowcover was often greater than 75% during the peak calving period on the Bathurst and northern Beverly calving grounds. The calving grounds and immediate surrounding areas appeared to be the last portions of each herd's range to become snow-free.

The vegetation on the Bathurst, Beverly and Kaminuriak calving grounds is not unique when compared to the vegetation in surrounding areas. The presence of greening vegetation during the peak of calving is not characteristic of, at least, the Bathurst and Beverly

calving grounds. Approximately 2 to 3 weeks after the peak of calving new green vegetation emerges and is utilized by the cows. The calving grounds are the last portion of each range to develop newly greening vegetation; therefore, the phenological characteristics of calving grounds differ from surrounding areas to the south and west. Vegetation phenology on the calving grounds is influenced by topography, which is varied and provides the cows with an opportunity to engage in alternative foraging strategies.

The available information suggests that wolf numbers are low on the calving grounds. The numbers of other potential predators such as grizzly bears and golden eagles are also low on the calving grounds relative to the surrounding areas.

Therefore, the selection of calving grounds by caribou could result from the following advantages:

1) Many wolves den at, or south of, the treeline, so there are fewer wolves hunting the caribou cows and their vulnerable newborn or young calves.

2) Calving on that part of the annual range which is last to become snow-free ensures that high quality vegetation is available to lactating cows, who must feed calves and rebuild body conditions depleted by winter. New vegetative shoots, unfolding leaves and flower buds have a higher nutrient quality than during the rest of the year.

3) Calving on the northern part of the annual range delays the

exposure of the cows and calves to biting insects.

Our tentative comparisons from the literature and our empirical observations of the areas do not suggest the calving grounds are comprised of, or affected by, distinct and obvious characteristics of topography, snowmelt patterns, vegetation, and predators. These characteristics cannot be used to delimit calving grounds from other portions of the tundra used by each herd later in summer. The choice of specific calving locations may be influenced by traditional behāviour. There are benefits in following the same pattern of behaviour as long as it is successful or at least not detrimental to population maintenance.

The annual locations of the calving ground (delineated at the peak of calving) do not precisely overlap (Fleck and Gunn 1982). In some years, the variations can be attributed to heavy, wet snow during spring migration, which serves to delay the arrival of the cows on the calving ground (e.g., 1957, 1958 and 1979 for the Beverly herd). For other years the causes of the variations are unknown but may be partially attributed to different observers applying criteria under the auspicies of the various techniques to determine the calving ground boundaries. More recently there has been a tendency for the Beverly calving grounds to shift to the north and northeast; the Beverly cows have not used the areas south of Beverly Lake since 1974 (excluding 1979 when the calving ground was unusually large).

Behaviour and Range Use Patterns of Caribou on the Beverly Calving Ground, NWT, 1981

We separated the field season into a calving (2-9 June) and a post-calving (11-23 June) period. Cows spent 49% of their time foraging during calving and 47% during post-calving. Cows were bedded 33% and 40% of the time during calving and post-calving, respectively. Calves spent most of their time bedded, 59% and 66%, during calving and post-calving, and only foraged or nursed 16% of the time during both periods (Jingfors et al. 1982).

Most caribou bedded or foraged in Lichen Upland range type, which was relatively more snow-free during the calving period. During the post-calving period caribou mostly used the Lichen Upland range type to bed down, probably because they preferred a dry substrate for resting. Succulent green vegetation was relatively more available for foraging on Meadow and Dwarf Shrub range types at that time. Although snowmelt occurred later on Meadow and Dwarf Shrub range types, early phenological development of cotton grass (Eriophorum vaginatum) in these range types provided new green growth and caribou selected this early growth in the few areas where available.

The measurements of behavioural patterns are repeatable and refined enough to enable future comparisons of disturbance-induced behaviour. By classifying activities (states) and events into mutually exclusive categories that could be uniformly recognized by all observers, we reduced subjective interpretation and observer

bias. We found general agreement between observers, which suggests that each type of behaviour was adequately defined and that the results were largely representative of caribou behaviour in all areas of the calving ground.

Behaviour and Range Use Patterns of Caribou on the Beverly Calving Ground, NWT, 1982

We separated the field season into calving (3-13 June) and post-calving (14-27 June) periods (Gunn et al. 1982). There was significantly ($P<0.05$) more time spent by calves trotting during calving in 1982 (1.86%) than in 1981 (0.6%). During the 1982 post-calving period, cows spent significantly ($P<0.05$) less time foraging (37.7% versus 47.5%) and standing (2.7% versus 4.3%) than in 1981; calves also spent a significantly ($P<0.05$) smaller proportion of their time foraging in 1982 (11.2%) than in 1981 (16.0%). These differences likely reflect the delayed onset of greening of the vegetation, as snowmelt was 5-7 days later in 1982 than in 1981.

During the 1982 calving period, 93.5% of all bedded caribou observed and 78.0% of all those observed foraging were on bare ground, while the remaining 6.5% and 22.0%, respectively, used snow-covered ground. The proportions of bedded animals on snow and

snow-free ground were similar between years. A larger percentage of caribou was observed foraging on snow covered ground in 1982 than in 1981, probably as snowmelt was later in 1982 and thus more ground was snow covered. The caribou demonstrated less affinity for bedding on the Lichen Upland range type during the 1982 calving period than during the 1981 calving period; however, the selection of the Meadow range type for bedding was greater during the post-calving period in 1982 than in 1981.

These differences are not significant overall, but they are explained by the later snowmelt in 1982. In addition, it is worth noting that the body condition of cows was excellent in April 1981 and good in April 1982 (D.C. Thomas pers. comm.). Investigating the effects of other factors would have jeopardized the intensity and quality of our sampling efforts, therefore, they were not investigated.

We completed 16 helicopter landings during the post-calving period. A landing included: overflight, descent, landing, activity of people, and the start-up and departure of the helicopter. We recorded behavioural observations before, during and after the landings. The helicopter landed 950 $\pm$ 650 m (SD) away from the caribou under observation and shutdown for approximately 20 minutes. The observers were often surrounded by more than one group of caribou. Therefore, it was necessary to ensure that the approach

flight lined up with the observing team and the caribou under observation. The helicopter began its turn over the caribou while at an altitude of 300 m agl; however, the actual descent was completed up to 1 km away from the caribou.

It is important to note that these experiments were preliminary and that the small sample size limits the validity of the statistical analyses.

Landings were completed under a variety of situations. Some landings were completed relatively close (300 m) to caribou, while others were completed up to 2,200 m away. In addition, helicopter tests were completed with caribou on an island (approximately 1.7 km2 in size). In this case, we landed on a neighbouring island 400-500 m from the caribou, which were located on the shoreline of the opposite island. It was not clear whether the caribou were reluctant to, or could not leave the island because of hazardous water and ice conditions. The responses were similar to those recorded for caribou inhabiting unrestricted locations,probably because the caribou walked and trotted out of sight of the helicopter. The fact that the helicopter landed on an adjacent island may have contributed to the similarity of responses. Subsequently, we repeated two additional landings 400 m and 800 m away from the caribou on the adjacent island. The caribou were able to observe the landing, and responded by walking or trotting out of sight.

We gathered post-disturbance data on 11 groups of caribou. We

had previously collected pre-disturbance observations on 7 of the 11 groups. Therefore, we completed comparison studies of activity patterns of the same groups of caribou during pre-disturbance and post-disturbance periods. The difference was more marked for calves, which showed an approximate threefold (2.7) increase in the proportion of walking, trotting and galloping during post-disturbance than was observed during pre-disturbance periods.

The increase in locomotary activities in response to the disturbing stimuli during the landings, and the resultant tendency of foraging caribou to move away from the disturbing stimuli as the helicopter landed, resulted in the initially observed group being completely out of sight of the observers during seven landings, and most caribou out of sight during an additional six landings. Therefore, we can conclude that almost all caribou under observation during the initial phases of 13 of the 16 landings were displaced in excess of 1 km before the disturbance periods were completed.

A greater proportion of caribou responded by engaging in subtle locomotary behaviour. This condition most likely prevails because of the often unobtrusive displacement of caribou from the areas under observation. That is, they foraged while slowly drifting away from the disturbing stimuli. We did not classify foraging as a response. The general conclusion is that caribou groups exposed to helicopter landings at a distance of 300-2200 m responded primarily by moving away from the source of the disturbing stimuli.

Descriptions of Water Crossing Sites and Their Use by Migratory Barren-ground Caribou in the Districts of Keewatin and Mackenzie, NWT

The physical characteristics of the 27 designated water crossing sites were varied (Williams and Gunn 1982). Most crossing sites were relatively narrow and included peninsulas, shoreline irregularities, or offshore water turbulence.

References to, and records of, caribou use of the water crossing sites are relatively scarce; however, when combined with the information about native hunting patterns, the evidence indicates that caribou have persistently used specific water crossing sites. Gaps in our knowledge of the use of water crossing sites do not necessarily mean that the crossing sites were not used; simply that no one was there to record their use by caribou.

There are only two periods when the summer movements were described in consecutive years. The movements of the Kaminuriak herd were monitored from May to November, 1966-68. Use of the water crossing sites was deduced from figures provided by Parker (1972). Results from the caribou monitoring program provided some information for 5 years (1978-82) of movements of the Beverly and Kaminuriak herds between 15 May and 31 July (Mychasiw 1984). On the ranges of both the Beverly and Kaminuriak herds, portions of the summer ranges were not used in the 1960's and 1970's. Correspondingly, a decrease in the use of the water crossing sites

on the lower Kazan River and the Thelon River between Beverly and Baker Lakes occurred. These areas are used by hunters from Baker Lake who were able to detect a change in movements.

Only a few anecdotal accounts of caribou behaviour at water crossing sites are available, and they can not be used to predict the response of caribou at water crossing sites. The use of inukshuks in association with hunters to direct caribou implies that caribou respond to lines of structures and activity. That the hunters took the trouble to build blinds or pits strongly suggests that human activity was recognized as a technique to deter caribou, especially the leading caribou, from entering the water. Other accounts suggest that human activity will deter caribou from entering the water. Some limited evidence (e.g., the existence of tents (Arima 1975)) and disused inukshuks suggests that static structures (i.e., without noise and movement) do not prevent caribou from using a water crossing site. The responses of the leading caribou are likely to determine whether or not caribou use a particular water crossing site. Lead caribou are usually cows with calves, the most cautious sex-age class. Once the caribou are in the water, they are usually persistant in completing a crossing.

Annual range use can vary markedly. It is safe to assume that annual use of water crossing sites varies as well. Even though the use by caribou of any given water crossing site may be periodic and sporadic, the relative long-term importance of these sites

remains intact.

On examination of the trail patterns leading to water crossing sites, we found well-defined trails outside the designated boundaries at some sites. At the present time, the prohibition of land-use activities within 5 km, and the prohibition of blasting or camp construction within 10 km, of designated water crossing sites provides protection to approach and departure areas. We do not have data to evaluate the need or adequacy of the 5 and 10 km zones. In addition, we do nōt have the data to determine the relationship of trail systems that parallel the banks of long stretches of the rivers and lakes to the designated water crossing sites.

Recent and historic use of designated water crossing sites 22 - 26 on the Thelon and Hanbury Rivers is partly a result of those river systems forming a major east-west barrier to caribou migrating in a north-south direction to the traditional calving areas north of Beverly Lake. Water crossing sites 23 (centre Thelon Sanctuary) and 24 (west Thelon Sanctuary) are also used because of the tendency of caribou to follow topgraphic features until they reach major irregularities in the shoreline, which the crossing sites represent. Water crossing sites 19-21 were previously used more during pre- and post-calving movements of the Beverly herd when part of the traditional calving grounds were located south of Aberdeen Lake, and post-calving movements were to the northeast.

A few recent observations of caribou use of water crossing sites 13-18 are probably the result of recent Beverly post-calving

movements to the south and west from the calving ground (located north of Beverly Lake). The designation of water crossing sites 13-18 resulted from information gathered during interviews with local hunters. The long-term importance of these sites for hunting is supported by archaeological evidence.

A proposed ranking of Beverly water crossing sites, in decreasing order of use based on recent crossing patterns is: sites 22-26, 19-21, 27, and 13-18. We strongly emphasize that changes in Beverly herd size, migration routes, and location of calving grounds may annually alter the use of water crossing sites.

Observations of recent use of water crossings are reported for water crossing sites 4, 5, 7, 8 and 9 on the Kaminuriak herd range. There are no recent direct observations of use of water crossing sites 1-3, 6, 10, 11 and 12 during the open water period.

The designation of the lower Kazan River crossing sites (9-11) resulted from information gathered during interviews with hunters. Archaeological evidence indicates that hunting at these sites has occurred for a long time. There is little evidence in the literature to support the designation of water crossing sites 1-3, 6 and 12, although on-site observations in 1980 suggest that large numbers of caribou used water crossing site 3. A proposed ranking of Kaminuriak water crossing sites, in decreasing order of use, based on recent crossing activities is: sites 4, 5, 7, 8, 9; sites 10, 11; and sites 1-3 and 6. Crossing site 12 was examined in 1982 (C. Gates pers. comm.), and although caribou used it as

an ice crossing in 1980-82, it should be included in the first ranked group. As for the Beverly herd, we emphasize that changes in herd size and migration routes may greatly alter the use of water crossing sites annually.

We do not have the biological data to predict the importance of individual water crossing sites to caribou herds. The possible detrimental influences to the well-being of individual caribou or caribou herds as a result of disruption or displacement from specific water crossing sites is also unknown. Similarly, we are unable to define the "importance" of any one water crossing site because we do not know the long-term consequences of altering the use of that water crossing site.

SUMMARY DISCUSSION

The objective of the research on the calving grounds and at the water crossing sites (focus of the Caribou Protection Measures) was to obtain information to provide sound biological advice on the potential effects of human activity on caribou. The long-term goal is to minimize or eliminate the impact of those effects on caribou. The research initiated on the Beverly and Kaminuriak herds in 1980 was designed to collect baseline data. Emphasis was placed on collecting repeatable baseline data to provide a foundation for future research designed to address caribou/human interactions in the areas studied. Therefore, this research cannot be used to explicitly and comprehensively evaluate the Caribou Protection Measures.

At the beginning of our research program, it was clear that information describing calving grounds and water crossing sites was scattered in published papers and unpublished government reports. The information was compiled to determine the characteristics of the calving grounds and water crossing sites (Fleck and Gunn 1982, Williams and Gunn 1982).

The second step in the research program was to continue the collection of baseline data by describing how cows and their newborn calves used features of the calving ground.

The behavioural descriptions provided by this research program are the only detailed quantitative descriptions of barren-ground caribou on their calving ground, except for work completed on the calving grounds of the Porcupine herd (A. Martell pers. comm.). In order to quantitify the sensitivity of cows with calves to land-use activities, we initiated a preliminary field experiment. Caribou did not always conspicuously respond; however, they did leave the area of helicopter activity even when it was relatively distant from them.

The research program was one link in a chain of events that was triggered by changes in herd size and summer movements of the Kaminuriak and Beverly herds of barren-ground caribou in the 1970's. The case was heard in court where the local hunters claimed that the changes resulted from mineral exploration activities, while biologists and the mining companies countered by proposing that hunting was the cause of the apparent decline of herds. The evidence presented to the court amply described how mostly personal experiences rather than indisputable data were offered as evidence.

Two important points stand out from the evidence, namely, the need to establish cause-effect relationships (causality) and the need for objective, quantitative information on the effects of human activities on wildlife.

Understanding the ecology of a species and the role of various environmental factors in shaping subpopulation and population characteristics, is necessary in order to assign an effect (e.g.,

decline in numbers) to a cause (e.g., snow conditions or seismic activity). The inability to relate cause and effect has made the issue of the effects of industrial activities on wildlife a contentious one. Data on subpopulation and population parameters, in addition to an understanding of normal (undisturbed) responses to natural environments, are required in order to recognize and describe causality. As Caughley (in Connolly and Wallmo 1981) so aptly put it, "one cannot credibly infer causes if an effect has not been reliably demonstrated". Some responses to human activity are conspicuous (e.g., the grouping together of a muskox herd), while other responses are less conspicuous (e.g., a decrease in the amount of time spent foraging). Comparisons between disturbed and undisturbed behaviour, physiology, and population dynamics may often be required to identify and substantiate the effects of human activities.

When studying the effects of human activities on wildlife in the north, the lack of baseline data that are required to recognize and describe responses, is frequently compounded by deficiencies in the techniques employed. The techniques must be sufficiently accurate and precise to identify small-scale changes and sufficiently standardized so the data are consistent and comparable between studies (e.g., Geist 1975a).

The 1980-83 research on the Beverly herd, and to a lesser extent on the Kaminuriak herd, was designed to provide a standardized and objective description of the normal (undisturbed)

behaviour and use patterns of the calving grounds. This approach is necessary if the Caribou Protection Measures are to be fully evaluated.

It is less than a decade since the Berger Commission and the Baker Lake court case highlighted the issue of caribou and industrial activity. Information published since the mid-1970's has provided additional evidence describing the complexity of factors influencing caribou behaviour and demonstrated the need for research on their adaptability (Bergerud 1974) of caribou (e.g., Whitton and Cameron 1983a, Davis et al. In Press, Valkenburg and Davis In Press). Much of the information on the responses of caribou to human activities has been incidentally collected during other studies (Miller et al. 1972, Thomson 1975, 1977). Most studies specifically designed to describe the responses of caribou to human activities have relied on descriptions of an individual's behavioural responses (e.g., Miller and Gunn 1979, Fancy 1983, Smith and Cameron 1983).

Shank (1979) argued that a response had to be demonstrated at the population level (e.g., a change in reproductive rate) if observed behavioural responses to human activities were to be of concern to wildlife managers. Bergerud et al. (1984) examined the absence of population level responses in caribou herds exposed to varying levels of human activities. However, the argument that population-level responses to human activities have to be demonstrated before it can be accepted that there is cause for concern is misleading. Firstly, current techniques limit our

ability to collect precise information as only large changes (i.e., in excess of 10%) can be measured. Secondly, a population parameter results from the influence of several interacting environmental factors. Therefore, the influence of any one single factor is difficult to isolate by, for example, population trend analysis (McCullough 1979). Field experiments to isolate the effect of any one factor on a population's size and integrity is extremely difficult (e.g., McCullough 1979). Field experiments suffer from practical and logistical problems, which are compounded by the inadequacies of experimental designs and techniques based on simple correlative reasoning and single factor hypotheses (e.g., Quinn and Dunham 1983).

Given the current absence of well developed and proven experimental techniques to demonstrate the effects of human activities on caribou populations, the tendancy will be to rely on comparisons between populations and between Rangifer subspecies. Recently, the responses of caribou in Newfoundland and Alaska have been described against an array of human activities. These examples (e.g., Bergerud et al. 1984, Davis et al. In Press, Valkenburg and Davis In Press) add to an appreciation of the complexity and flexibility of caribou behaviour; however, they refute none of the original concerns relating to the effects of land use activities on cows and calves (e.g., Cameron et al. 1983). These concerns for cows and calves are emphasized in the Caribou Protection Measures, because cows with calves are especially responsive and vulnerable to land-use activities.

The Caribou Protection Measures are comprised of temporal and spatial controls designed to manage land-use activity during the most vulnerable periods to the cows and calves. The information compiled during the research is the basis for the following comments on the need for, and timing and location of, the controls.

1. Responsiveness of Caribou During Calving and Post-calving

Detailed descriptions of caribou cow and calf behaviour justify and emphasize the need for the avoidance of human activities in the vicinity of cows and calves during calving and post-calving periods (e.g., Lent 1964, 1966, 1974, Espmark 1971). After birth, the cow requires up to an hour to learn to recognize her calf, which is probably remembered through smell. The cow's ability to recognize her calf is vital to establishing and maintaining the cow-calf bond. The calf develops the attachment to its mother over a period of days, not hours. The bond between cow and calf is usually intense and persistent. A cow will search for days if separated from her calf, and even death of the calf does not result in immediate elimination of the bond (Banfield 1954, Lent 1964, 1966, Miller and Broughton 1973).

The close relationship of a cow with her calf is necessary because the cow provides protection while the calf learns to cope with the environment. Imitation of the cow may help the calf to acquire the necessary foraging and movement behaviours. After weaning the cow-calf bond persists into late fall (Lent 1966)

and winter (Shea 1979). Shea (1979) found that the calf benefited from the cow's cratering behaviour. In addition, it is possible that female calves learn the route and location of the calving ground by following their mother back to the calving ground.

The strength of the cow-calf bond is influenced by a number of factors which confound the measurement of the relationship of cow-calf behavioural responses to human activities between caribou herds or even between years. The strength of the cow-calf bond may be partly determined by the physical condition of the cow as demonstrated by experiments on reindeer (Espmark 1980) and white-tailed deer (Langenau and Lerg 1976). After studying calving caribou of the Nelchina herd, Bos (1974) commented that the cow-calf bond was weaker during a year of late and deep snow cover, and that more occurrences of helicopter-caused cow-calf separation were evident. Davis and Valkenburg (1981) noted exceptionally strong cow-calf bonds in the Delta herd, a herd characterized by high nutritional status. The effect of severe winters and difficult migratory conditions may be compounded by the wide annual fluctuations in the dates of the onset of the greening up of sedges and other important forage plants (Krebs 1964, Gunn et al. 1983), which, when late, could impose further nutritional stress on the cow.

Nutritional status is not the only factor known to influence the strength of the cow-calf bond. The strategy evolved by the caribou against calf predators will also influence the type of cow-calf bond. Bergerud (1971) suggested that lynx predation would

favour concealment of calves and strengthen cow-calf bonds in some of the Newfoundland herds. The evolution toward a strengthened cow-calf bond likely influenced the responses of those cows and calves to the type of helicopter hazing described by Bergerud et al. (1984) of cows in the Pot Hill herd, a small herd of several hundred woodland caribou (Rangifer tarandus caribou) in Newfoundland.

The cow and calf need relative freedom from situations that could cause their separation and interrupt or prevent formation of the cow-calf bond. A newborn calf (a few days old) will follow other caribou or even other moving objects or animals and can easily become separated from its maternal cow. There are no descriptions of what duration and what frequency of interruptions will impair bond formation. Although the concerns for the effects of human activities on calving grounds have been frequently and repeatedly stressed (e.g., Lent 1966, Bergerud 1976), there are in fact few published accounts of human activities causing calf separation and abandonment (e.g., Pelto 1973, Bergerud 1974, Bos 1974, Mauer et al. 1983). The paucity of published accounts is not surprising in view of the difficulty of observing calf abandonment. Almost any stimulus that causes cows and calves to withdraw (e.g., walking or galloping) can potentially impair bond formation. There is a marked absence of data to evaluate this potential. Bergerud (1974) noted that separation of cow-calf pairs was more likely to occur in mobile than in sedentary groups of caribou. He contrasted his observations by describing the ease with which cow-calf separations in the

Kaminurak herd were facilitated in 1968 with his experiences with Newfoundland caribou where post-calving groups are more sedentary and developing stronger cow-calf bonding because of lynx predation (Bergerud 1971, 1974).

Calves, although able to run as fast as cows at 3 days of age, tire easily and are vulnerable to stumbling and falling. Human activities on the calving grounds will usually cause cows and calves in the vicinity to walk and/or trot away. Our experimental helicopter landings demonstrated that even when the calves were 1-2 weeks of age, the cows led them to an area 1-2 km away from a single overflight and landing of a helicopter. Human activities near or approaching the caribou will elicit more intense responses such as trotting and galloping; calves can be left behind, exhausted, or injured during their more intense responses.

The calves are born at the beginning of, or during, the snowmelt; a time when the physical environment is rapidly changing. The climatic conditions during the first 2 weeks of June on most barren-ground caribou calving grounds usually fluctuate between cold, wet, and windy weather and warm weather. Caribou calves are potentially vulnerable to chilling and pneumonia during prolonged wet and windy weather.

The cow can protect her calf by bedding and providing the calf with shelter and milk. As cows with young calves are quick to respond to any perceived human activity by walking or trotting away, a calf may be deprived of shelter and hindered from nursing.

Warm weather can also threaten young calves. Snowbanks soften and caribou can no longer travel on the snow surface. Lake slush and the water which collects at the base of snowbanks that edge lakes and islands can also inhibit safe, easy movement. Calves, especially if they are forced to trot or gallop to keep up with the cow, often have difficulty moving through areas of soft, wet snow. The calves can expend a considerable amount of energy in these conditions; the combined effects of exertion and chilling can cause death. In mid- to late June, as the edges of lakes and islands become ice-free, ice shelves form obstacles to a calf who follows the cow across lakes or streams, especially if the cow and calf are startled or panicked into the water. If the calf struggles for more than a few minutes, exhaustion and death can follow (e.g., Kelsall 1968, Bergerud 1974, Miller et al. In Prep.).

The less conspicuous effects of human activities on the calving ground are also of concern. Walking or standing when alerted to human activity not only interrupts the care given to a calf by a cow, but can also result in lost foraging time. In June on the calving ground and on the early post-calving areas, the vegetation is at its most nutritious state. This coincides with the demands on the cow to provide milk for the calf, and replenish fat reserves to carry her through the period of insect harassment. Cows must develop adequate fat reserves in order to breed, carry a fetus and survive the winter. In addition to reduced foraging time, there is an energetic cost associated with the act of moving away. These

considerations are theoretical in the sense that they have not been demonstrated in the field, and there are disagreements about the importance of energetic considerations in the absence of data (e.g., Skogland and Molemen 1980). However, the importance of summer body weight on winter survival of reindeer has been experimentally demonstrated (Jacobsen et al. 1976, Haukioja and Salovaara 1978). Boertje (1981) constructed an energetic model for the Denali herd in Alaska. His calculations showed that running for in additional 15 minutes each day in response to a stimulus adds 1.6% to the annual energy budget requirement.

By mid-July, the calves are considerably stronger and benefit from improved stamina. Nevertheless, the cows and calves are still vulnerable to human activities, as they tend to be aggregated into large groups of thousands and tens of thousands. If caribou in large groups respond to human activity by trotting or galloping the entire group may follow; cows and their calves may become separated, and calves can be kicked or knocked over (Bergerud 1976).

The increased responsiveness of cows, the importance of the uninterrupted establishment of a strong cow-calf bond, and the greater vulnerability of caribou, especially calves, in large groups when startled and panicked, indicate that the elimination of all or most human activities on the calving grounds, on the post-calving areas, and at water crossing sites is desirable and recommended (Lent 1966, Bergerud 1976, 1978).

Since the Berger Commission in the mid 1970's, when concerns for the effects of human activities on caribou were emphasized (especially for caribou using calving and post-calving areas), information that could be used to question the validity of those concerns has been published on three caribou herds exposed to human activity on their calving grounds. Workers have provided examples for the Pot Hill herd (Bergerud et al. 1984), the Delta herd (Davis et al. In Press) and the Central Arctic herd (Cameron 1983 et al., Bergerud et al. 1984) by describing caribou under different ecological conditions than the Beverly and Kaminuriak herds. Hence there is need for extreme caution in extrapolating from the three examples.

Bergerud et al. (1984) found that the hazing of cows with a helicopter did not apparently effect calf survival. The likely greater strength of the cow-calf bond in the Pot Hill population and the sedentary behaviour of the groups (Bergerud 1971) may have contributed to this area's specific condition. The calving segment of the Pot Hill population is small, and is estimated to range between 250-550 individuals on the calving grounds (approx. 192 km^2). The degree of reinforcement of behavioural responses through contagious behaviour is unknown; however, the lower densities and smaller, stationary groups on the Pot Hill population calving grounds suggest that caribou responses to helicopter hazing could be different from the responses of the thousands of barren-ground caribou on the Beverly and Kaminuriak calving grounds.

The numbers of caribou have continued to increase in the Delta and Central Arctic herds in Alaska (Davis et al. 1983, Whitton and Cameron 1983b), despite the fact that the Delta herd's calving grounds are located on a military practice range, and that the Prudhoe Bay oilfield overlaps onto the calving grounds of the Central Arctic herd. Both are small herds (5,000 to 10,000), exposed to low hunting and predator pressures. Wolves have been controlled on the ranges of both herds. These factors, in conjunction with the short seasonal migration routes, could contribute to the high nutritional status of the cows and in turn, strong cow-calf bonding (Davis et al. 1983) and high calf survival.

The Delta herd has been exposed to frequent light aircraft overflights, as well as to the sounds, and less frequently, the sight of military aircraft (Davis et al. In Press) since the 1950's. Valkenburg and Davis (In Press) suggested that the low responsiveness of individuals in the Delta herd to aircraft overflights was the result of habituation. The initial responses of the animals and the process of habituation in the Delta herd in the 1950's are unknown.

Cows from the Central Arctic herd calve on an oilfield comprised of an intensive network of roads, oil pipelines, and associated facilities. Air and vehicular traffic is common.

Distributional information from visual and radio-telemetry surveys (e.g., Cameron et al. 1983, Smith and Cameron 1983, Whitton and Cameron 1983a) suggest that cows and newborn calves avoid roads and other structures while on the calving ground. The redistribution of cows and calves within the calving ground has not led to a measurable decrease in calf survival or productivity, nor to major distributional changes; however, in view of the fact that oilfield development is increasing in area and intensity, conclusions about the effects of such development on the Central Arctic herd are premature.

The examples of the Pot Hill population, the Delta herd, and the Central Arctic herd cannot be used as convincing evidence for relaxing the regulation of land-use activities on the Beverly and Kaminuriak calving grounds and post-calving areas. The important differences are the larger numbers and high densities of cows, which are constantly mobile except briefly at the peak of calving. The tendancy of cows to move to join up or remain with other cows in groups, leading to calf separation has already been noted (Kelsall 1968, Bergerud 1974). Wolf predation of newborn calves and of cows remains a potent force in modifying the behavioural strategies on the calving grounds of Canadian barren-ground caribou. In the early 1980's, wolves annually killed 50-70% of the calves found dead on the Beverly calving ground, probably 1.5 to 7% of the calf crop (Miller et al. In Prep.). The importance of wolf predation in the context of land management is that it likely increases the responsiveness of caribou to ground activities of humans. The

possible differences in the responsiveness of caribou to ground activities, and differences in the strength of the cow-calf bond, are potentially compounded by the different types of human activity. Some caribou in the Pot Hill population were exposed to a brief helicopter chase once a day for one calving period. This is perhaps, comparable to the effect of an unsuccessful predator attack to which the caribou are adapted. The cows in the Delta Herd are already habituated to aircraft from year-round exposure. The cows of the Central Arctic herd are exposed to a variety of human activities, but because the site of these activities is primarily fixed (vehicles on roads, aircraft flight paths), and thus predictable, the cows can reduce the stimuli by avoiding the vicinity. The conditions least likely to lead to habituation include a variety of stimuli in an unpredictable pattern such as would likely be associated with mineral exploration - currently the greatest contributor to land use activities on the Beverly and Kaminuriak calving grounds.

Little is know about habituation in field conditions; however, Geist (1975b, 1978, 1982) has actively promoted understanding the role of such learning behaviour in wildlife management. Laboratory experiments indicate that the decline in behavioural response is relatively stimulus specific. However, tests have not been undertaken to determine, for example, if caribou habituated to aircraft overflights respond less to a man on foot. The need for such research is evident. It must be conducted in an atmosphere of

careful interpretation. For example, caribou not hunted by man or wolves could potentially respond less to a man on foot than hunted caribou. Valkenburg and Davis (In Press) believe the differences between the responses of caribou of the Delta herd and the Western Arctic herd to aircraft are related to their exposure to different hunting practices, as well as the relative frequency of aircraft overflights. In addition, these authors recommend that research focus on habituation, not detailed descriptions of caribou responses to aircraft.

2) The Locations of Traditional Calving Grounds and Water Crossing Sites

The affinity of caribou and reindeer to calving areas is well substantiated. The evidence that the use of calving areas and migratory travel routes is traditional is also well documented. Wilson (1975:168) called tradition "... the ultimate refinement in environmental tracking", and he described tradition as a specific form of behaviour passed on by learning between generations. Acceptance that affinity to a calving ground or water crossing site is traditional explains the observed use patterns of caribou calving grounds.

The calving grounds are susceptible to land use activities mainly through drastic and extensive habitat changes (e.g.,

flooding). At the present time, it is the presence of cows and calves that requires the regulation of land use activities. Mineral licks are, however, an exception to the rule.

Sodium enriched mineral licks were found on the Beverly calving ground during the field studies (field notes). The licks are located along a small river draining into the northwest side of Deep Rose Lake. In 1981, 1982 and 1983 concentrated numbers of cows were observed at the licks during and after calving. As the cows likely use the licks repēatedly and replenishment of minerals is important, land-use activivities that could modify the land surface or drainage pattern of that area should not be permitted. Additionally, geological and hydrological characteristics of the mineral lick should be investigated and used to identify other mineral licks (cf. Calef and Lortie 1975).

The Caribou Protection Measures have evolved (Mychasiw 1984) to a system that is sufficently flexible to provide protection wherever the cows calve. That is, although there are mapped Protection Areas, the Protection Measures can be applied to land use activities outside as well as inside the Protection Areas.

The Caribou Protection Measures provide flexibility in allowing the Land Use Inspector the discretion to release a land use site inside a Caribou Protection Area, if the cows are not expected to use the area around the site. Impressions from pre-calving movements of the Beverly and Kaminuriak herds (C. Gates pers. comm.)

suggest that the distribution of cows contracts from the periphery of the calving ground as calving commences. That impression requires documentation from systematic monitoring during the 7-20 days preceeding the peak of calving. If a peripheral contraction is visible, it will be useful knowledge for Land Use Inspectors. Such knowledge has, however, to be weighed against the fact that pre-calving cows will migrate with speed and determination. The drive of cows to reach the calving ground is strong - cows will even trot the last short distance as they approach the calving ground (Kelsall 1968). For example, cows that are some 50-100 km away from a calving site, can reach it in a few days.

In the absence of a monitoring program, the protection of cows and calves has to be based on the area most likely to be occupied - the traditional calving grounds. Although the traditional calving grounds are larger than the area used in any one year, there are currently no data to predict exactly which part of the traditional calving ground will be occupied. It is especially important to protect the peripheral areas when poor travelling conditions have delayed the cows, and when the cows are in poor physical condition. Cows in poor physical condition produce weaker calves and/or form weaker cow-calf bonds, and hence, are more vulnerable to the effects of aircraft and other human activities (e.g., Bos 1975). The area within the traditional calving grounds that will be used in any one

year is not predictable from current knowledge; therefore, effective management can be facilitated only by protecting the known traditional calving grounds.

The mobility of cows and calves after the end of the calving period, and our inability to accurately predict the locations of post-calving areas requires that the caribou, and not land areas,be protected (except at traditional concentration sites like water crossing sites). Protection should emphasize the elimination or marked reduction of stimuli which may startle and displace caribou aggregations from water crossing sites. This can be accomplished by prohibiting low-level aircraft flights, close approaches by people, and ground activity at water crossing sites.

The seemingly unpredictable variations in the numbers of caribou using water crossing sites, a function of changes in the areas used after calving (Darby 1978, Cooper 1981, Clement 1982, 1983), makes the regulation of land-use activities difficult. In this context it is important to note that the absence of caribou in any one year, or in a series of years, does not imply that caribou will not use the area in the future. In addition, the extensive movements of the Beverly herd to the west and southwest (Darby 1978, 1980, Cooper 1981, Clement 1982, 1983) result in the herd being out of the range of the Monitoring Program.

The need to protect caribou from human activities at water crossing sites remains an important requirement.

Compiled information suggests caribou are sensitive to human activity rather than to stationary structures during their approach to water crossing sites. Once the lead caribou are swimming, the crossing is likely to continue. The consequences of interrupting or preventing a crossing are unknown, but almost certainly depend on the availability of alternative water crossing sites - a difficult concept to evaluate as caribou sometimes use sites that appear dangerous to a human observer. The consequences of altering the use of traditional water crossing sites, either by people at the site or altering the site's physical or hydrological characteristics, have not yet been determined.

3. Timing Of Calving and Post-calving

The application of regulatory measures to biological processess is difficult because biological processess are interrelated and complex. Furthermore, they may vary during and between years. Therefore, the Caribou Protection Measures cannot be designed solely according to the timing of use of specific areas in conjunction with the various life-history phases of caribou; reasoned judgement must play an integral role in the design. For example, in a herd comprised of tens of thousands of cows, some cows will be in the post-calving phase while others are in the pre-calving or calving phases.

The breeding dates of caribou are highly synchronized; however, they do not impute complete predictability in precisely defining the dates for each life-history phase. The timing of calving is largely determined by the timing of breeding (the rut), but the factors influencing the timing of the rut are not understood. Holthe (1975) reported that calving peaked on 6 May, 12 May and 29 May for three wild reindeer populations whose ranges were at the same latitude in southern Norway. Holthe (1975) ranked four factors that influenced the timing of breeding. In order of importance, they are: genetic differences between populations, physical condition before and during the rut, age structure of the males, and hunting activities before and during the rut. He noted that there was variation in the timing of the peak of calving of one population. Poor range conditions and the presence of hunters and tourists (which caused cows to spend increased proportions of their time walking and trotting) in late summer resulted in a delayed rut and a delayed calving period. Holthe's (1975) results emphasize that ground-based human activity, which leads to increased walking and trotting by caribou in late summer, could result in poor body condition and hence delays in the rut and calving. Foraging strategies of parturient and lactating cows are closely tied to plant phenology. Changes in the timing of calving could cause changes in foraging patterns and occupancy of various segments of the calving grounds.

The birth of calves was observed between 27 May and 23 June for the Beverly caribou during CWS calf mortality studies conducted from 1981-83. The ratio of newborn calves to cows suggests the peak of calving was 2-5 June in the eastern segment and 7-8 June in the centre of the calving ground in 1981 and 9-12 June in 1982. Thomas (1959) estimated that calving peaked between 1-4 June in 1959, which is similar to Cooper's (1981) observations for 1980. Similarly, the peak of calving on the Kaminuriak calving grounds has been recorded as occurring betwēen 1-11 June.

Variations in the peak of calving are also attributable to a variation in the duration of gestation. Gestation is prolonged if the cows are in poor physical condition (Bergerud 1975, Espmark 1980, Davis and Valkenburg 1983). Therefore, the annual variation in the peak of calving should be reflected in the Caribou Protection Measures. The calving period of 31 May to 15 June is the average timing of calving (Fleck and Gunn 1982). The variation of calving is 27 May to 23 June; however, because relatively few observations have been recorded at each extreme, we have arbitrarily shifted the period to extend from 25 May to 25 June for the calving period of the Beverly and Kaminuriak herds.

The post-calving distributions of Beverly and Kaminuriak caribou are more difficult to predict than calving distributions. In addition, we have considerably fewer data on the distribution of post-calving caribou. During the last 2 weeks of June and the first week of July, caribou form large aggregations which can move

rapidly; they can cover up to 80 km a day (F.L. Miller pers. comm.). The size and persistence of the aggregations depends on a number of factors, including weather and mosquito activity. By mid-August the caribou normally disperse, but they may aggregate again at water crossing sites and in response to insect harassment. The data on group size and movements (e.g., between-year variations) are inadequate, and can be used only to assign an arbitrary date for the end of the post-calving period, which is mid-August.

The Caribou Protection Measures (1984) address the calving period as defined in this paper (25 May to 25 June) and part of the post-calving period (25 June to 15 August) for all land use activities in the vicinity of cows and calves. After 15 July when the distribution of caribou is less predictable, cow-calf aggregations are still protected at designated water crossing sites (until 1 September). Additionally, the Land Use Inspector has the authority to suspend certain land-use operations (e.g., blasting, use of all-terrain vehicles, and aircraft flying lower than 300 m agl) in the vicinity of cows and calves. Thus, not withstanding practical problems (e.g., developing a definition for "vicinity") associated with managing highly mobile caribou, the cows and calves are protected during their most vulnerable period.

In view of the biological and environmental differences between the Alaska herds (Delta and Central Arctic herds), the Newfoundland herd, and the Beverly and Kaminuriak herds, it is not possible to directly translate research results between them. In addition, our

preliminary experiments were not designed to evaluate the responses to repeated exposures of a variety of disturbances. The wide spectrum of land-use activities which occur under the auspices of Land Use Permits, sometimes in the same areas, reduces our ability to accurately extrapolate behavioural responses to one type of situation.

The herds of the northeastern Keewatin, on Baffin Island and in the west (e.g., the Bathurst herd), share more common environmental and biological features with the Kaminuriak and Beverly herds than with the Alaskan or Newfoundland herds. There are no indications from even qualitative observations of histories of extensive exposure to human activities that any of the barren-ground caribou herds in the NWT are currently habituated to aircraft or other forms of human activity.

Not all activities are regulated by Land Use Permits, and other activities involving tourists, photographers, scientists, etc., could also inadvertently affect cows and their calves, as those types of activities mostly involve people engaging in activities on the ground. Many activities are recorded through the Scientist's and Explorer's Permit and/or the Wildlife Research Permit. Through such permits, people could be advised of the vulnerability of cows with calves.

CONCLUSIONS

The baseline approach of the research program was made necessary by the absence of quantitative descriptions of the calving ground and its use by cows and calves. We used our baseline data as control data in a preliminary experiment to measure the behavioural response of cows and calves to helicopter activity. The experiment demonstrated that such activity can disrupt on-going activities and result in displacement; however, the results do not measure the significance or consequences of the disruption and displacement.

Our conclusion that the Beverly, Bathurst and Kaminuriak calving grounds are not discrete physical entities with recognizably unique physiographic or vegetative characteristics, emphasizes that it is the cows and calves using the area, not the area itself that require protection through the regulation of human activities. Recently, the tolerance of,or resilience of, cows and calves to aircraft, vehicles and pipelines on the calving grounds in Alaska has been described. However, before the examples from Alaska can be extrapolated to the NWT the historic and environmental differences must be quantitified and their influences on the responses of caribou to human activities evaluated.

In reviewing caribou/human interactions, we found that the variability in and adaptability (Bergerud 1974) of caribou behaviour impedes the development of generalized conclusions. Some examples indicate caribou are attracted to human activities like logging (Bergerud 1974, Salo 1975), and are tolerant of aircraft (Valkenburg and Davis In Press). Other examples indicate caribou avoid aircraft or vehicles (Cameron et al. 1983, Gunn et al. 1983). Responses deleterious to the health of caribou have been documented as a result of chasing (herding) and confinement (Pelto 1973, Rehbinder et al. 1983); however, it is also important to note that there is varation in the responses (Bergerud et al. 1984) of caribou to harassment.

The causes of response variation to human activities are not well understood. For example, by conducting nutritional experiments workers have demonstrated that some variation in the cow-calf bond is attributable to the nutritional status of the cow. Despite data showing variation in caribou responses to human activity, there are no data to refute the concerns for land-use activities on the Beverly and Kaminuriak calving grounds. Equally, the data reviewed suggest that these concerns are applicable to the cows and calves of other herds of barren-ground caribou in the NWT. The data also predict that the vulnerability of cows and newborn calves is increased after severe winters and delayed spring migration.

At the present time, the significance of displacement can be addressed only in a theoretical context (e.g., Cameron et al.

1983) and by drawing parallels with suitable models. However, workers have considered the biological and environmental characteristics of possible models (Thomson 1980, Bergerud et al. 1984, Davis and Valkenburg In Press), and suggest that these models are unsuitable for the Beverly and Kaminuriak herds. Neither our research nor published information refutes the assertion of the vulnerability and responsiveness of cows and calves of the barren-ground herds in the Northwest Territories.

RECOMMENDATIONS

Research

1. Critically review recent and current research programs which deal with the responses of caribou to human activities in order to define the types of data required to increase the comparative value of such studies and to evaluate shortfalls in design and methodology.
2. Evaluate the design of studies to address variability in the responses of caribou to human activities including factors related to physical condition and previous experience (e.g., habituation).
3. Obtain quantitative data on the rate of movement and the distribution of caribou cows during the calving period (25 May to 25 June) in order to develop consistant criteria to define calving grounds and to provide sound advice to the monitoring program of the Caribou Protection Measures. Describe the geological and hydrological characteristics of mineral licks of the Beverly and Bathurst calving grounds in order to develop a predictive capability to recognize other potential mineral licks. Additionally, caribou use of the mineral licks requires quantification.

Caribou Protection Measures

1. Current data do not refute the assumptions underlying the Caribou Protection Measures. The Caribou Protection Measures should continue to be applied.
2. The specific recommendations for the current Caribou Protection Measures were developed by Mychasiw (1984) under the assumption of a continued monitoring program. Maintenance of these conditions is recommended.
3. Human activities not addressed by Land Use Permits, during the period, and in the areas regulated under the auspicies of the Caribou Protection Measures should be monitored. People working under the auspicies of the Scientists' and Explorers' Licences and/or the NWT Wildlife Research Permits should be advised of the sensitivity and vulnerability of caribou in those areas at those times.
4. No land-use activity should be allowed to change the hydrological or land-surface characteristics of the mineral licks on the calving grounds even in absence of caribou.
5. In the event that people engaged in land-use activities supported by a helicopter do encounter caribou, they should not land within 2000 m of the animals.
6. Land Use Inspectors should base their calculations of the rate of movement of caribou in relation to land-use sites on a factor of 80 km/day.

7. Protection of caribou cows and calves on other calving grounds in the NWT should be considered if land-use activity occurs in these areas.

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LITERATURE CITED

Anonymous 1980. Transactions of the Caribou Disturance Workshop, Yellowknife, N.W.T. 17 October 1979. N.W.T. Wildl. Serv. unpubl. rep. 119 pp.

Arima, E.Y. 1975. A Contextual Study of the Caribou Eskimo Kayak. Nat'l. Mus. of Man, Mercury Ser., Can. Ethn. Serv., Pap. No. 25. Natl. Mus. Can., Ottawa. 262 pp.

Banfield, A.W.F. 1954. Preliminary investigation of the barren-ground caribou, Part 2: Life history, ecology and utilization. Can. Wildl. Serv. Wildl. Manage. Bull. Ser.1. No. 10B. 112 pp.

Bergerud, A.T. - 1971. The population dynamics of Newfoundland caribou. Wildl. Monogr. 25:1-55.

Bergerud, A.T. 1974. The role of the environment in the aggregation, movement and disturbance behaviour of caribou. Pages 552-584. In Geist, V. and F. Walther, (eds.) The behaviour of ungulates and its relation to management, Vol. 2 IUCN Publ. New Ser. No. 24, Morges, Switzerland. 940 pp.

Bergerud, A.T. 1975. The reproductive season of Newfoundland caribou Can. J. Zool. 53:1213-1221.

Bergerud, A.T. 1976. Impact on the living environment. Transcripts of the Mackenzie Valley Pipeline Inquiry, Yellowknife, N.W.T. Vol. 110.

Bergerud, A.T. 1978. Caribou. Pages 83-101. In Schmidt, J.L. and D.L. Gilbert, (eds.). Big game of North America - ecology and management. Stackpole Books, Harrisburg, PA. 494 pp.

Bergerud, A.T., R.D. Jakimchuk and D.R. Carruthers. 1984. The buffalo of the North: Caribou (Rangifer tarandus) and human developments. Arctic 37:7-22.

Bos, G.N. 1974. Nelchina and Mentasta caribou reports. Alaska Department Fish and Game, Projects W-17-5, W-17-6, Prog. Rep., Juneau, Alaska. 50 pp.

Bos, G.N. 1975. A partial analysis of the current population status of the Nelchina caribou herd. Pages 170-180. In Luick, J.R., P.C. Lent, D.R. Klein, and R.G. White, (eds.). Proc. 1st. Int. Reindeer/Caribou Symp., 1972., Univ. Alaska, Fairbanks. Biol. Pap. Univ. Alaska. Spec. Rep. No. 1. 551 pp.

Boertje, R.D. 1981. Nutritional ecology of the Denali caribou herd. M.S. Thesis, Univ. Alaska, Fairbanks. 294 pp.

Calef, G.W. and G.M. Lortie. 1975. A mineral lick of the barren-ground caribou. J. Mammal. 56:240-242.

Cameron, R.D., K.R. Whitten and W.T. Smith. 1983. Response of caribou to petroleum-related development on Alaska's Arctic Slope. Alaska Dept. Fish and Game, Prog. Rep., Fed. Aid in Wildl. Restor. Proj. W-21-2 and W-22-1. Juneau. 75 pp.

Clement, H. 1982. Beverly and Kaminuriak caribou monitoring and land-use controls. N.W.T. Wildl. Serv. Prog. Rep. No. 6. 49 pp.

Clement, H. 1983. Beverly and Kaminuriak caribou monitoring and land-use controls. N.W.T. Wildl. Serv. Prog. Rep. No. 8. 41 pp.

Connolly, G.E. and O.C. Wallmo. 1981. Management challenges and opportunities. Pages 537-545. In Wallmo, O.C., (eds.), Mule and black-tailed deer of North America. Univ. Nebraska Press, Lincoln NE, 605 pp.

Cooper, S. 1981. Beverly and Kaminuriak caribou monitoring and land-use controls, 1980. N.W.T. Wildl. Serv. Prog. Rep. No. 4. 74 pp.

Darby, W.R. 1978. Beverly and Kaminuriak caribou monitoring and land-use controls, 1978. N.W.T. Wildl. Serv. Comp. Rep. No. 1. 83 pp.

Darby, W.R. 1980. Beverly and Kaminuriak caribou monitoring and land-use controls, 1979. N.W.T. Wildl. Serv. Prog. Rep. No. 3. 51 pp.

Davis, J.L. and P. Valkenburg. 1981. Yearling mortality in the Delta caribou herd. Alaska Dept. Fish and Game, Final Report, W-17-11, W-21-1, Juneau, 18 pp.

Davis, J.L., P. Valkenburg. 1983. Demography of the Delta herd under varying rates of natural mortality and harvest by humans. Prog. Rep., W-22-1, Alaska Dept. Fish and Games, Juneau. 50 pp.

Davis, J.L., P. Valkenburg and R.D. Boertje. 1983. Demography and limiting factors of Alaska's Delta caribou herd. 1954-1981. Acta. Zool. Fennica 175:135-137.

Davis, J.L., P. Valkenburg and R.D. Boertje. In Press. Disturbance and the Delta herd. Proc. 1st N. Amer. Caribou Workshop, Can. Wildl. Serv.

de Vos, A. 1960. Behavior of barren-ground caribou on their calving grounds. J. Wildl. Manage. 24: 250-258.

Espmark, Y. - 1971. Mother-young relationship and ontogeny of behaviour in reindeer (Rangifer tarandus L.) Z. Tierpsychol. 29:42-81.

Espmark, Y. 1980. Effects of maternal pre-partum under-nutrition on early mother-calf relationships in reindeer. Pages 485-496. In Reimers, E., E. Gaare and S. Skjenneberg, (eds.), Proc. 2nd Int. Reindeer/Caribou Symp. 1979, Roros, Norway, Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

Fancy, S.G. 1983. Movements and activity budgets of caribou near oil drilling sites in the Sagavanirktok River floodplain, Alaska. Arctic 36:193-197.

Fleck, E.S. and A. Gunn. 1982. Characteristics of three barren-ground caribou calving grounds in the Northwest Territories. N.W.T. Wildl. Serv. Prog. Rep. No. 7. 158 pp.

Geist, V. 1975a. Harassment of large mammals and birds. Exhibit 359 entered before the Mackenzie Valley Pipeline Inquiry, Yellowknife. 62 pp.

Geist, V. 1975b. On the management of mountain sheep: theoretical considerations. Pages 77-105. In Trefethen, J.B. (ed.), The wild sheep in modern North America. Boone and Crockett Club and Winchester Press, New York. 302 pp.

Geist, V. 1978. Behaviour. Pages 283-296. In Schmidt, J.L. and D.L. Gilbert, (eds.), Big game of North America: ecology and management. Stackpole Books, Harrisburg, PA. 494 pp.

Geist, V. 1982. Adaptive behavioural strategies. Pages 283-396. In Schmidt, J.L. and D.L. Gilbert, (eds.), Big game of North America: ecology and management. Stackpole Books, Harrisburg, PA. 494 pp.

Gunn, A., R. Glaholt, F.L. Miller and K. Jingfors. 1983. Caribou behaviour, range use patterns and short term responses to helicopter landings on the Beverly calving ground, N.W.T. 1982. N.W.T. Wildl. Serv. File Rep. No. 30. 126 pp.

Harper, F. 1955. The barren-ground caribou of the Keewatin. Univ. of Kansas, Allen Press, Lawrence. 163 pp.

Haukioja, E. and R. Salovaara. 1978. Summer weight of reindeer (Rangifer tarandus) calves and its importance for their future survival. Rep. Kevo Subarctic Res. Stat. 14:1-14.

Holthe, V. 1975. Calving season in different populations of wild reindeer in Norway. Pages 194-198. In Luick, J.R., P.C. Lent, D.R. Klein, and R.G. White (eds.). Proc. 1st. Int. Reindeer/Caribou Symp., 1972, Univ. Alaska, Fairbanks. Biol. Pap. Univ. Alaska, Spec. Rep. No. 1. 551 pp.

Interdisciplinary Systems Ltd. 1978. Effects of exploration and development in the Baker Lake area. Vol. 1. Study Rep. Rep. to Dep. Ind. and North. Affairs, Ottawa. 340 pp.

Jingfors, K., A. Gunn and F.L. Miller. 1982. Behaviour and range use patterns of caribou on the Beverly calving ground. N.W.T. Wildl. Serv. File Rep. No. 22. 118 pp.

Jacobsen, E., R.S. Bjarghov and S. Skjenneberg. 1976. Nutritional effect on weight gain and winter survival of reindeer calves (Rangifer tarandus tarandus). Meldinger fra Norges Landbrukshogskole 56:1-13.

Kelsall, J.P. 1968. The migratory barren-ground caribou of Canada. Can. Wildl. Serv. Monograph No. 3 . Queens Printer. Ottawa.

Krebs, C.J. 1964. Spring and summer phenology at Baker Lake, Keewatin, N.W.T. during 1959-62. Can. Field-Nat. 78:25-27.

Langenau, E.E., Jr. and J.M. Lerg. 1976. The effects of winter nutritional stress on maternal and neonatal behaviours in penned white-tailed deer. Appl. Anim. Etho. 2:207-223.

Lent, P.C. 1964. Calving and related social behaviour in the barren-ground caribou. Ph.D. Thesis, Univ. Alaska, Fairbanks. 220 pp.

Lent, P.C. 1966. Calving and related social behavior in barren-ground caribou. Z.f. Tiersphsychol. 23:701-756.

Lent, P.C. 1974. Mother-infant relationships in ungulates. Pages 14-55. In Geist, V. and F. Walther, (eds.). The behaviour of ungulates and its relation to management. Vol. 1. IUCN Publ. New Ser. No. 24. Morges, Switzerland. 940 pp.

Mauer, F.J., G.W. Garner, L.D. Martin and G.W. Weiler. 1983. Evaluation of techniques for assessing neonatal caribou calf mortality in the Porcupine caribou herd. Arctic National Wildlife Refuge Rep. No. FY83-6, U.S. Fish and Wildl. Serv., Anchorage, Alaska. 44 pp.

McCullough, D.R. 1979. The George River deer herd - population ecology of a K-selected species. Univ. Michigan Press, Ann Arbor. 271 pp.

Miller, F.L. and E. Broughton. 1973. Behavior associated with mortality and stress in maternal-filial pairs of barren-ground caribou. Can. Field-Nat. 87:21-25.

Miller, F.L., E. Broughton and A. Gunn. In Prep. Mortality of migratory barren-ground caribou on the calving ground of the Beverly herd, District of Keewatin, Northwest Territories, 1981-1983. Can. Wildl. Serv. Comp. Rep.

Miller, F.L. and A. Gunn. 1979. Responses of Peary caribou and muskoxen to helicopter harassment. Can. Wildl. Serv. Occ. Pap. No. 40. 90 pp.

Miller, F.L., C.J. Jonkel and G.D. Tessier. 1972. Group cohesion and leadership responses by barren-ground caribou to man-made barriers. Arctic 25:193-202.

Murie, O.J. 1935. Alaska-Yukon caribou. U.S. Bur. Biol. Survey, N. Amer. Fauna 54:1-93.

Mychasiw, L. 1984. Five-year review of the Beverly and Kaminuriak Caribou Protection Measures. N.W.T. Wild. Serv. File Rep. No. 42. 133 pp.

Parker, G.R. 1972. Biology of the Kaminuriak population of barren-ground caribou. Part 1. Total numbers, mortality, recruitment, and seasonal distribution. Can. Wild. Serv. Rep. Ser. No. 20. 95 pp.

Pelto, P.J. 1973. The snowmobile revolution: Technology and social change in the arctic. Cummings Publ. Co., CA. 225 pp.

Quinn, J.F. and A.E. Dunham. 1983. On hypothesis testing in ecology and evolution. Amer. Nat. 122:602-617.

Rehbinder, C., L.E. Edqvist, K. Lundstrom and F. Villafane. 1983. A field study of management stress in reindeer (Rangifer tarandus L.). Rangifer 2(2):2-21.

Salo, L.J. 1975. Review of recent reindeer studies in Finland by State Game and Fisheries Research Institute and University of Helsinki. Pages 420-422. In Luick, J.R., P.C. Lent, D.R. Klein and R.G. White, (eds.) Proc. 1st Int. Reindeer/Caribou Symp., 1972, Univ. Alaska. Fairbanks Biol. Pap. Univ. Alaska, Spec. Rep. No. 1. 551 pp.

Shank, C.C. 1979. Human-related behavioural disturbances to northern large mammals: a bibliography and review. Report prepared for Foothills Pipe Lines (south Yukon) Ltd., Calgary. 254 pp.

Shea, J.C. 1979. Social behaviour of wintering caribou in northwestern Alaska. M.S. Thesis, Univ. Alaska. 112 pp.

Skogland, T. and O. Molemen. 1980. Prehistoric and present habitat distribution of wild mountain reindeer at Dovrefjell. Pages 130-141. In Reimers, E.,E. Gaare, and S. Skjenneberg, (eds.). Proc. 2nd. Int. Reindeer/Caribou Symp., 1979. Roros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim, 779 pp.

Smith, W.T. and R.D. Cameron. 1983. Responses of caribou to industrial development on Alaska's Arctic Slope. Acta Zool. Fennica 175:43-45.

Thomas, D. 1959. Caribou calves caught during June, 1959. Can. Wildl. Serv. unpubl. rep. 24 pp.

Thomson, B.R. 1975. Leadership in wild reindeer in Norway. Pages 462-473. In Luick, J.R., P.C. Lent, D.R. Klein and R.G. White, (eds.). Proc. 1st Int. Reindeer/Caribou Symp., 1972, Univ. Alaska, Fairbanks. Biol. Pap. Univ. Alaska, Spec. Rep. No. 1. 551 pp.

Thomson, B.R. 1977. The behaviour of wild reindeer in Norway. Ph.D. Thesis, Univ. Edinburgh, Scotland. 428 pp.

Thomson, B.R. 1980. Behaviour differences between reindeer and caribou (Rangifer tarandus L.). Pages 545-549. In Reimers, E., E. Gaare and S. Skjenneberg, (eds.), Proc. 2nd Int. Reindeer/Caribou Symp., 1979, Roros, Norway, Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

Valkenburg, P. and J.L. Davis. In Press. The reaction of caribou to aircraft: a comparison of two herds. Proc. 1st. N. Amer. Caribou Workshop, Can. Wildl. Serv.

Whitten, K.R. and R.D. Cameron. 1983a. Movements of collared caribou, Rangifer tarandus, in relation to petroleum development on the Arctic Slope of Alaska. Can. Field-Nat. 97:143-146.

Whitten, K.R. and R.D. Cameron. 1983b. Population dynamics of the Central Arctic herd, 1975-1981. Acta Zool. Fennica 175:159-161.

Williams, T.M. and A. Gunn. 1982. Description of water crossings and their use by migratory barren-ground caribou in the Districts of Keewatin and Mackenzie, N.W.T. N.W.T. Wildl. Serv. File Rep. No. 27. 209 pp.

Wilson, E.O. 1975. Sociobiology the new synthesis. The Belknapp Press of Harvard Univ. Press. Cambridge, MA. 697 pp.