TRANSACTIONS OF THE CARIBOU DISTURBANCE WORKSHOP

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Introductory Remarks - Dr. Norm Simmons, Superintendent, N.W.T. Wildlife Service, Yellowknife

Wildlife research in the Northwest Territories, outside of universities and other private agencies, is reviewed by three agencies, Canadian Wildlife Service, Department of Indian Affairs and Northern Development and the N.W.T. Wildlife Service. The Directors of these agencies are members of the Canada-N.W.T. Wildlife Research Coordinating Committee and are responsible for the funding of most research north of 60°. We review research projects in an effort to eliminate duplication and to coordinate efforts and complement projects. What appears frequently is the question of the effect of human disturbance on wildlife. What are the effects of major exploration or development projects, the harassment effects, or the disturbance effects on animals? We know of course, that animals are disturbed by man and machines, but how do we measure this disturbance, and how do we assess its long-range effects on wildlife?

What the funding agencies receive is a variety of proposals and opinions about how to answer these questions, but we, or at least I, am so ignorant about the state of the art and science of studying disturbance and measuring it, that I'm uncertain, and I think the other panel members are uncertain, where to put our dollars. So, Bob Hornal, the Regional Director

of DIAND seized the bull by the horns and proposed that the committee invite a group of experts in the field of disturbance studies to Yellowknife, to assist us in assessing the state of the science and art of measuring behavioural response of caribou to industrial exploration and development. Such measures would be used in estimating the cost of industrial activities to caribou populations. We have zeroed in on caribou because that is our prime concern north of 60°. There are other areas of concern, for example, sheep and woodland caribou in the Mackenzie Mountains, but the top priority right now is barren-ground caribou.

We are fortunate in pulling together a pretty good panel. This morning they will present fairly formal presentations on the state of the art but the key, however, will be this afternoon's informal discussions, that is what we will benefit from as we take their information, digest it and question it. Bruce Stephenson, who is our Territorial Wildlife Service's head of research, was the gentleman who pulled the panel together, and I'd like him to introduce the panel members.

Panel Introduction - Bruce Stephenson

We tried to pull together a fair mix of individuals for our panel that had specific expertise in both the behavioural and physiological assessment of caribou disturbance or harassment. We selected Dr. Dave

Klein to serve as moderator. He has had a lengthy history of work on caribou in the North, in Alaska particularly, and he is currently with the Cooperative Research Unit at the University of Alaska in Fairbanks. He will be able to not only introduce the subject, but to tell us a little bit about the experiences which Alaska has encountered in relation to disturbances of caribou from pipelines, haul roads and other activities. If you happen to have a copy of the former agenda, we had another individual by the name of Dr. Peter Lent from Anchorage, Alaska, who was going to dwell on some of his experiences with physiological parameters in relation to disturbances in Alaska, and some of the Alaskan experiences along this line. Dave has assented to give us a little of that background in the absence of Peter Lent.

On my far right we have Bob MacArthur who is with the University of Calgary. He is a physiologist and I believe something of an electronics expert as well. He has worked with Dr. Val Geist rather closely for the past six years. Dr. Geist, as you may be aware, is a behaviourist who works a great deal on mountain sheep, and the last few years has extended his scientific endeavours to remote monitoring of physiological parameters associated with normal activities and the changes that take place under disturbed situations. The prime factor here is the measurement of heart rate, so Bob is the proponent of the physiological approach to measure, and attain quantitative field information on disturbance activities.

The next gentleman is Bill Darby who for the last two years has been gaining a great deal of experience in relation to caribou and land-use activities in the Keewatin portion of the N.W.T. He will outline some of the aspects that he has been studying, some of the practical considerations and the problems that are currently facing us and then he will outline some of the problems which we are trying to seek solutions to here today.

The next gentleman is Dr. Eoin McEwan with the Canadian Wildlife Service in Vancouver. Eoin has done a great deal of work in the past with caribou in relation to their physiology, growth and nutrition. His background is largely laboratory experimentation and he will dwell on this aspect, the need to obtain some baseline information under more controlled conditions than you can attain in the field.

On my extreme left is Dr. Frank Miller, CWS in Edmonton. He has done a great deal of work in the North in relation to observing behaviour, overt behaviour of caribou and how caribou respond to certain disturbances, mainly aircraft disturbances.

Several of these gentlemen have just returned from a meeting in Norway which was the Second International Caribou/Reindeer Symposium. They undoubtedly picked up a great deal of information from the presentations

and discussions with fellow members, and I'm sure that they will be able to bring out a great many points that were raised at these meetings. I'll turn it over to Dave Klein who will accept the role of moderator.

Dr. Dave Klein - Cooperative Wildlife Research Unit,
University of Alaska.

Today, it is valid to ask the question, why are we here? Many of us who have been working with caribou for some time first raised the question about a decade ago of the consequences of caribou disturbance associated with northern development. We raised this question when there was an increased focus on oil and gas exploration in the North, partly associated with the large discovery at Prudhoe Bay, Alaska. We challenged industry to consider the consequences of their activities with regard to caribou, and industry wisely offered a counter-challenge to us to indicate what the consequences might be for varying types of harassment or disturbance. We weren't in a very good position to respond to industry's challenge. Since then there have been studies of a varying nature which put us in a little better position, but how much better is again for us to try to assess in today's discussions.

There have been numerous studies of overt behavioural responses of caribou to varying types of harassment and particularly harassment by low flying

aircraft both in Alaska and Canada. Some of these studies often lacked standardization of methodology and were therefore of limited value, but I think that the more recent work of Miller and Gunn has added a degree of refinement to this approach and Frank Miller will be talking more about this later. Dr. Val Geist was among the first to focus attention on the possible physiological consequences of harassment, or disturbance of caribou. This was in an article he wrote in "Oil Week", in which he extrapolated from work with domestic animals and did a lot of speculating, but at least he provided a basis for considering possible physiological consequences of disturbance to caribou.

We are here today at the invitation of the Government of the Northwest Territories and hopefully we can provide some guidelines for managers as well as a basis for establishment of priorities for additional research. Specifically, our job in today's discussion is to provide an overview of knowledge regarding effects of various industrial disturbances on productivity, survival and movements of caribou. We do not want to exclude the possible consequences of new technology used in hunting of caribou, and the impact of biological surveys and study techniques on caribou populations. We want to address the question of how valuable for management are studies of overt behaviour associated with disturbance, including both qualitative and quantitative descriptions of this behaviour. We also want to ask the question is there a need for assessment of the physiological consequences for caribou of disturbance, and if so, are techniques

available which are sophisticated enough to yield sound quantitative data which is readily interpretable in terms of physiological cost to the animals? Is more work required in the laboratory, or with captive animals before these techniques can be taken into the field? We also have to be practical and ask, what is the cost in dollars of both development and application of research techniques, and how long before such research will yield results as a basis for management decisions?

To provide a background against which the panelists will speak I'm going to draw some general conclusions about the reaction of caribou and reindeer to obstructions and disturbances. These conclusions are based on my own research, experience, a review of available literature, and experiences from other parts of the world not always recorded in reports or publications. I did this summary for presentation at the 2nd International Reindeer/Caribou Symposium in Røros, Norway last month. I'm going to read the conclusions that I've come to relative to the impact of obstructions and disturbance on caribou and reindeer.

"Some conflicting observations appear in the literature and there are genetic differences in behaviour exhibited between populations of Rangifer, but for the most part, when variations in environmental conditions are considered, similar patterns exist in the reaction of caribou and reindeer to obstructions and related disturbances associated with northern development.

These can be summarized as follows:

1. Roads, railroads, pipelines, powerlines, artificial or altered water courses or other man-made linear features can, independent of other human activities, block, delay or deflect the movements of caribou and reindeer. The effect of such structures as obstacles to the movement of Rangifer is dependent upon the mode of construction and how much they alter the existing terrain either by presenting physical barriers to movement, or by visibly altering the landscape to create the appearance of physical barriers, or by creating visual scenes which appear threatening to the animals. Highways or railroad beds elevated substantially above the surrounding terrain present both physical and visual barriers to moving large animals, and deep construction cuts and associated obstacles such as snow fences or steep snow berms, have similar effects. In open terrain, roads, railroads, or pipelines are visible from a great distance, consequently, approaching animals may react to them sooner and thereby be delayed longer in their movements than when approaching such features in forested terrain. On the other hand, cleared transportation right-of-ways in forested areas create sharp breaks in the habitat which may be reacted to with a high level of alarm. Caribou and reindeer appear to be less disturbed by elevated pipelines and power lines in forested terrain and cross under them more readily than in open tundra. The strange substrate of the road or railroad surfaces may cause deflection of moving animals either because of

their reluctance to walk on it or, particularly in winter, because it offers an easy surface to travel on. The avoidance response shown by caribou and reindeer to man-made features is apparently partially associated with predators' avoidance behaviour. Therefore, if such features provide cover or better visibility for predators, or if they simulate natural features where predators may be more effective, or if they are constructed adjacent to natural terrain features that may favour predators, avoidance by caribou and reindeer can be expected.

2. The level and type of vehicular traffic and other human activities associated with roads, railroads and other man-made features are major factors influencing the reaction of caribou and reindeer. Experience has shown that caribou and reindeer usually show much greater alarm and avoidance to traffic and other human activities than to the constructed features themselves. Generally, the larger the vehicle, the greater the disturbance, and blowing dust or snow increase the disturbance effect. The greater the frequency of traffic, the greater is the deterrence to moving animals. Caribou adapt more readily to infrequent, regularly spaced traffic than infrequent but irregularly spaced traffic. The sounds associated with traffic appear to accentuate the alarm reaction, although sound in itself, if associated with fixed non-threatening objects such as oil drill rigs, or simulated gas pipeline compressor stations, or

from non-visible sources such as supersonic aircraft (Espmark 1972; McCourt et al. 1974) appears to be readily adapted to.

3. Caribou and reindeer react to obstructions and associated disturbances differently in relation to the season of the year. During spring and summer, females accompanied by young of the year, show much stronger avoidance of obstructions than during the winter. This behaviour is apparently related to predator avoidance in which this cohort, in tundra areas, also avoid stands of riparian willow which may hide wolves and other predators (Roby 1978). During summer, when levels of insect harassment are high, caribou and reindeer seem preoccupied with seeking relief from insects, show strongly motivated movements to insect relief areas and seem less responsive to other disturbances. At this time they more readily cross roads, pipelines and other obstructions which may lie in the path of their movements to insect relief areas and in some cases seek relief from insects (particularly parasitic flies) by standing on elevated, gravel road surfaces, pipeline pads and airstrips. During migration to the calving grounds by pregnant females in late winter and during fall migration to the wintering grounds, the migratory urge is strong and movements are less likely to be impeded by obstructions than may be the case when animals are on summer or winter range areas, when movements are primarily associated with feeding activities and they are less strongly directionally oriented. When caribou and reindeer

are preoccupied with rutting activities, which usually coincide with fall migration to the wintering grounds, they are also less likely to be impeded in their movements by obstructions.

4. There are pronounced differences in response to obstructions in relationship to sex and age of the animals involved and to group size. In addition to the avoidance behaviour of females with young, mentioned above, adult males in general, appear more adaptable to man-made features and habituate more rapidly to their presence. They also usually show less alarm reaction to highway traffic and other human activities than females with young. Generally, the larger the group, the greater the likelihood of avoidance reaction or deflection when confronting obstructions. This appears related to the fact that group movement is the product of the majority of the animals in a group following intention movements of "leaders" or individuals that show alarm reaction or otherwise may be the first to respond to stimuli. Therefore, one would expect a linear response to obstructions and disturbances in direct relationship to numbers within the group. This generalization, however, needs to be qualified. Single animals often appear strongly motivated toward rejoining a group and under such circumstances are particularly resistant to disturbance or deflection from their intended movement direction. Cow-calf pairs, during the immediate post calving period, show less group fidelity than other animals. During harassment by mosquitoes or by biting or

parasitic flies, caribou and reindeer become less responsive to other stimuli and therefore group size may be less important in influencing response to obstructions and disturbances.

5. Caribou and reindeer, as well as other ungulates, more readily adapt or habituate to obstructions and associated disturbances if they are resident in the area of the obstruction rather than being present only seasonally or during migration. Habituation to obstructions and disturbances occurs more readily in populations that are unhunted than in those that are hunted, as well as in populations free of large mammalian predators such as wolves and bears.

Variations in behaviour exist between genetically distinct races of Rangifer which may lead to differences in response to obstructions and disturbances. Woodland caribou (R.t. caribou Gmelin and R. t. sylvestris Richardson), for example, as a rule have less extensive migrations and show less pronounced sociality than tundra forms. Consequently, they can be expected to be less strongly motivated to cross roads, railroads, or other linear obstructions and to react more individualistically than tundra forms. Woodland caribou exist in relatively small herds and because they are locally resident they can be expected to be more adaptable to disturbances within their habitat. The consequences for caribou and reindeer of northern

development which creates roads, pipelines or other obstructions and associated disturbances on their range lands will vary considerably according to the conditions which have been outlined above. Specific effects, however, can be anticipated.

Local overgrazing and trampling of winter range was a consequence of impeded movement of wild reindeer by a gas pipeline in Siberia. Range abandonment through disrupted movements has been documented where railroads cross Rangifer rangelands and similar patterns of discontinued range use can be anticipated where roads have sufficient traffic to discourage crossing by reindeer or caribou. Discontinued use of range components when it occurs because of such obstructions is not, however, instantaneous. Many years may be involved in the breakdown of movement patterns.

The effect on populations of caribou or reindeer of loss of use of a portion of their rangelands will vary depending on the relative importance of the lost component. Loss of a portion of the food resource of a herd may lead to a reduction in its numbers, if it was at carrying capacity. If below carrying capacity, although no herd reduction may occur, potential future population increase may be precluded. If traditional calving areas are lost, the consequences may be lowered calf survival through use of less favourable calving areas. Loss of access to insect relief areas may expose animals to

levels of harassment by insects which will reduce feeding opportunity and lead to increased energetic expenditure of the animal, thus reducing growth rates of young and curtailing deposition of body reserves in preparation for breeding and winter. Historically, fractured Rangifer ranges through human development activities have led to range abandonment, herd reduction or extinction, or alternatively, fracturing of herds into smaller but discrete components. In the latter situation the total number of animals in the small herds has apparently consistently been less than in the original herd they displaced.

Geist (1975) estimated the energetic costs associated with deflection of movements of migrating caribou. There are additional energetic costs associated with all aspects of disturbance by vehicular traffic and other human activities (from aircraft disturbance as well). This has been discussed in the literature, primarily in relation to harassment of caribou and reindeer by low-flying aircraft; however, there has been virtually no research into the actual physiological consequences of such disturbance for the animals involved. It is possible to extrapolate from work with domestic animals, including reindeer, as Geist and others have done. This is clearly an area deserving high priority for future research.

The energetic costs and other physiological consequences of disturbance can be assessed with properly designed research. The capability of caribou and reindeer to accept these consequences and to adapt to them will vary with the circumstances involved. Obviously the species has evolved along with natural disturbances such as predators, insect harassment and hunting by humans; however, these influences, where they occur, are compensated for in various ways. Reduced productivity may be a consequence of high levels of insect harassment and extensive seasonal migrations may be the result when there are moderate to high levels of predation. Archaeological evidence suggests that historical methods of hunting, including the use of lead fences and stone or sod cairns that simulate obstructions, have not led to the disruption of traditional movements of caribou or reindeer nor to the extinction of specific herds. The location of these traditional hunting sites, however, has usually been along migration routes, rather than on the calving grounds, or wintering grounds where presumably hunting activities would have been more dispersed. The use of new technology in hunting, such as snowmobiles, may change this situation. Adding new disturbances through other human activities will nevertheless lead to increased physiological costs to the animals. These costs may be met through increased forage intake (if this option is available), altered behavioural patterns (accommodation to the disturbance or abandonment of areas of disturbance), or reduced allocation of energy to other requirements (growth, reproduction and escape from predators).

I have sort of given an overview of some of the consequences of disturbances and obstructions with regard to caribou and reindeer and I'll save any specific comments about some of the research that has been carried out in Alaska for the discussion period. So I think I would like to call upon the next panelist who is Bill Darby, to talk about the situation in the Northwest Territories.

Bill Darby - N.W.T. Wildlife Service.

Mr. Moderator, Fellow Participants, and Members of the audience.

First, I will give you some background information to set the stage for the other presentations to follow. Mineral exploration activity occurs within the summer ranges of the Beverly and Kaminuriak herds from Great Slave Lake east to Hudson Bay and from the Manitoba border north to Chesterfield Inlet, the Back River and the Thelon Game Sanctuary. During the past summer, approximately 60 land use permits were issued for this area. Most companies were exploring for uranium, and their activity involved such things as 10 to 40 person tent camps, personnel walking ground traverse with scintillometres, diamond drilling, and helicopter and fixed-wing transport. Aerial scintillometre and electromagnetic surveys were conducted at low altitude over portions of the area. The exploration season extends from approximately May 1st to August 31st. Thus, exploration activity on winter ranges is not of primary concern at this time.

Since 1970, the community of Baker Lake has been expressing concern over the effect of mineral exploration activity on caribou in the area. This concern relates mainly to effects on movement patterns of the herds, and to population dynamics of the Kaminuriak herd.

In April 1978, a court injunction and a new policy announcement of the Department of Indian Affairs and Northern Development resulted in temporary changes to land use controls in the area. Special zones and restrictions on land use activities were established to protect cows and calves during the spring migration, calving and post-calving periods. That is, most land use activities were excluded from calving and post-calving areas during the appropriate periods in late May, June and July. A monitoring program was conducted from April to September during 1978 and 1979 to record movements and determine the effectiveness of the special zones and restrictions. Results of the 1978 monitoring program and evaluation of 1978 controls were provided by myself in a report published last year (Darby 1978).

During the last two years there has been little interaction between exploration activities and large numbers of cows and calves because of the land use restrictions. Mining companies have also been cooperative in not conducting aerial scintillometre or geomagnetic surveys over migrating cows in spring. Company personnel have described some interactions with migrating bulls and non-breeding caribou in which camp activity did not appear to deter migration of the passing animals.

Given the present system of land use controls in the area, it is my belief that current uranium exploration activities are not harming either the movement patterns or population status of the herds. However, without adequate controls, I believe that they have the potential to do so if they occur in sensitive areas at sensitive times, especially if the intensity of activity increases. The most damaging conflicts would probably be associated with such things as:

1) camps operating in calving areas during the calving period;

2) exploration activity at important water crossings where there are no alternative routes of travel for caribou nearby;

3) Aerial scintillometre or electromagnetic surveys being conducted over migrating or calving cows, or post-calving aggregations. Surveys of this type are usually done at altitudes of less than 50 m above ground level and along transects spaced as close as 0.4 km apart. They are often conducted with large noisy aircraft such as a DC-3 or a Canso.

There is already pressure from the mining community to have the present controls lifted or be made more lenient. It can be expected that this pressure will increase, especially if development is stimulated by the new government in Ottawa.

There is also the secondary and larger task of preparing for and dealing with the problems associated with long-term development. One company may soon develop a uranium mine approximately 80 km west of Baker Lake. In light of this, the intensity of uranium exploration in the area can be expected to increase and other sites may be found to be suitable for mine development.

So what are the important issues? What are the issues for which specific regulations must be formulated, based upon something more than gut feelings? In this regard, one must keep in mind that the mining companies are already pressing for statements of the rationale behind regulations, and they are pressing for hard facts.

Firstly, I will outline the spectrum of issues concerning exploration activity. It may not be possible to address all of the problems in the short term.

1) low level aircraft activity - both helicopter and fixed-wing.

This can include daily helicopter transport of personnel to and from various locations around a camp for the purpose of walking ground traverses. It includes slinging fuel and equipment to new sites, an operation that can involve numerous passes along the same route over varying distances. It can include aerial scintillometre and geomagnetic surveys over large tracts of land.

2) Ground activities - the effect of diamond drilling, blasting, personnel walking traverse, and camp activity.

3) Water crossings - at the present time 28 water crossings have been designated by the Department of Indian Affairs and Northern Development for the Beverly and Kaminuriak herds. No land use activity is permitted, on a year-round basis, within 4.8 km. of the boundary of these water crossings.

Secondly, there are issues associated specifically with long-term development that may have to be addressed.

1) Airport activity including heavy aircraft operation such as that of DC-3's, Hercules and even 737 class aircraft.

2) Surface blasting and heavy equipment operation.

3) The presence of a winter road on a calving ground in spring. The winter road might be slow to thaw, and might persist at calving time.

No construction of all-weather roads or powerlines is anticipated in the foreseeable future because uranium ore concentrate, called "Yellowcake" can be flown out profitably. But requests for road and powerline construction may arise if mines become established.

Disturbance investigations should concentrate on the effect of both exploration and long-term development on caribou in calving, post-calving and spring migration areas. In general, investigation should consider: the effect of disturbance factors at various times of the exploration season; and, the relationship between response level and group composition, size and activity.

So, what information is needed to address the problems?

1) There is a need to know the affinities for and locations of critical areas - calving grounds, post-calving areas, rutting areas, and migration routes. Most of these are being investigated by the caribou monitoring program that, along with past information in the literature, is providing a substantial amount of baseline data. The monitoring program should be continued to augment existing data and to keep abreast of year-to-year changes.

   However, we also need to investigate the biophysical attributes of traditional calving and post-calving areas to evaluate the environmental factors that make them important. Are the areas unique in those attributes? Baseline data of this type are needed to assess the consequences of displacement of calving caribou.

2) There is a need to conduct simulation studies on the effects of diamond drilling, blasting, personnel walking traverse and other exploration activities.

3) There is a need to fill the gaps in our knowledge of caribou response to aircraft harassment, especially with regard to the two herds in question.

Such gaps include the effect of aircraft overflights at altitudes higher than 300 m agl, especially on large, dense aggregations. The reason I feel that it should be investigated is because through the last two years with the monitoring program I have been doing most of the flying at 1,000 ft. agl, and find that on many occasions the animals gallop rapidly in response to the passing of my aircraft, especially when the animals are in large, dense aggregations on warm sunny days in July. As an example, on a sunny day in late June of this year, I was searching for a substantial number of cows and calves that I could not find by flying these transects, so we did a survey at 4,500 ft. agl. The animals were still in their winter pelage so they were easy to spot, and I found about 7,000 in six aggregations that were fairly close together. Every time we passed over one of those aggregations, the whole aggregation would start to gallop rapidly. If we circled at 4,500 ft. agl in most cases the aggregations continued to be disturbed as long as we were overhead. Especially this last year I have gained the impression (I don't have any data to verify it because the personnel that were involved in the monitoring program were not sufficiently trained to collect data on behavioural responses), but I gained the impression that Kaminuriak animals react

more readily and more strongly to aircraft than the Beverly animals do.

4) There is a need to study the disturbance behaviour of caribou at water crossings in response to simulated exploration activities.

5) There is a need to study the effects of airport activity on caribou. This could probably be done most easily at existing airstrips affecting other herds, or airstrips scheduled for construction.

6) There is a need for simulation studies to help us predict the effect of disturbances associated with mines, for example, blasting, heavy equipment operation, and a winter road that is slow to thaw on a calving ground.

There are two basic approaches to the disturbance issue. One is to consider the effect of disturbance in its ultimate state, that of affecting population status by reducing reproduction or survival, either directly or indirectly. The other is to consider the effect of disturbance on patterns of movement and range utilization which may or may not be intermediate stages between cause and the ultimate effect on population status. I believe that several questions in the Keewatin can be answered adequately with overt behavioural data that describes:

a) how caribou respond to diamond drills, or blasting, or people walking traverse, etc., and,

b) the size of the zone of avoidance around these activities, if one exists. In other words, how far must caribou be from the source of disturbance before overt behavioural responses, or changes in movement patterns, become undetectable.

Ultimately, one could argue that there still remains a need to study the end result of the disturbance no matter what the initial overt behavioural responses were. The feasibility of such studies is debatable, and I hope that the subsequent presentations and discussions can clarify that. My point is that several questions can probably be answered with short-term overt behavioural studies.

Dr. D. Klein - Cooperative Wildlife Research Unit,
University of Alberta.

We are going to move on through the panel presentations before discussion and I'd like Eoin McEwan to talk about some of the physiological and behavioural aspects of caribou harassment and the potential he sees for laboratory studies or controlled studies in assessing the effects of disturbance on caribou.

Eoin McEwan - Canadian Wildlife Service, Vancouver.

I would like to give you a description of what the classical description of stress is according to Hans Selye. He described the adaptation syndrome which is the sum of the non-specific physiological and morphological responses to stress other than the specific adaptive responses - Selye has divided the stress syndrome into three parts; the normal reaction, the resistance, and finally the exhaustive phase. I think a lot of people lose track of what stress really is in terms of the ultimate phases. The characteristics of the exhaustive phase (Selye 1947) are hypoglycemia, involution of lymphoid tissue, adrenal cortical hypertrophy, decreased liver glycogens, diminished fat content of the adipose tissue, lipid decomposition in the liver, increased NPN with a negative nitrogen balance, reversal of the albumin/globulin ratio, decrease in blood chlorides, rise in blood potassium and a marked decrease of ascorbic acid. Now that's the exhaustive phase, and I don't think our animals are quite that stressed.

There is a voluminous amount of literature on stress which mainly deals with confined populations especially in mammals, reviewed by Christian and Myres. These studies involved stress in captive animals from crowding at high densities where constant strife led to physiological changes in the endocrine system. There is much evidence for the behavioural endocrine feedback system at high densities in confined populations. This is yet to

be confirmed in free-ranging animal populations. Cervids appear to be less directly affected, although this has not been proven so far. The difficulty with free-ranging animals is the presence of several problems which affect the assessment of harassment. One of these factors is the seasonal rhythms in weight, physiological activity, blood counts, heart rate, metabolism and energy intake. These have been recorded for several large groups including reindeer and caribou. There has been a large number of physiological values for reindeer and caribou including cellular blood erythrocytes, hemoglobin, leukocytes, so that we do have a background in cellular and chemical aspects of blood chemistry available under captive conditions. One major disadvantage is that excitability can influence physiological values such as glucose, rectal temperature , respiratory rates and heart rates, and some of the blood enzymes which reflect cell necrosis. In reindeer and caribou, blood values are lowest in June and highest in December, according to Cameron and Luich.

These workers also found a deterioration of body composition from December to June which was accompanied by decreases in total blood, red cell and plasma volumes. Some seasonal changes are quite dependent on external environment. Luick et al. (1973) suggested that the high rates of glucose metabolism by female reindeer reflected the high quality of food ingested. Low values in January were attributed to declines in the quality and availability of food. The lowest rate of glucose metabolism was observed

in May, during a period of extremely low food availability. Seasonal changes in weight, food intake, physical activities, blood, and heart rate can hardly occur without concomitant changes in metabolism. In Norway, it was reported that there was a decrease in serum thyroxin in free-ranging (Spitzburgen) reindeer, reported by Nilssen and Lingberg (1979). They concluded that reindeer exhibit a state of hypothyroidism and probably reduced metabolic rate as a mode of energy conservation in response to fasting during winter. Metabolic rate and energy intake, measured in reindeer and caribou by McEwan and Whitehead (1970) were 35-45% lower in winter than in summer.

Controlled studies to measure cold stress in calves at Mosquito Lake (Hart, Heroux, Colth and Mills),were very similar to what is going on at the moment - trying to measure from the external effects.

The other study is one recently done by Bob White and others in which they tried to measure insect harassment on animals and other natural forms of stress that these animals are affected with each year, an approach in which both behavioural and physiological studies are combined in a simulated model so that you are not looking at one thing. I think there is a problem with some of the methodology at the moment. Stress can be short-term, but the effects you are really looking at are long-term studies to assess the effects of stress. The only difficulty is that before you ever start any field studies using caribou, you are going to have to start working on the

feasibility of using techniques on animals, whether you are prepared to monitor heart rates, systems for relating activity and oxygen consumption, or whether you are using other techniques. But all of these techniques have to be worked out under lab conditions, otherwise you don't know what your variation is, and if your variation is fairly high, the results are not very reliable. The other difficulty that I see in this type of study is that there are various conditions, and various factors to look at. You also have a group factor, a sex factor, and an age factor. When you start working with experimental animals you are working with individuals. Although you may work with 6 or 7 animals, you hope they are going to be very similar. As I see it, the only way you are going to answer some of these long-term questions, is to use both the overt behaviour and lab studies.

Dr. D. Klein - Dr. Bob MacArthur is the next panelist. Bob has been working on the development of techniques for assessing physiological parameters, and Bob should be able to give us an idea of what the potential use would be for caribou.

Robert MacArthur - University of Calgary.

Because of my background I think I have probably a different perspective from several of the people in the audience concerning the topic of wildlife

disturbance. In looking at the literature in this field, a literature which has very rapidly proliferated, it seems to me there is a very notable lack of information regarding the physiological correlates of disturbance. I think this is cause for concern because any investigation of harassment must ultimately address the physiological and energetic consequences of stress - particularly if our aim is to predict the impact of that disturbance on productivity. We must know to what degree the costs of excitement or alterations in behaviour induced by harassment draw energy and nutrients away from such vital functions as growth and reproduction. Unfortunately these are rather difficult questions to answer, largely because of the technical problems associated with measuring physiological changes, and especially energy costs, in free-ranging large mammals.

Of the methods that are currently available to the field biologist however, one of the most promising appears to involve the measurement of heart rate by radiotelemetry. There are several reasons for this:

First, an elevation in heart rate is central to the physiological arousal mechanism by which an ungulate prepares itself for flight; it is one of the principal means by which an animal increases cardiac output and enhances blood flow to skeletal muscle during excitement. Secondly, because heart rate is an important determinant of blood flow and therefore O_2 supply to tissues, one might predict some association between heart rate and energy

expenditure. Thirdly, of the physiological variables that can presently be monitored by telemetry - including body temperature, respiration rate, and blood pressure - heart rate is one of the easiest to measure.

To assess the feasibility of using this technique in disturbance studies of large mammals, we have spent the past two years studying variation in heart rate in bighorn sheep in southwest Alberta. I would like to demonstrate the sorts of data that we have been obtaining using this system, as well as outline what we feel are the major advantages, as well as disadvantages of using heart rate telemetry in a study of caribou disturbance. (* Slide presentation given).

Telemetry system - developed at the University of Calgary and designed specifically for use on free-ranging ungulates. Basically, the ECG was detected by an FM transmitter stitched into a pocket of a leather saddle that fastened to the back of an animal by means of elasticized girth and neck strap. Silver or stainless steel wire electrodes were implanted subcutaneously at opposite ends of sternum, and connected to the transmitter via flexible steel leads stitched to the underside of neck and saddle straps. During the past two years we have instrumented and released a total of ten adult bighorns (9 females, 1 male) from two populations, and of these, 9 have provided usable data for periods ranging from 3 to 9 weeks per animal. During these observation periods the harnesses fit well and

caused no apparent handicap to animals. I should point out though, that immediately after release most sheep withdrew to cliff terrain on nearby mountains, where they remained isolated from other sheep for one to three days. Once they rejoined a band however, behaviour was consistent with that of other animals in the group, with a similar age and sex class. We also found the method of electrode attachment resulted in no visible infection in either domestic sheep or bighorns recaptured one to two months after initial instrumentation.

Receiver and recorder system. The initial receiver consisted of a modified commercial FM radio connected to a high-gain yagi. With this system we had a range of 2-6 km, depending on topography. The output from receiver was fed into one channel of a stereo tape recorder, while a verbal description of the animal's behaviour and environmental circumstances was noted on a second channel. Back in the lab, the taped signal was decoded, and heart rate determined from the ECG tracing on a strip chart recorder.

One of our first objectives was to examine the relationship between heart rate and behaviour in order to provide a baseline against which we could assess effects of disturbance. We found that mean heart rates and their variances were minimal when sheep were bedded, and maximal during periods of movement. This is what we would expect if heart rate reflects energy costs in bighorn sheep. We also found that when sheep were moving at night

or through timber by day, heart rates tended to be higher than during daytime movements across open slopes. It appears that in mountain sheep at least, terrain has a bearing on heart rate, and at present, we are trying to inter-relate baseline variation in heart rate to the physical and social environments of the animal, as well as to such factors as weather and season.

The second phase of this study, and one I'd like to concentrate on, concerns the responses of sheep to transient stimuli. Here we used two basic approaches:

a) First, every effort was made to document heart rate changes during social interactions, and during normal exposure to predators, vehicle traffic, and aircraft.

b) Secondly, deliberate harassment trials were conducted, in which sheep were approached to within 50 m by a person on foot.

We ranked the transient stimuli to which sheep were exposed, in order of decreasing importance, based on magnitude of heart rate responses they evoked. The appearance of free-ranging canids, be they dogs or coyotes, evoked maximal increases in heart rate, with mean elevations of 80-100 bpm.

It is also of interest that the response to an approaching human was greatest when the person was accompanied by a dog. The response to a canid was significantly reduced when the animal was associated with man. This finding may be explained by the fact that in the sanctuary, sheep are at least partially habituated to humans. Habituation may also account for our finding that sheep responded to humans only at close range, usually within 50 m. Similarly, vehicle traffic on roads elicited heart rate responses in only 14% of observed passes, and then only when the vehicle was within 200 m. The appearance of a low-flying helicopter resulted in no response whatsoever, at distances of 500-1500 m. On the other hand, a single pass by a helicopter directly over one ewe at a height of 200 m resulted in a dramatic 3.5 fold rise in heart rate.

So far I have only discussed changes in heart rate. But very often disturbance also evoked withdrawal reactions, in which animals bolted or withdrew from disturbing stimulus in "alarm posture". Our results indicate that the mean maximum rise in heart rate from disturbance and the frequency of these withdrawal responses were highly correlated. These data might suggest the observed changes in heart rate were simply a result of locomotor activity. However, this does not appear to be the case. In 78% of the trials, maximum rise in heart rate occurred several seconds before, or even in absence of any obvious motor responses. Another point to be drawn from these responses to transient stimuli was that they were very brief in

duration. In most trials, heart rate peaked within 60 seconds of the onset of the response, and recovered to pre-disturbance baseline in less than 200 seconds. This raises the obvious question, just how significant are these disturbances in terms of energy expended? Even if there is a 3.5-fold rise in heart rate during an overflight by a helicopter, how can this possibly be costly if the response lasts only 3 minutes? Taken individually, these spikes in heart rate are probably not costly at all. But if they occur frequently enough, we believe the cumulative effects could be energetically significant. Combined effects of multiple spikes in heart rate is evident if we compare the mean heart rate of sheep during sustained exposure to a nearby human with that immediately preceding the disturbance. In this case the presence of a human resulted in a 20% rise in mean heart rate. In comparison there was no significant change during sustained exposure to a distant low-flying helicopter or a distant coyote.

Finally, I'd like to mention two situations in which there was a prolonged recovery in heart rate following the termination of disturbance:

1) The first of these involved extended recovery following a period of intensive running. In this case the ewe had run 1-1.5 km along a canyon rim from an unknown disturbance, and after she stopped, approximately 50 minutes elapsed before heart rate dropped to a normal resting value.

2) The second situation involved the actual instrumentation of sheep. We found that after releasing ewes with harnesses, several hours often elapsed before heart rate stabilized and returned to normal even though sheep were resting in escape cover well away from human activities.

3) I would stress that in both these situations, animals were completely inactive during the recovery phase, and showed little if any, outward manifestation of alarm.

In summary, there were several points raised by the sheep study that are highly relevant to an investigation of caribou disturbance. First, our data suggest that heart rate is a sensitive physiological indicator of disturbance in bighorn sheep and probably other ungulates as well. Heart rate changes complemented behavioural reactions. Moreover, the hierarchy of responses we observed to a broad range of stimuli conformed very closely to expectations based on behavioural theory. Second, and perhaps more important, in the majority of cases the response preceded or even occurred in the absence of any obvious form of withdrawal behaviour. This finding strongly suggests that active inhibition, or physiological arousal is an important component in an ungulate's reaction to harassing stimuli. Third, these results indicate that when an animal is severely stressed, the

physiological response and presumably the cost of the disturbance may continue for a considerable period after the disappearance of the harassing agent.

Finally, so as not to overstate the case for using heart rate telemetry, I should point out that there are several disadvantages, and that these must be weighed against potential gains if we are going to come to a reasonable decision concerning the use of this technique on caribou. First, there is a great deal of controversy surrounding the use of heart rate to predict energy costs in mammals under captive conditions. If this method is to be used to predict energy requirements in caribou, it is essential that heart rate be correlated with metabolic rate to determine under what circumstances heart rate can or can not be used to estimate relative energy costs. Aside from theoretical considerations there are practical problems. It is a new technique. This means no one can predict how successful the system will be on caribou. It also means the system must be initially tested on captive reindeer to evaluate and if necessary, modify the transmitter-harness assembly. It would also be desirable to conduct preliminary harassment trials on captive animals. All of this testing and calibration requires time, probably at least 1-2 months. There is also the problem, and I suspect a fairly costly one, of capturing specific animals at specific times of the year for instrumentation. And lastly, there is a potential problem of maintaining continuous contact with a given animal from day to day.

With a maximum ground-to-ground range of 6 km, an aircraft would have to be continuously available for location purposes.

On the positive side, we believe the measurement of heart rate would strengthen, as well as add a new dimension to conventional behavioural studies. Sheep data suggest that it is an extremely sensitive means of identifying potential stressors, and more important, it permits a more precise definition of the intensity and duration of an animal's response than behavioural cues alone. Consequently, it should be an extremely useful tool for testing the effectiveness of measures enacted to minimize caribou disturbance.

Another advantage concerns objectivity. In a long-term research project in which several investigators may be involved, consistent methodology is absolutely essential, and I would argue that the measurement of heart rate is far more objective than the standardizing and quantifying of behavioural observations. At the very least, heart rate should provide a check against behavioural data collected by different observers. Also, because heart rate can easily be recorded on magnetic tape, a permanent copy of an animal's response is available. Because specific activities result in characteristic "noise patterns" on the radio receiver, the investigator can, with experience, identify certain behaviour patterns, even when the animal is obscured from view. With sheep we could distinguish resting,

feeding, walking and running behaviour. Also, because the signal is highly directional, the transmitter can be used for tracking purposes. Thus, in addition to providing heart rate data, this system can be used to construct detailed activity budgets and evaluate daily movement patterns of individual animals. In closing, we feel the advantages far outweigh the disadvantages, and that this system could play a significant role in understanding, and hence minimizing, disturbance to caribou associated with Northern Development.

Dr. D. Klein - The final panelist this morning is Frank Miller, who will talk about studies of overt behavioural responses to varying types of aircraft disturbance.

Frank Miller - Canadian Wildlife Service, Edmonton.

First of all, harassment can be defined basically as the introduction of an unidentified stimulus into an animal's environment, and in overt behaviour studies, we attempt to measure such harassment, or evaluate such harassment, by quantifying the animal's response while attempting to adjust to this introduction of an unknown stimulus. If you're a real purist you can take that to mean that any form of unknown stimulus constitutes an harassment; therefore, a snapping twig or ice breaking loose is a form of harassment to an animal until they can identify the source and determine whether or not it is detrimental enough for the animal to respond.

Direct observation of animals appears as the most simplistic approach to evaluating disturbance of wildlife but such work actually requires much detailed planning and design to be of true value. I believe there are at least several elements of such studies that are critical for successful results. First the quality of the observers, the method of choice of responses and environmental variables that are to be observed and the exact definition of those responses and variables, and lastly, as much quantification of those responses and variables as possible.

With regard to the quality of observers, ideally we would want people who have had experience observing animals in natural situations, but that's a luxury we don't often come by, especially if the studies involve several observers. As soon as you get more than one observer on a study you run into the problem of relevant judgements as to what they are seeing. It's just amazing if you've got six or eight observers, as we had one year, when you take the tapes and you start out by attempting to train these people all at one time and watching the same situations and record their version of what took place. There is a real need for a preliminary training session; we've got to train people by showing them films. It is very valuable to have someone who has been trained as a biologist, because one has to develop an appreciation of what he is looking for, i.e., escape, alarm, alert, etc. To know that an animal does something, like an excitation jump is a rather obvious response by a caribou, but a head

high alert, or more so, a head low alert, is something that you could easily miss if you don't know it as a defined behavioural act.

The choice of responses and variables is really a difficult consideration because at best it's sort of an educated guess as to what variables are really significant in the harassing-stimuli that an animal encounters. The animal is part of the total environment and you are attempting to isolate certain things like the position of the sun, or direction of the wind relative to harassment stimuli. I am talking now mainly about helicopter harassment that we studied, so we were interested in things like the direction of the wind relative to the flight of the helicopter, and the type of terrain the animals occupied at the time you disturbed them. It is critical that you define all these responses and variables, and techniques for measurement in great detail so that if anybody wants to repeat or evaluate your work, he really knows what you did and what you measured. It is quite significant that a major complaint with many of these types of studies is that there is insufficient description of what the workers did. Most earlier harassment studies done in Canada were supplemental to some other objectives, usually population counts, sex and age counts, or classifications, therefore it is argued that they often lacked to varying degrees the necessary planning and design of harassment studies. Objections to those studies were mainly that they were not repeatable as the definition of responses and variables was too imprecise. However, where harassment work or disturbance work is the main objective, all these shortcomings can be overcome by careful planning and design.

I don't think that people can argue that the observation of overt behaviour is too simplistic or too crude to be of true value. Such observation can be refined to the point where it has value, and can evaluate how the animals are responding to different types of harassment stimuli.

Perhaps the greatest problem in evaluating the animal's response to harassing stimuli is in determining what environmental variables are of significance in the harassment stimuli-animal situation. Harassing stimuli may be in a visual form, sound, smell or combination of two or more. You have to really develop an appreciation for what the animal perceives. An example: when we were doing our overflights of Peary caribou and muskoxen, we divided our harassment flight up into four phases, called A, B, C, D. The A phase began when the observer could hear the helicopter. It seemed like the animals were hearing the helicopter about the same time the observers heard the helicopter. The best you can do is say the harassment phase began when the observer heard the helicopter approaching. Then you have a variation right there, everyone has differences in hearing. You attempt to refine that by timing, how long it takes in seconds when the chopper could be overhead and so forth. Then you have the wind consideration. If the helicopter is flying upwind, the observer, or the animal, won't hear the machine until it's right on top of them. This creates a startling response under such conditions. If the helicopter is flying downwind, you can hear the helicopter for several miles away. The

animal might discern that as something he can't identify, and there isn't anything in its natural repertoire of behavioural patterns to be responding to stimuli at great distance. Any predator response would be at relatively short ranges, so the animal may become alerted to the sound at a greater distance and by the time the sound gets to it, it has sort of worked it out that it's not something to be concerned about, or if he is concerned he'd show it at a lower level. This is why it is very important to decide what physical and environmental variables you are going to measure. On the visual part, when the helicopter is flying in on the animals and the sun is behind the helicopter, it appears as a large dark object coming at the animals. The lower it gets to the ground the more it appears to be land-oriented, and you are dealing with animals that are concerned with land predators. They are not really concerned with avian predators, so you would expect that if its response is going to be in relation to a predator-prey reaction that you would get a greater response when the helicopter is low and our results indicate this to be true.

Also very important, is what effect the current history of the animals has on their subsequent responses. This is a big unknown. You don't know the current history of that animal or group of animals you are harassing. Maybe they were harassed by wolves a half hour before you came in. Therefore, you'd get very different results than if they hadn't been harassed by wolves for the last week. It would be a consideration that when you get into a

controlled study that you would attempt to work with the same group of animals over a period of time, so you could get so-called undisturbed information data on behaviour, data in rhythm patterns, etc. Therefore, you could document the current history and it would be better to evaluate the different levels of responses to what appears to be the set of harassment stimuli.

What role does the individual variation in behaviour play in the harassment responses? There is no reason to believe that all of these animals are the same any more than we are all the same. We know that these animals are highly sociable species. In their socialization, you have dominant animals and you have subordinates, and so on. You would not expect the dominant animal to behave like a subordinate animal under a certain set of harassing stimuli, because that dominant animal has developed a different repertoire of behaviour, or for whatever reasons, he behaves differently. You have to take the socialization into consideration when attempting to evaluate the responses that you can see.

Probably of even more importance towards the physiological side, is what is the natural range of functioning of physiological systems within individuals, and how does it vary? That is, are the mean values for functions truly significant, can they be used accurately for evaluating the levels of stresses imposed on different individuals. If you end up with

such a wide range around your means, then it doesn't allow you to really evaluate the costs to the individual on an individual basis.

The number one question, I believe, is how do you truly interpret and evaluate these functions such as heart rate, respiratory rate and ventilatory volume? Current literature indicates that we really haven't succeeded in doing this and that these functions may be of marginal value as indicators of energy expenditures. And, of those three indicators I mentioned, heart rate and respiratory rate were actually suggested by some to be of even more marginal value than ventilatory volume, a more accurate indicator of energy expenditures.

Our basic contention is that physiological studies on heart rate and respiratory rate are in their infancy and that they are very much still in the experimental stage. Much more detailed controlled work is necessary before such work can be applied to free-ranging populations of animals in a truly meaningful way. In terms of management applications, how do you really evaluate the cost to a population by so-called average energy budgets or whatever. I can't figure how you can come up with a meaningful value from such calculations.

There is no justification whatsoever in initiating harassment studies on caribou that have any real potential for causing long-term detrimental

effects on those animals. Using water crossings as an example, I just can't bring myself to believe that there is any justification for us experimenting at water crossing sites that could possibly lead to the animals stopping use of those sites. If that happens, you document it and the harm is done, so you might as well let them drill a hole or build a mine or whatever they want to do there after you've stopped the animals from using the crossing. I just can't support studies that are a simulation of harassment which may never occur, but could have a long-term effect on the animals. I realize it is much harder to follow an actual exploratory operation around and try to collect worthwhile data, but I just can't see going out and causing the harm ourselves. We are in enough trouble already; I don't think we have to do any more in that area.

Dr. D. Klein.

I'd like to take a couple of minutes and draw some comparisons with work that has been done in Alaska, because we do have an "experimental" situation in Prudhoe Bay, and the TransAlaskan oil pipeline and associated haul road. Studies have been carried out in a rather systematic way to try to determine what the effects of these activities and the associated structures have been, both on a short-term basis during construction, and on a long-term basis. It's an experiment that's continuing and one of the important points I'd like to make is, it's very difficult to draw conclusions about the

effects of these activities on caribou and migratory movements on a short-term basis. The response is going to take place over a long period of time if there is going to be a response. There may be short-term responses but you are never sure that these are permanent ones. The approach that has been taken there is to observe the overt behaviour of the animals, to monitor their movements through observations along the haul road and from the air. To facilitate these observations a number of animals have been equipped with numbered collars and several with radio-transmitting collars which transmit a signal to facilitate location and identification of those specific animals. With that technique and the combination of ground and air observations, it has been possible to determine whether there has been any significant change in the use of the range by caribou as a result of the development activities. Up to now, the observations have indicated that the traffic along the haul road is a major deterrent factor to the free movement of cows and calves from the time of calving until the rutting season. The traffic and human activities during construction work were important factors, and now following construction, it is primarily the traffic. The animals learned to associate the human activity around the pipeline and the traffic on the haul road with some type of threat. The cows and calves then stopped their free movement across the pipeline and haul road. This is a special situation not necessarily representative of other caribou herds because this is a small herd of about five or six thousand animals and their movements are primarily

parallel to the pipeline. There seems to have been some habituation to the pipeline but again it's been primarily by the bulls, and to a much lesser extent by the cows and calves. In the winter there seems to be good habituation to the use of the road and the pipeline and there are movements across it. But what the long-term consequences are, we are really not in a position to assess at the present time. I just wanted to point out that this work has been started and is being carried out, and will be continued as long as funding is available in the State of Alaska.

Termination of morning session.

DISCUSSION

Anne Gunn:

Dave outlined the consequences of harassment and the other panel members mainly emphasized approaches and methodology to study harassment, but I would like to emphasize that the context we are talking about is strictly management. I think this group has got to look at some management aspects of harassment. What we really need to know is how we are going to manage harassment, so first of all, what is harassment, and what is disturbance?

The second aspect is what is a harassment situation and how do you recognize one? The only way you can evaluate harassment situations is by the responses of the animals, so that of course, raises the question, how are you going to describe the responses? There already seems to be a polarization of the approach, one into physiological approach and the other into just using overt behavioural responses.

I certainly concur with anyone who said the physiological approach is necessary, but I think it's premature to be considered as part of management of harassment. If the technical problems are overcome to the extent that they can be used in the field with caribou, then we can measure and extrapolate the individual parameters such as heart rate, ventilation and

respiratory rates. There is still a problem to extrapolate them to an energy budget for an individual. Even if we could overcome both those problems, and I think in time we will, we know so little about the overall annual energy budget of a population and its incredible variation; for example, the effects of snow conditions, the amount of predation on that particular population, etc. Even if we can say that harassment from an aircraft overhead costs 1% of the budget of an individual we'll probably never be in a position to say what that means to the population. Would it mean the animals would have less fat that year, there would be less reproduction, or what? We're such a long way from that type of evaluation, that it seems almost meaningless to start talking about measuring energetic costs of harassment if you're interested in management.

Bob said that heart rate complements behavioural studies, or you could look at it vice versa, but I think the value of overt behavioural studies is that they provide relatively large samples of quantitified data on the responses to harassment without having to wait for technical delays to be overcome, without having to wait for the lab studies, because really, time is critical; the Baker Lake case illustrates this. We need data on managing harassment now and not waiting a year or several years to overcome technical problems.

The use of behavioural studies still leaves the point of what is the level of harassment that is acceptable or unacceptable to the manager? Some

levels are obvious, we already know that harassment to the point of pathological syndromes must be avoided, but we really don't have to do studies on that. There is one study that should be done, and that's to look at the effect of harvest techniques on animals, particularly the use of snow machines to chase animals should be studied fairly soon so we know whether we are getting pathological conditions or whether it's just behavioural ones resulting from that. I doubt that this would affect the level of harvest. The largest gap then between the measurement of the responses is the cost that can be borne without affecting the well-being of the population. There are those that would say that any additional cost is too much, but really that's outside management, so really what is the practical management goal, and what studies are necessary to achieve them?

I would like to point out here, I think there is a difference between a controlled study of harassment and a simulated study. With the controlled study you can take ongoing harassment and measure the variance and that would give you some control. It's critically important that we avoid simulated harassment, like putting compressors at water crossings, because we shouldn't be in the position of having caused the detrimental effects of harassment. There should be basic behavioural studies, at least to determine the normal behaviour of animals so that you have baseline information to look at the effects of harassment. Bill made the point about looking at the behaviour of animals at water crossings under

undisturbed conditions and that's probably the approach that should be taken. I really believe that movements are the key to harassment concerns, how they are interrupted by barriers and how we can manage them. I think the sort of study that Dave is talking about that was done in Alaska, where they looked at both behaviour and then used marked animals to monitor the movements is the sort of approach we should be considering.

Finally, I think the one important thing that has to be included in the concept of management harassment is the need for education studies. That is, we have to tell people why harassment is bad, we have to approach the pilots, we have to approach the people who are using the roads, we have to approach tourists and explain that photography can be a severe source of harassment to animals.

D. Klein:

Thank you, Anne. I'd like to open the meeting for a more general discussion, but if some panelists have specific questions on their minds, they could raise them now. Before they do that, there is one question on my mind and relative to Bob MacArthur's comments on the work that has been done with the heart rate telemetry with mountain sheep. It is my understanding, Bob, that there are techniques that have been used with domestic animals, sheep and cattle, to study metabolism and costs of various activities that

utilize pressure devices, that record respiration rate and even magnitude of respiration. It seems to me that these could be quite readily adaptable to a harness type of situation and I'd like to know if you've looked into this, and if you have, why you haven't made some effort to utilize that technique along with the heart rate studies.

Bob MacArthur:

Yes, we've looked into that possibility, and one of the reasons for selecting a harness design is that it permits us to multiplex the telemetry package. For example, by incorporating a strain gauge in the harness we could read respiratory rate, or by implanting an internal sensor we could also detect body temperature. There is some question that heart rate perhaps isn't as good a physiological indicator of metabolic rate as some of the other physiological parameters mentioned. In fact, the converse is usually true; it's only in humans that respiration rate is a better predictor of oxygen consumption than heart rate. But, I think because all of them are bioenergetic variables, one might be better off to consider a multivariate approach that integrates body temperatures, respiration rate, and heart rates. These variables are all correlated to some degree with oxygen consumption and perhaps this might be a better approach to take. Although we have thought of it, we just haven't tried it out as yet.

Bill Darby:

I would like to direct a question to Frank Miller. I would like to have a clarification of your viewpoint concerning simulation studies. This is a major topic that should be clarified. Are you of the opinion that no simulation studies should be done? Should we be simply conducting baseline data studies and then looking at mining company activities directly, regardless of all the attenuating problems that they have?

Frank Miller:

It's probably not a question I can answer without a great deal of qualification. The basic answer is yes. As I said before, I'm against any study that has a real potential for causing the long-term effect or impact on a group of animals, especially if it wouldn't have occurred had they not simulated the disturbance. I know you could argue it around to the point where someone says, "yes, we are going to develop mines within three miles of major water crossings, or ten water crossings," well, when you are faced with that reality, that changes the picture. Then I think you might have justification for going in and doing simulation work under those conditions. You may be asked if we built something at 5 miles is that acceptable? Then if that's acceptable, well then, how about at 4 miles? The lack of knowledge about the general behaviour of the animals,

or how you'll disturb the animals may lead you in a short-term study to believe it isn't of consequence. Then a year or two later, your animals abandon the range and it really was of consequence, but you didn't know it at the time, because of the type of work you were doing.

Bill Darby:

There is one thing that I'd like to point out at the present time. We have these sensitive issues and the mining companies are prevented from working in sensitive situations so you don't have sites that you can go to and look at the disturbance of the diamond drills on cows and calves. At the present time, they are prevented from interacting to a large degree. It can be expected that mining companies will put pressure on the government to open up some of these restricted areas and interaction will take place, in which case you've still got the same thing.

Frank Miller:

Yes, I know, it boils down to the case that we're never going to win the war. We have to win every battle, they only have to win one battle to win the war. I don't know how you get around that. I really doubt that we know enough about the animal right now to do the type of studies that would really give us the right answers. Especially if they are firefighting

types of studies where we go in on short-term, do a limited amount of work in a situation that could be totally different the next time the animals come through. You know how the seasons vary from year to year, what impact the insects may have at a water crossing, some year you get cool summers, relatively little insect activity. You wouldn't expect your animals to necessarily behave the same way that year as they might the next year if you get a hot dry summer and a great deal of insect activity. To do the type of studies you are talking about, it would have to be long-term studies. It seems that all this boils down to a matter of priorities and where we want the most information. Right now I'd argue that we want the most information in just understanding the behaviour of the animals, their natural undisturbed behaviour.

Now to go to Bob about heart rate, I believe at one point he said it was a measure of stress, because these animals had elevated heart rates for several hours after they were in the traps, but I'll go back to my old bit on A. Moen's work on whitetailed deer. He's been working on deer physiology for 15 years or more, and is into heart rate and so forth, in a big way. His results show that you can get as much elevation or more elevation in heart rate when animals respond to rain falling on dry leaves, or when fawns that are bottle-fed hear their bottles being prepared for feeding, as they do when one drives a skidoo by them within a couple hundred yards. So I ask you, how do you interpret that? How do you assign a value to those types of readings? Are you going to tell me that an animal exposed to

rain, like a black-tailed deer, should never have come into existence since it has to live through nine months of rainfall? Every time a calf sucks on a cow it's suffering stress.

Bob MacArthur:

I think there are several things here, and one is that Moen worked only with captive deer, and another is that the holding pen was adjacent to a road and a nearby farm. The animals were raised by hand, and again it comes back to the question of just how realistic is that situation in terms of wild deer? All their data were based on young animals, while we worked only on adults. There might also be some species differences involved. I can honestly say that with the sheep at least, there was surprisingly little variation in heart rate. By very simple means, we demonstrated fairly significant and consistent changes in heart rate, and our confidence limits were quite narrow for the most part, certainly with all maintenance activities. So I don't think that's a major problem.

Frank Miller:

You know from watching caribou in the wild that in the course of an hour, animals quite commonly become alerted or alarmed to something. You can't perceive what they are alerted to; it might be some sound, or a whiff of a wolf. If this is a stressed situation then we've got to take into

consideration the elevated heart rate for so many seconds or minutes. I just can't see how you begin to evaluate the excess of energy expelled.

Bob MacArthur:

I've worked under all kinds of weather variables including snowfall, wind speeds, etc., and various social contexts of the animals and I'm really having a hard time finding consistent relationships between those variables and heart rate. There just isn't that much variation in heart rate during maintenance behaviour in bighorn sheep. This may or may not hold true for other ungulates.

Dave Klein:

It seems that free-ranging physiological monitoring techniques has a lot of potential in helping to understand what we are observing with regards to behavioural responses, and it falls in the category of gathering baseline data to aid in understanding reactions of animals. But I guess the concern that is expressed by Frank, and I think that which I tend to agree with is that we're not in a position to understand baseline activities of caribou in relationship to physiological responses. Are we in a position then, to initiate a study to determine harassment effects and to be able to interpret those effects in a realistic way? By this I mean in terms of a regional payoff in view of the amount of time and money we'd have to invest.

Bob MacArthur:

I don't think you can divorce the two items, you would have to, hand-in-hand, do a seasonal study of the variation of heart rate, and as I mentioned, probably metabolic rate too. You certainly just can't go out and do a few flight lines over an animal and look at the increases in heart rate and make any kind of judgement. Also, I'd like to stress that I'm not suggesting that heart rate is an alternate approach, it's just a refinement of a behavioural approach. It's simply adding another sense. You really have to work with this system to get a feeling for the insight it gives you into the state of security of the animal. You combine that with behavioural observations, and you have a very powerful tool. I think when we're concerned about harmonizing industry with caribou biology, it's important to provide quantitative data on responses to a wide range of potential stressors.

Others have brought up this point that we're not in a position to measure productivity and I agree 100%. Even to look at it from an energetic point of view, we have to know what the cost of that disturbance is, and I'm not really sure heart rate will give us that kind of information. We have to know the cost of harassment in terms of the seasonal energy budget of the animal, and then on top of that we have to know something about the ability of the range to supply energy and nutrients to possibly offset the cost of

that disturbance, and this could vary seasonally. So I don't think even with heart rate we can come close to that objective on a short-term basis. But as I have stressed again and again, what we have got is a method for identifying stressors which is much more objective and much more sensitive, and defines the time frame much more accurately, than strictly behavioural observations. I would emphasize that so long as there is a physiological response, even if you can't equate heart beats with calories, there is bound to be some cost to the animal because arousal, which involves an increase in muscle tone, mobilization of energy reserves, and massive cardiovascular changes, generally requires an increase in energy expenditure. Animal scientists have known this for years. Again, there may not be a proportional change between heart rate and calories expended, but there's probably a cost just the same. So maybe there is a 20% increase in oxygen consumption, a 40% increase in heart rate or maybe only a 5% increase, but the point is, there may be a cost involved, and I think we can make a more intelligent guess as to the potential impact of these stresses by combining heart rate with conventional behavioural observations. That would be my main point.

Dave Klein:

But wouldn't you think that it would be desirable to do the calibration of the relationship of heart rate to energetic costs of varying activities in the laboratory?

Bob MacArthur:

Oh, definitely. I agree with that too, that would give you at least a rough idea of quantitative values in relation to the seasonal energy budget, rather than just defining the critical periods during calving, post-calving, etc. We probably have a lot of insight right now into which are the critical periods, but this way at least we can identify when the energy demands of caribou are greatest, even if it's only using heart rate in combination with metabolic studies. Even just measuring metabolic rates with semi-captive animals, I think would be very useful.

Another point I would like to bring up, and one on which I agree with Dr. McEwan, is that there are just certain things we can't measure any other way except by bringing the animals into captivity. But why not look at some of these changes, the sorts of things he was talking about. We're not presently in a position to go out and measure hormonal levels in the bloodstream, for example, by telemetry. But why not look at some of the physiological changes that are associated with stress, changes that are potentially pathological, and determine how they relate to parameters like heart rate that we can measure using radio telemetry.

Anne Gunn:

Moen has about 10-15 years' data on heart rates. He used captive calves that were trained from within a day of birth to wear the elastic bandage

and he submitted them to various disturbances, including skidoos. His conclusion was (and also Rollins who worked on elk calves agreed) that the heart rate is just too sensitive to use as a measure of disturbance. It responds to too many things that really aren't necessarily a disturbance to the animal. Like Frank mentioned, raindrops and the approach of another animal cause more disturbance than a wolf howl or a skidoo. I think what we're saying, Bob, is not that heart rate is no good, not that a metabolic approach is no good, but it's not really much use to managers at the moment because it doesn't really tell us very much that we can use.

Bob MacArthur:

You mean it's not really that important to be able to discriminate very subtle responses to potential stressors? I'm just saying, if you really have to make an intelligent estimate as to the sorts of things that may be stressful to caribou, you are still better off using heart rate rather than behavioural observations alone.

Anne Gunn:

I think it's wrong using both approaches and since we're short on time, and since we're concerned about talking to industry tomorrow rather than in 2 or 3 years, then the behavioural approach offers the best alternative.

Dan Caruthers:

I'd like to make a comment to emphasize the importance of both approaches. There are situations where you have human activity going on and you could be watching your animals apparently carrying on quite normally. You note this human activity approaching or retreating, but the animals are not exhibiting overtly any response that you can detect towards this activity. The animal is carrying on its activities apparently normally, but it is really avoiding that human disturbance which is approaching it, but you can't distinguish that overtly. I wonder if in situations like that, which I think occur quite frequently, that you are, in fact, disturbing quite a number of animals but not recognizing it, by overt behavioural responses. If they were instrumented physiologically, you might detect some other response, a physiological response which is above normal.

Dave Klein:

That's a good point, because that's one of the questions that resulted from some of the work that was done along the TransAlaska pipeline and haul road. Caribou were not present in as large a density close to the haul road, as away from it, yet we didn't see a lot of obvious response of animals when a vehicle went by. But even without any visual evidence that the animals were aware of the traffic, they nevertheless didn't approach or didn't occur at the same densities close to the road as they did further away from

the road. Now, what are the conclusions from this? Our problems were precisely those you raised. Are those animals that are close to the road responding, at least without any overt response to the stimuli, responding physiologically in some way? Is it conceivable that there could be some stress generated without overt response? I think that's a really valid question to ask. I think the problem, however, is in whether the technique of heart rate monitoring is going to provide an answer to that question. I think that most of us are saying that it may potentially in the future, but the degree of refinement now is such that we can't interpret the results from heart rate monitoring in a way that would provide the answer to that specific question. But I don't think there's any disagreement that the approach, heart rate or other monitoring of physiological parameters, has potential for answering those questions in the future.

Anne Gunn:

Dave, I think looking at overt behaviour will provide the answers to the points you raised as to whether the animals were disturbed. If you watch the animals for long enough you will know if they are avoiding an area. At least if some of them are, you could look for more subtle things like changes in daily activity patterns. You can get all that information without monitoring physiological parameters, so why not take the behavioural approach?

To go back to the point that Bill raised about industries asking why can't we move in, and asking us about simulated studies, I think the approach to take is to collect the basic information, how the animals respond at water crossings and then allow industry a limited approach, and say this is a trial basis, and we will see in several years what happens. I think we have to take a compromised approach, and that we can't be purists and say you industries can't go in, we don't want to do simulated studies either because we don't want to disturb them. I think we've got to accept life as Frank pointed out, there may be some sacrifice areas to gain the knowledge to protect the other animals. I think it's critical that we have to obtain knowledge of that behaviour first.

Cormack Gates:

I wonder if I could comment on that and perhaps ask a question at the same time. We're talking about the readiness of physiological monitoring in relationship to immediate need and to assess the level of disturbance and the effects of disturbance. If we're talking in that context, then acquiring the necessary background data to determine the activity pattern of normal activity versus altered activity patterns of animals would take a tremendous amount of time.

Anne Gunn:

I think perhaps that's true. Because the animals have to face such variations in weather patterns, we do need several years lead time, but I don't see any way of shortening it.

Question:

What's needed at this point in order to refine our assessment of what disturbance actually does to the animal is basic research, be it on the behavioural side or physiological side, and we're talking about some time involvement here in developing that data base or techniques or whatever. It seems to me that with the time required for the behavioural baseline data to be acquired and the readiness of some of these systems that you're talking about, perhaps the two techniques could be combined. We could then talk in terms of a combined approach to basic research and perhaps addressing the problem of limited resources. Do we need to go the route of basic research at this time?

Dave Klein:

I think maybe Bob, you should tell the people here that perhaps this system you've been working on is not as complex as a lot of us might think it is.

Bob MacArthur:

Yes, I don't think it is myself. I guess it frightens people because it appears to be a new approach. However, I would point out that the idea of using heart rate as a measure of arousal is not new at all; it's been used for the last 20 years by psychologists in situations and experiments to measure anxiety. It is being used right now in the medical field for assessing occupational stress in people. In fact, someone has built a cardiotachometer which actually integrates heart rate over 24 hours in a person. It has a built-in tape deck, the output of which is fed directly into a computer. So heart rate telemetry is only new in the wildlife application, and as far as I'm concerned, the major problem is not whether it should be used, but whether or not it is feasible to use it on caribou and whether or not it can provide useful management data for this species.

As far as we can tell, there really are no major technical problems. We don't foresee any major problem with instrumenting animals, but because I've never worked with caribou, I can't be certain of this. It may only require modification of a harness. But I would also like to point out that even if we worked only with reindeer in captivity we would still get useful information, even if it was just correlating heart rate and behavioural responses.

Dave Klein:

In response to concern about aerial surveys and how we count caribou raises another point that is very relevant to our discussion about disturbance. Biologists carry out aerial survey work to count animals and to survey for sex and age compositions. In doing so they fly at relatively low levels over the animals, and no effort, at least very little effort is made to assess what the consequences of that activity may have on the animals. Yet, on the other hand, we certainly decry that type of activity associated with industrial activity. It seems to me that a high priority should be placed upon assessing the consequences of biological survey work on caribou and other wildlife. How much disturbance are we causing to the caribou by this type of activity? We obviously need information for management on the numbers of the animals, and the sex and age composition. But are there some cases where the costs in terms of animal disturbance may exceed the justification for doing the survey work? I don't think that this has been dealt with adequately by management agencies throughout North America.

Anne Gunn:

Dave, that raises the point, how do you estimate cost? And we're back to our old argument, I think.

Bob MacArthur:

I think that's one area where heart rate would be quite useful. Bill mentioned the potential for harassment at 1,000 feet above ground level, but I'm also struck by the skill that's involved in making accurate behavioural observations at that height. With heart rate telemetry, of course, you can fly at any height you like, and still monitor the animals' response. Again, I think telemetry will give you an extremely sensitive measure of what types of aircraft disturb the animals, and to what degree, at least in terms of a physiological function. So, I think this is one area, just by itself, in which it would be very useful to put at least a few transmitters on animals and do overflights.

Frank Miller:

I'd like to caution that any kind of studies to determine the response of animals, whether you're just looking at overt behaviour or looking at physiological responses, should not think in terms of just people in aircraft, because you have to have people on the ground to determine the behaviour of the animals prior to the disturbance and the duration of response. You may be able to monitor the heart rate from aircraft but you can't monitor the behaviour adequately. You have to relate the two in order to interpret your data.

Bob MacArthur:

That's true, but by using telemetry, you can monitor both heart rate and behaviour from the ground or air without seeing the animal. If he runs into a gully, and this has happened with bighorn sheep quite frequently, you can continue to record these variables. Of course, interpreting behaviour from radio signal fluctuations, requires several hours of watching the animals beforehand. Then if he does disappear on you, or if you're 1,000 yards away or a mile away you can still record the response.

Anne Gunn:

I think you'd be walking into a real pitfall if you say you don't have to watch the animals. You may know from the calibration that the animal ran but what you may not have seen is that a wolf suddenly appeared out of the bush, and caused that animal to run at the same moment that your plane went overhead.

Bob MacArthur:

Well my point is that you can calibrate certain behaviour patterns by watching the animal and listening to the radio signal, and you can consistently determine the behaviour of the animal subsequently whether

it be at night or when the animal is obscured by vegetation. It is true that you should consider concurrent environmental factors that might coincide with the stressor, and possibly bias the animal's response. However, if you do enough samples I think you can minimize that problem. The example you suggested is a very unlikely event, I would think.

Doug Crompton:

The point I would like to raise is with a great deal of concentrated discussion on whether physiological factors or observed behaviour is the better measure of response to a stressor or harassment, we still seem to be far away from the main problem which to me is how much worse off is a caribou population when subjected to certain levels of harassment? I say worse off as a very general term because I'd like to try and see some definition arrived at, in terms of what does it mean to a caribou population to be well-off? Okay, so you stress a caribou or set off caribou whatever way you want to do it and you either raise the heart rate or elicit an observable response, but is there any way to know what that is going to mean to the population in terms of reduced winter survival or reduced population. Is there any way to get at closing this knowledge gap, the knowledge gap of overall effect of harassment on the total well-being of the population.

Dave Klein:

I think you've put your finger on something that is extremely important and that is, we cannot interpret the results of experimental harassment work, whether it's behavioural or physiological unless we have adequate baseline data about the biology of the animals and that includes energy budgets that you've mentioned. I think that an underlying assumption has to be that that kind of work has to be carried on before, or simultaneously with any other work related to harassment.

Doug Crompton:

I think one point would be, not only that we need baseline data on the energy system, the behavioural system and the reproductive system of the animals, but that harassment studies should consider whether there are mechanisms by which the animals can compensate for energy losses. In other words, is summer forage adequate to replenish energy losses due to harassment on summer ranges especially where it may not be available on winter ranges.

Dave Klein:

Yes, I think that it is important when talking about the Northwest Territories as we are, that it's not necessary to re-invent the wheel here,

or for that matter in Alaska. There's a real advantage in being able to use comparative work that's being done with caribou and reindeer throughout the world. This was brought very much to our attention last month when we were at the International Caribou/Reindeer Symposium in Norway. It's quite obvious that if you are studying your own little population in your own environmental setting that you frequently don't see answers to obvious problems until you realize that someone else is doing a study on another population where some of the variables are different. Then you might be able to answer questions that you hadn't been able to answer previously, and probably wouldn't for a very long time if you continued your own approach in isolation. So there are opportunities then to apply knowledge from other studies done in other parts of the world, and the level of knowledge is advancing rapidly, particularly with regard to basic biological factors such as energetics of seasonal cycles of animals.

I, from my own experience, know that if you're doing research on animals you can accelerate your accumulation of knowledge if you study two or more areas in such a way that you can compare them rather than just study one population and try to draw all conclusions from that one population. But I think it certainly is critical that baseline information be gathered. Our experience in regard to Prudhoe Bay and the oil pipeline situation is that now we find ourselves in the awkward position of having difficulty in interpreting some of the data we are gathering because we didn't have

adequate baseline information prior to the development activities and this limits the conclusions we can draw from the data we are collecting.

Mike Kingsley:

Nonetheless, it seems very difficult for any of the proposals so far presented to ever be able to detect changes in growth, reproduction, or survival, even if you had baseline data.

Dave Klein:

I think a single study isn't going to answer that question. All you can do is get bits of information which, when used with other knowledge from other areas and other populations, and other situations, you can build a case then for management, a scenario that would provide adequate management guidelines. I think that's what we're doing now and I think that we'll have to continue that approach in the future. We can however, refine that approach, and where we have unique environmental situations then we have to focus studies on those particular situations to give us the additional information to help to interpret the knowledge that is available.

Anne Gunn:

Mike pointed out the gap, that we don't really have the baseline information to extrapolate from the response of an individual to the population, so it

is difficult for us to decide how much harassment that population can take. There is one area where we can look at harassment on a population and that pertains to barriers. We do know that a part of the population is moving, and if we put a barrier across that movement then it will have a marked effect on the population. That's why I think that barriers are similar in respect to pipelines; it could be such a critical area that it should be studied straight away. I think we should be focusing on that now regardless of the actual approach.

Dave Klein:

There are many good examples in Scandinavia and Siberia where transportation corridors have resulted in fracturing a range or forcing the animals to use a smaller portion of the range. This has lead to reduced productivity and reduction in population size and abandonment of portions of the range. In Scandinavia with wild reindeer, there is pretty good evidence of reduced calf survival associated with intensive recreational activity by skiers on the calving grounds at the time of calving.

Question:

Is there also some evidence showing up now that perhaps some of these abandoned ranges are now being re-occupied?

Dave Klein:

In Norway there is a case where a range was split in half by a highway and a railroad and the wild reindeer after several years discontinued their crossing of the corridor. The resultant density was very high then for the remaining range available to the reindeer, and they over-grazed the range and the herd declined very drastically from 15,000 to about 1,500 animals. The abandoned range went unused for a number of years and then finally a few animals started drifting over and using it. They have established a new population there now which is increasing fairly well on the new range. But the recovery of the other half of the range has been very slow so that there it is apparent that the consequence has been reduced overall productivity. Whether the two populations which are essentially separate, are equal to the original population, remains to be seen. Offhand, that's the only one I can think of, but there may be others where there's been re-occupation of abandoned ranges.

I think if the range is abandoned as a result of a transportation corridor, the opportunities for re-establishment are greatly reduced. It seems to me that is a consideration with regard to North America that may be very important. Several caribou biologists maintain that the exchange of animals between populations is extremely important for the long-term population dynamics of large herds. When a herd is reduced to a very low

level for whatever causes (climate, predation or human predation or all of them together) that it may not be able to recover because of continued predation pressure or other factors, without a spillover of animals from an adjacent herd which may be at a higher level. The point is that the chances may be greatly reduced for this spillover if a transportation corridor is developed between herds.

Even though there may be no major migration between herds, for example, the Trans-Alaskan oil pipeline goes between two major herds (the Western Arctic and Porcupine herds). We can argue that this is really fortuitous and therefore has been no impact as a result of the pipeline on those two herds. Although that certainly has been the case up to now, what about possible long-term exchange between herds. We know that there have been exchanges in the past. We don't know how large, or how significant they were in terms of the population dynamics of the two herds, but at least on a theoretical basis that's a major consideration. Also on a long-term basis we know that there has been genetic exchange between herds and we assume that this has had some long-term value in terms of the evolution of caribou. Whether that's a consideration for management purposes on a human time scale, we don't know. These are things that should be at least thought about.

Bruce Stephenson:

What concerns me is the remark that Bill Darby made, and that is industry is questioning our regulations and why we impose them. They want answers and they want facts. Is it sufficient to say that reindeer have been affected by human disturbance in other areas; that when you have a disturbance the caribou obviously runs off a mile, its heart rate quadruples and, as Eoin will tell me, that it took another 500 kilo-calories for this energy expenditure, but it could possibly recover that through available food, depending on the season? In other words, we come back to theory, how this will really affect that animal and its ability to survive, or reproduce. Is this type of information adequate to meet the questions raised by industry?

Dave Klein:

I'd say not in itself. Anne Gunn's point is a critical one, and that is education. If you're going to be effective in management you have to convince the people who are going to be affected that what you are doing has some basis in reality. I think that there is a great lack of appreciation for the complexity of ecosystems of which caribou are a part. Industry is ready to draw whatever conclusions they see fit from the Trans-Alaskan pipeline and they may not appreciate the fact that it may take 50 or more years before we can draw any sound conclusions about the effect of

that pipeline on this small herd of caribou, the Central Arctic herd which is adjacent to the northern portion of the pipeline.

Caribou are exposed to many variables; their migratory movements put them into very different types of habitat where they experience different climatic factors, different predation levels and different hunting pressures by people. All of these variables are things that make studying caribou extremely difficult and it makes the system to which they belong very complex, so it's not surprising that we find so many areas where we can disagree. Because the problem is a difficult one, I think we have to convey the complexity of this problem to the public, to industry and to other people. This is where I think education is of critical importance, not to say that we don't know the answer but to say that the answers are complex, and these are some of the reasons why they are complex. When we prescribe a management regulation, maybe we're doing it on the basis of limited knowledge, but it's related to an understanding of the more complex relationships that exist. Why do we want to avoid harassment of caribou in a given area? There are many reasons. One of the more important ones is as it relates to the tradition of movements. If you break those traditions, then you've precluded the use of certain range components which we presume are essential to their well-being. I think the point of education is a critical one which needs to be stressed more than it has.

Question:

You mentioned drilling yet do we really know the noise level of drill rigs and associated activity? If industry are allowed to go in, say close to the calving ground, or close to water crossings, and set up things, what effect does this noise have on caribou?

Bill Darby:

These are the kind of things which are on the board for study, all baseline data are certainly going to be looked at. They are the kind of things that we can do because we know we can handle that aspect of it. It's the other controversial issues that we're trying to settle. We're going to be looking more closely at the use of water crossings and the normal behavioural patterns of caribou at water crossings. As far as diamond drilling and things of that nature, these are rather minor issues which we're not really that concerned about. The main concerns relate more to long-term development and much more serious aspects of industry's presence. The problem is that everything is coming so rapidly. The increase of exploration activity in the Baker Lake area has grown substantially in just 2-3 years; there is a necessity for regulations to be developed within a season or two. There are situations where companies have claims on certain water crossings. They've already expended perhaps so many million dollars in investigating those claims and now there is a year-round closure on their activity there.

Well, as soon as things are settled on a political level, the possibility of them being in there, going to court over the issue is not remote, and you're faced with these kind of situations where you have to present factual data in a court room, on which you are arguing that the necessity of having this crossing closed to mine development is indeed important. What facts are you going to be using in trying to prove your point? The problem is, we are trying to operate on a margin of error, we are trying to operate with controls which give us a little bit of room to move, a little bit of leeway to correct for our inaccuracies and our lack of data. We're always under pressure to use only the bare bones minimum controls. We don't want any room for error, we don't want that incorporated into regulations. So where are we, you're two-bitted to death even after you establish those minimum controls, and we're just trying to get a concensus as to the approach which is the most efficient on a cost-benefit basis to give us the specific answers, or an insight into the specific answers that we need as soon as possible.

Question:

Say you've got 28 water crossings, are these ancestral ones or are these just intermittently used?

Bill Darby:

Some of them have a lot of documented use and others, their importance is more tenuous. They are being looked at one by one in an attempt to evaluate just what their status is. At the present time, they have been designated because they have been pointed out as being important by both biologists and Inuit.

Questioner:

But caribou only use the water crossing at very specific times of the year?

Bill Darby:

That's right, but if an open-pit mine developed there, it's not going to matter if the mine shuts down for the two week period, you can't move the equipment out.

Questioner:

Well, there's been a lot of mining and exploration around Yellowknife and there's still caribou.

Bill Darby:

We are not trying to exclude industry, if there is room for industry to be compatible with caribou, fine. What we are trying to do is to walk that narrow path in the dark for there is a possibility of mines developing within the next ten years on a calving ground, and that possibility is not remote either. There are ore bodies known to exist in the Beverly calving ground which may, with further investigation, prove to be quite interesting and there'll be requests or pressure to allow intensive exploration that might indeed, show a mine development to be feasible there. So you have a mine developing on a calving ground, well, that in itself may not be so bad, the area involved with uranium mining is quite small, but we have to try and evaluate or estimate the consequences of all the related activity which would be less than 10 sq. km. I think there is a mine in Australia that is a very large one and it only involves about 10 sq. km. This is a relatively small area in relation to a traditional calving area, for example, the Kaminuriak calving ground is something like 15,000 sq. km. It's not simply that. What are the consequences of the related activity? For instance, the possibility of road construction or power line construction may be an issue in the foreseeable future. We're not really worried about those kind of permanent developments yet, but a winter road is a foreseeable request. What are the effects of a winter road traversing part of the calving ground perhaps to where a mine site might be?

It would likely be slow to thaw in the spring when the cows moved in there. Would it cause some problem in movement? Should it be knocked down by bulldozers before the cows move in to facilitate its thawing? These are the things and issues which we are trying to cope with.

Questioner:

Are you suggesting that you are going to build (simulate) a winter road?

Bill Darby:

I'm suggesting that perhaps a short section might be built on a calving ground to study caribou movements, and their reactions to it not with any traffic, but just the structure itself.

Questioner:

What if the reactions are detrimental, what if they desert the calving ground?

Bill Darby:

Well, I'm not talking about a calving ground in total, I'm only talking about a very small portion of it. What we would be looking for would be

a zone of avoidance around the road, or perhaps try to quantify the amount of crossing activity, if any.

Questioner:

I think there's enough information now in the literature and from other studies to just extrapolate on, to provide guidelines for how you deal with a winter road on the calving grounds. I think that probably for management purposes there are certain things that you should do, maybe we've already done that. One is to classify the calving ground as a critical management area, so that industry or anybody else that is going to work in those areas have to be prepared to accept greater restrictions on their activities. You'd be very conservative in terms of how you deal with those activities. If there are some things that you cannot prevent such as development or exploration in an area that has already had a tremendous amount of investment in dollars invested in it, and if you can not stop that in the heart of the calving area, then you provide strict guidelines to minimize the impact on the animals. You may have to provide some restrictions that may not be too well documented for studies, but it's better to be on the safe side than to take a risk with these populations. I agree that you can't stop development solely for maintaining the caribou habitat in its pristine state but I think you have to use the guidelines for management, that you should try to retain that state as much as possible.

Bill Darby:

Your recommendations in that regard have already been implemented in general terms by the Territorial Wildlife Service through coordination with the Land Use Branch of Indian and Northern Affairs. The zones have already been delineated. As to informing mining companies what development may take place in these areas, the companies can expect to have to adhere to strict regulations to ensure the accessibility and the value of the areas to caribou. What we are looking for however, are data with which we can shore-up our arguments because we foresee a need to have to strengthen them.

Anne Gunn:

I would like to reiterate the point that we have to compromise with industry. Like you said, we can't keep the caribou range in a pure state. We're going to have to expect some sacrifice areas. I believe the calving grounds should be totally protected, with no experiments and no simulations on them. They are relatively few, and only one to each herd, therefore they are that much more critical. Each herd uses several water crossings. We don't know why because we lack the basic information as to why they prefer one over the other in certain years. Perhaps we could allow some industrial development near some of those. Industry is then getting some of what they want and we're keeping back some of what we want.

Bill Darby:

The problem in that regard is the specific crossing you are talking about. The ones which will receive requests for development are ones that are not being used by the Beverly herd at the present time. There are very few caribou using them. The majority of the herd is moving west during the post-calving period and not using the crossings along the lower Thelon River by Aberdeen and Schultz Lakes. So the companies move in and they are allowed to go ahead and develop the area and then bang, the herd changes its pattern and starts moving east in post-calving movements, perhaps because of some unknown environmental or range change, and all of a sudden they are presented with these obstacles. There are only a few alternative crossings in that area; it's a topographical situation where you have narrow funnel gates to the other part of the range. So it's pretty hard to argue, that because you haven't seen any caribou activity there in five years you should be allowed to develop a mine there.

Anne Gunn:

I agree it's a possibility that we could get situations like that but I don't see any other way around the problem, and I don't think using simulations would give you the answer.

Norm Simmons:

Back to your statements about what is known world-wide on caribou, reindeer and other species interactions with humans and their structures and vehicles, have you in Alaska, been able to bring this stuff together and use it effectively in your dialogue with "John Q. Public"? Has it been of value in effecting legislation to protect any of your species there, or is this still something that you're calling for?

Dave Klein:

Recently, we've used it most effectively relative to the Alaska Lands Legislation that's before U. S. Congress to set aside wildlife refuges and national parks in several areas in Alaska. I testified before Congressional Committees three times in Washington, specifically on the problems of development, particularly oil and gas development relative to caribou. In the testimony that I've given, I've drawn heavily upon other areas besides Alaska, but using also the Prudhoe Bay and oil pipeline situation in Alaska. By using this approach and continually hammering it home, I think we've been effective in getting recognition by U. S. Congress of the problems. Now what the final decisions will be, I'm not sure, but the focal point has been primarily the calving grounds of the Porcupine caribou herd which is presently in the Arctic National Wildlife range. The proposed Legislation raises the question of whether this area should be

declared a wilderness area, which would then preclude oil and gas exploration, or whether it should just be a wildlife refuge but available for oil and gas exploration under strict regulations. The House of Representatives has passed, overwhelmingly, one bill which would give it total wilderness status and would eliminate oil and gas exploration there. The justification was because of the potential impact on caribou. That's surprising in view of the current energy situation in the U.S. However, the U.S. Senate also has to vote on this legislation and the Senate is more energy conscious and less environmentally concerned. It is quite likely that their legislation will not include wilderness protection for the Porcupine herd calving grounds and then the two bills will have to be ironed out in joint committee, and my guess is that the Senate version will prevail. So all I can say is that I think we've made Congress aware of the problem, so now, at least when they make the trade-off they know what the potential consequences are. But also in any legislation that comes up, there will be more strict guidelines with regard to research activities to be carried out, either before the exploration activities are undertaken or concurrent with them. Presumably there will be rather high level funding for this research. So yes, I guess we have used this approach, we've made some headway. On the other hand, there are some elements in our society that are trying to play down the impact of northern development on fish and wildlife values and aren't listening or are trying to re-direct the public's interest.

Norm Simmons:

I overheard in Toronto at the North American Wildlife Conference a criticism of the forest industry in calling for more research into this and more research into that, without pulling off the shelf the data that they have and selling it to John Q. Public. I think this is what you and Anne touched on, and as we make up a budget for the next fiscal year, we wonder where the emphasis should go. Bill has sketched a scene about things happening rapidly and others are saying we don't know what we're doing. We're walking in the dark as far as data on human-caribou interactions go -- can you toss me a lifeline and say that really, we had better start using what we have. Perhaps speculating, perhaps extrapolating from an area remote from the N.W.T. and selling this information now to the legislator, to John Q. Public, to the schools and so forth. And that is where we should focus more emphasis. Not at the price of research, but certainly more strongly than we are now.

I wish that we, as a profession, were more courageous in making statements based on shaky data. Certainly other professions do this. We always have to have the thing nailed to the wall before we'll make any statements at all, and this I think, is weakening us when we get up to propose legislation and protected measures for an animal.

Dave Klein:

I think that one of the problems that we face in wildlife management is that we all recognize that wildlife management isn't a very precise science. We're always making guesses, you're never going to know exactly how many animals are out there, whereas in agriculture a precise count of animals is possible, or in mining survey work can be done that will give estimates of mineral potential. Biological systems are also very complex, and as a result we know that wildlife management is not a very exacting science. On the other hand, when we go out and collect data ourselves, even though it's not very precise, we somehow seem to feel that we can stick our neck way out on the basis of that data, but we are very reluctant to do so on somebody else's data, especially if it comes from outside of our region. I think that we should recognize the limitations of our science, but then we should also use all of the data that is available and use it most effectively and save a lot of money in the process.

Norm Simmons:

When we are faced with several declining herds in the N.W.T. alone and we refrain from making recommendations or decisions, then we may well end up doing what we usually do, and that is documenting decline.

Dave Klein:

SUMMARY

I'll try to summarize some of the salient points, but please recognize that I haven't, and won't attempt to cover everything. I think it was basic to the panel discussion that Bill Darby pointed out some of the urgent and unique problems that are facing the N.W.T. with regard to caribou management and the focus on caribou disturbance. He said that there were three areas that needed information for management:

1) the possible consequences of low level aircraft flights;
2) the effects of ground activities associated with drilling, exploratory drilling and traverses; and
3) the proposed developments at specific caribou water crossings.

He also pointed out that for proper management of caribou in the N.W.T. there is an important need for baseline data on populations and range components. Eoin McEwan stressed the difficulty in working with free-ranging animals and pointed out that it was almost impossible to use controls when you're doing studies with free-ranging animals, particularly studies that relate to physiological consequences of harassment. The handling effects associated with instrumenting animals is also a difficult one to contend with when you're unable to have controls bearing instruments that have not been handled. He also stressed the difficulty of interpreting

the effects of stress. Most studies of this nature, including the studies of overt responses to harassment, are only measuring the short-term effects on the animals and there have been no long-term studies because the experimental designs for such studies are perhaps too complex to be realized in the near future. Bob MacArthur demonstrated through the effective use of slides, the development of the heart rate monitoring technique which has been extremely successful and problem-free in the field with mountain sheep. He also stressed the value of this technique in differentiating between active responses in animals that may be stressed or disturbed versus the overt behavioural responses of the animals. I think he also acknowledged the need to correlate heart rate with other indicators of metabolic rate. He certainly acknowledged the limitations of the technique with regards to its application in the field, although he expressed optimism with regards to its potential for caribou studies.

Frank Miller pointed out that caribou respond to disturbance in relationship to whether the animals perceive the various disturbances as threatening. I don't think he used "perceive", that's my interpretation I guess, but in effect, he did point out that it is helpful to think a bit like a caribou if you're trying to interpret behavioural responses or other responses associated with disturbance. He stressed the critical importance in any disturbance studies in standardizing the methodology, training the observers, so that they are going to record information in a similar manner and he stressed the importance of developing experimental design which is clear-cut

and will serve the purpose that you are seeking. In other words, research of this nature is of little value unless the design is well thought out to eliminate as much as possible the variables which are going to influence the results that are obtained. He then drew on his own practical experience to stress the difficulty of doing controlled studies of any kind in the field. He pointed out that harassment studies are not easily repeatable and that when you are doing such studies, you have to have people on the ground as well as in the air. He also stressed the difficulty in interpreting the individual variation that is reflected in the response of animals, pointing out the difference between dominant and subordinate animals and their response to disturbances. He also stressed that in interpreting the data, you have to know something about the previous history of disturbance to the animals, and that knowledge is frequently lacking.

Anne Gunn mentioned that all of this work is oriented toward providing information for the management of disturbance or harassment and that the focus of attention frequently isn't on that objective with regard to studies of disturbance. We can conclude that the problem of management of caribou is an extremely complex problem. Wildlife management isn't a precise science and caribou management is perhaps one of the more difficult aspects of wildlife management. Caribou, unlike most other wildlife, and certainly other ungulates that are more sedentary and less social in their behaviour, are much more difficult to deal with, because they live in very complex and geographically very large systems. All actions, human or otherwise, that

affect caribou have synergistic relationships which are difficult to interpret. This complexity of caribou ecology makes field work, especially controlled simulation studies or disturbance studies, extremely difficult to undertake. The variables that are involved in influencing caribou behaviour and movements are usually not clearly understood, therefore the interpretation of results is extremely difficult.

I think it's generally recognized that the techniques for monitoring physiological responses offer the potential for interpreting studies of harassment in the future, but there is, if not a concensus, a majority feeling that heart rate monitoring needs further development under controlled conditions in order to be able to interpret the meaning of heart rate results carried out in the field.

The importance of baseline data was certainly stressed repeatedly especially with regard to migrations, calving grounds, energy budgets and population responses. Again, I want to stress the urgency of obtaining information on caribou biology for management of caribou in the Northwest Territories.

Simulation studies were discussed and some of the shortcomings were emphasized. I guess the shortcomings were that it was very difficult to simulate reality and that the simulation studies couldn't answer the questions that might ultimately come about with actual activities. Perhaps a better approach might be to look at the activities as they are taking place and design

experiments around them, recognizing that this isn't going to answer the questions before the activities actually start, which would be more ideal. However, we should maximize the opportunity to learn from projects that are underway, whether they are major projects such as pipelines or roads, or smaller operations such as localized drilling operations.

I think that we also agreed that the problem of management of low level aircraft harassment had been overstated. We probably have enough knowledge to design realistic management regulations to deal with low aircraft flights and that perhaps we ought to place more focus on ground activities and their effect on caribou.

Another point that I think came out very much in the discussion is that there is a wealth of knowledge available from throughout the world that perhaps hasn't been as effectively utilized as could be. Although the Northwest Territories is isolated in a sense geographically, it's not isolated in terms of communication with the rest of the world, or at least it shouldn't be. Perhaps it would be more desirable to place a stronger emphasis on review and utilization of information that is already available from caribou in the Northwest Territories.

Finally, I would stress the importance of educating the public as to the complexity of the problem and the need to deal with it objectively. If the public and all of the components of the public, including the

representatives from government and industry can appreciate the complexity of the problem, then I think they will be more inclined to accept regulations that may be conservative from their viewpoint but are important in terms of maintaining the long-term well-being of caribou populations.

RECOMMENDATIONS

The following recommendations are intended as guidelines for management decisions and for the establishment of a research program aimed at the problem of caribou disturbance from human activities in the Northwest Territories. These recommendations result from specific information presented by the invited panelists in the workshop, discussion by all participants in the workshop on the theme topic of caribou disturbance and of the information presented by the panelists, and proposals made by members of the Canada/N.W.T. Wildlife Research Technical Advisory Group in joint meeting with the workshop panelists immediately following the workshop. All recommendations are considered of high priority to provide the basis for the effective assessment of present or future anticipated disturbance effects and to enable effective disturbance management. The recommendations are grouped, however, into categories I and II according to need and feasibility of accomplishment. Category III includes recommendations peripheral to the central theme of effective caribou management and for more specific disturbance management.

I. First Priority

1) Review state of knowledge regarding caribou and reindeer (Rangifer tarandus) reaction to disturbances on a world-wide basis. (A review paper by Klein, titled "Reaction of Caribou and Reindeer to Obstructions and Disturbances - A Reassessment", presented at the Second International Reindeer/Caribou Symposium, Røros, Norway, September 17, 1979 is attached).

Determine and outline the relevance of knowledge of caribou and reindeer disturbance elsewhere to the situation in the Northwest Territories and its applicability to caribou management in the Northwest Territories.

2) Undertake behavioural studies of N.W.T. caribou to provide baseline information for the assessment of disturbance effects. Emphasis should be on the quantitative description of basic activity patterns within herds, including development of seasonal activity budgets in relation to forage availability, snow cover, insect harassment, predation, hunting and other environmental parameters. Methodology used should be consistent with that employed throughout the circumpolar areas so that results will be comparable between populations under differing combinations of environmental influences. The "standardized

normal daily activity patterns" will provide a basis for comparison of research data from areas of suspected disturbance.

3) Intensify efforts to better inform the public about caribou ecology, caribou management and the possible consequences for caribou of disturbance resulting from human activities. Emphasis should be placed on conveying to the public an appreciation for the complexity of the biological inter-relationships of caribou, their associated vulnerability to human influences and the need to obtain a comprehensive understanding of these inter-relationships in order to do an effective job of management.

4) Examine existing data on (radio) collaring of caribou in the N.W.T. and the subsequent observations of (radio) collared animals to enable assessment of the possible consequences of handling and associated disturbance on the well-being of these animals.

II. Second Priority

1) Undertake studies of the behavioural reactions of caribou to existing roads and other barriers. Standardize techniques to be consistent with similar studies elsewhere.

2) Examine the routing of proposed roads, pipelines and other developments in relation to caribou habitat components such as calving grounds, migration routes, water crossings, and winter range. Undertake studies, where necessary, to provide more precise information on the relative importance and location of critical habitat units and recommend specific routing of proposed developments to ensure their minimal impact on caribou habitat.

3) Initiate studies of the behaviour of caribou at water crossings and, where possible, examine the influences of human activities at such crossings on caribou movements.

4) Investigate the feasibility of designing disturbance studies around existing mining, seismic or other activities. Such studies should be undertaken only if the existing conditions of caribou numbers and observability make it possible to develop an experimental design that will enable the collection of sufficiently large data sets to yield statistically sound results. Controls must also be available where data can be collected from caribou in undisturbed situations for comparative purposes.

5) If conditions favourable for carrying out experimental work with captive reindeer are available in the N.W.T., undertake studies of

physiological indicators of energy expenditure, stress and reaction to disturbance. Emphasize the development and refinement of techniques which may ultimately be employable in the field on free-ranging caribou and the establishment of provisional energy costs associated with specific activities. Test the reliability of remotely monitoring heart rate, respiration rate and other physiological parameters as indicators of energy expenditure. Encourage similar work and more detailed physiological studies at research facilities outside of the N.W.T. where more sophisticated facilities and expertise are available.

6) Undertake studies of the effects on caribou of hunting activities particularly those involving the use of new technology such as snow scooters. These studies should provide a description of the hunting methods employed and of the reaction and behaviour of the escaping caribou. Data should be collected and analysed in a quantitative way so that the magnitude of the effects of hunting on caribou can be assessed. On the basis of these investigations actual disturbance studies can ultimately be designed to test the energy or other physiological costs of hunting disturbance on caribou.

7) On the basis of a review of the literature on caribou and wild and domestic reindeer, consider the feasibility of investigating, in

conjunction with other disturbance studies, the question of habituation of caribou to disturbances.

III. Third Priority

1) Continue monitoring the movements and seasonal range use of N.W.T. caribou with sufficient intensity to provide accurate baseline data for use in land use planning relative to proposed exploration and development activities and as a basis for assessment of future disturbance effects.

2) Investigate the environmental parameters that characterize caribou calving grounds in the N.W.T. Information from these investigations should enable more precise evaluation of the consequences for caribou of specific proposed activities and projects on the calving grounds.

Appendix A

Reaction of caribou and reindeer to obstruction - a reassessment

David R. Klein

1979

REACTION OF CARIBOU AND REINDEER TO OBSTRUCTIONS - A REASSESSMENT

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ABSTRACT

The past decade of accelerated oil and gas exploration and development in the North has focused attention on the effects of the construction of oil fields, roads, railroads, pipelines, and other developments on caribou and reindeer. Associated experience with these projects and investigations provide the basis for specific conclusions. Roads, railroads, pipelines, powerlines, artificial or altered water courses or other man-made linear features can block, delay or deflect the movements of caribou and reindeer. The level and type of vehicular traffic and other human activities associated with these features, as well as the season of the year, however, are major factors influencing the reaction of caribou and reindeer. The sex and age of the animals and their group size also influence their reaction to obstructions and disturbances. Caribou and reindeer tend to habituate more readily to obstructions and disturbances if they are resident in the area where they occur rather than experiencing them only seasonally in relation to movement patterns. Variations in behavior exist between distinct races of Rangifer which may lead to differences in response to obstructions and disturbances. The consequences for caribou and reindeer of northern developments can be local overgrazing and trampling of winter range; range abandonment and disrupted migratory patterns; loss of access to calving grounds, insect relief areas or other range components; fracturing of large herds; discontinuance of interherd movements; increased energetic costs to the animals and associated physiological consequences; and overall reduction in herd productivity, population levels or potential heard productivity.

1. Introduction

The discovery of a gigantic oil field at Prudhoe Bay, Alaska in January 1968 and the subsequent proposal to transport the oil via pipeline across the state of Alaska focussed public attention in North America on the possible effects of such a project on the movements and welfare of caribou. Prior to this time, little concern had been expressed by either the public or biologists about the effects of obstructions and disturbances associated with northern development on caribou and wild reindeer (Rangifer tarandus Linnaeus). A review of available information on the subject in 1971 (Klein 1971) drew primarily on experience with domestic and wild reindeer in Scandinavia; virtually no research had been done up to that time on the specific reaction of wild Rangifer to development activities.

Paper presented at the Second International Reindeer/Caribou Symposium, Røros, Norway, September. 17-21, 1979

Most initial efforts to anticipate the consequences for caribou and reindeer of increased human activitiy in the North were directed at assessing the reaction of these animals to harassment by low-flying aircraft. This potential problem became apparent with the accelerated oil and gas exploratory activity involving low level aircraft flights over a vast portion of the North American Arctic. Because of the migratory habits of most caribou and reindeer herds, concern was also felt for the possible influence of petroleum exploration and development activities which might influence their normal movement patterns. Consequently, several investigations were also begun to study the reaction of caribou to aboveground pipelines, highways and highway traffic, compressor station sounds and related activities. Concurrently, biologists working with caribou and wild reindeer on more generalized ecological studies began recording specific reactions of the animals to various types of disturbances incidental to their primary research efforts. As a result of this substantially increased effort to investigate the consequences of northern development for caribou and reindeer and the experience gained from large scale projects that have already been completed, a considerable body of knowledge on the reaction of Rangifer to obstructions and disturbances has now accumulated.

Several studies of the reaction of caribou to low-flying aircraft under varied environmental and flight conditions have been completed in North America and are reported in the literature (Klein 1973; Calef et al. 1976; Miller and Gunn 1979). Incidental observations of the reaction of wild reindeer in Norway to aircraft and other disturbances have been reported by Thomson (1972, 1977). Geist (1975) did a comprehensive review of the literature on aircraft harassment of wildlife as part of an environmental evaluation for the proposed Mackenzie Valley Gas Pipeline. He pointed out that although details of the behavioral reaction of caribou to aircraft under varying conditions have been described, little is known of the physiological and energetic consequences for the animals of varying levels of disturbance.

2. Reaction to Obstructions

Experience with highways and railroads as obstructions to the movement of Rangifer was summarized in my earlier publication on the subject (Klein 1971), however, subsequent experience with northern roads and railways and information from the Soviet Union now enables a broadening and a reassessment of knowledge on the subject.

Parovshchikov (1965) reported that in the Arkhangelsk Region of the USSR, the breeding grounds of wild reindeer lying between the Onega and Severnaya Dvina rivers are divided by a railway and that the southern breeding grounds of wild reindeer in the Nyusenskii District of the Vologda Region are "completely cut off" by the Kirov-Kotlas railway. Parovshchikov pointed out that wild reindeer

in the European part of the Soviet Union were reduced to virtual extinction through over hunting during the Revolution and as a result of competition for forage by domestic reindeer. They have been protected from hunting since 1935. In recent decades wild reindeer in this region have begun to reestablish herd identities and traditional migration routes where not prevented from doing so by agricultural settlement, domestic reindeer herding or transportation corridors. Wild reindeer in the White Sea coast area increased under protection and in 1956 began annual winter migrations to the south which necessitated two annual crossings of the Belomorvsk-Onega River railway. Traffic on this railroad was approximately one to two trains per day (V. A. Kuzyakin viva voce).

A railway, roads and a water pipeline in the Taimyr region of north central Siberia near the mining and industrial complex of the city of Norilsk were implicated in problems with movements of approximately 100,000 reindeer during October 1967 (Skrobov 1972). Many calves were lost in attempting to cross these structures and "scores" of reindeer were killed by trains, largely at night. A similar movement of wild reindeer occurred during October-November 1968. By the spring of 1969 a gas pipeline had been constructed 250 km from the Messoyakha field to the city of Norilsk paralleling the railroad and associated roads. The pipeline, 0.70 m in diameter, constructed about 1 m above the tundra surface on wooden pilings, was a complete obstruction to the wild reindeer except where it was suspended across ravines or small streams or covered by drifted snow. As the reindeer approached the pipeline and other obstructions on their way to the calving grounds in April 1969, Skrobov described the situation as follows:

> "Large accumulations of reindeer formed south of the railway stations of Kaierskan, Alykel and Tundra and on the left banks of the Yenisei near the gas pipeline, with the onset of spring twilight there was an increase in traffic of trains, trucks, all-terrain vehicles and tractors which interfered with the reindeer crossing the railroad and roads. In some cases where the herds of reindeer crossed the roads they were unable to cross the pipeline and moved parallel to it from east to west and back until they found a place blown over with snow or where ravines were deep enough so that they could pass under the pipeline... In may, during one flight along the railway, we counted up to 20,000 reindeer [mostly pregnant cows] milling about near the man-made barriers. In order to facilitate crossing of the railway by reindeer, the Norilsk City Council reduced to a minimum the movement of trains during the night hours. As a result the accumulation of reindeer decreased, however, some herds, consisting primarily of bucks, continued to wander south of the railway and pipeline even in June. Apparently some of the reindeer remained south of the pipeline and railway for the summer."

A second gas pipeline paralleling the first, but separated from it by 1 to 2 km, was built shortly after the first was completed. Although subsequent movements of wild reindeer in the area were not as large as during 1967, through 1969, crossing problems continued to occur (V. N. Andreev viva voce). Experimental efforts to bridge the pipeline with wooden ramps for use by the reindeer were unsuccessful and, after a lapse of three years, the pipeline authority completed several crossing facilities where the pipe was elevated approximately 3-6 m for a distance of 75-100 meters. Lead fences were also constructed to guide the reindeer to the crossings and to ensure that the animals using them passed under both pipelines. These crossing facilities were succussful in providing for the crossing of only about 25 percent of the reindeer confronting the pipelines. Finally, after several years, over 54 km of lead fences were constructed in conjunction with large lakes to guide the reindeer that were unsuccessful in crossing the pipelines to the east, completely away from the pipeline and other obstructions, and bypassing the city of Norilsk, into wintering areas in the Putorana Mountains. V. A. Kuzyakin (viva voce) has stated that the use of ice breakers in the Yenisei River from Dudinka to the Kara Sea during October and November poses an additional obstacle to those reindeer that successfully cross the pipeline.

Although winter rangelands east of the Yenisei River previously used are now largely unavailable to the Taimyr wild reindeer, the total herd, in excess of 400,000, continued to expand in numbers. V. N. Andreev (viva voce) feels that the greatest detrimental impact of the gas pipelines has been in causing the buildup of large concentrations of reindeer adjacent to them, resulting in local overgrazing and trampling of the range vegetation.

In Canada, the Hudson Bay Railway, built in late 1920's, crossed winter range of the Kaminuriak caribou herd. Caribou continued to cross the railway until the early 1960's, at which time the herd had declined by more than 50 percent in the preceeding decade. There is no basis however, to determine if a cause and effect relationship existed between the railway and the herd decline (Berger, 1977). In Labrador, the Churchill Falls hydroelectric project has flooded the calving grounds of one of the major caribou herds of eastern Canada, and a railway, haul road and power transmission line built in conjunction with the project also transects that caribou rangelands (Calef 1976). Apparently no studies of the consequences of those developments for caribou have been carried out. On Newfoundland, caribou continued to migrate across the railway transecting the island for several years after its construction before the turn of the last century (Bergerud 1971). Movements across the railway stopped during a drastic deline of caribou in the period 1915 to 1925, from an estimated 40,000 animals to perhaps less than 2,000. Bergerud (1971) associated the decline with

excessive hunting and predation by lynx. Segments of the herd closest to the railway increased to over 6,000 animals by 1966, but the recovery was not accompanied by reestablishment of movements across the railway.

Reactions of caribou to recently constructed highways has been studied in Alaska along the haul road for the Trans-Alaska Oil Pipeline and in Canada along the Dempster Highway in Yukon Territory. The former transects approximately 170 km of tundra rangelands of the Central Arctic herd which numbers about 6,000 animals, and the latter crosses about 400 km of forest and alpine tundra in the winter range of the Porcupine herd, which numbers about 100,000. Primary migration corridors across the Dempster Highway extend along approximately 280 km of the highway. Cameron and Whitten (1976, 1977, 1979) and Roby (1978) have reported on the Central Arctic herd and its behavior and response to the haul road and oil pipeline. In summary, their findings show that the most apparent effects of the haul road and pipeline on the behavior of caribou of the Central Arctic herd has been the avoidance of the transportation corridor by cows with calves from the time of calving until the commencement of rutting activities. This avoidance appeared to be primarily related to disturbance from highway traffic and activities associated with pipeline construction. Adult male caribou did not show the same avoidance behavior, they adapted more readily to the haul road, pipeline and related disturbances and were often attracted to these features to seek relief from biting insects and to feed on revegetated, fertilized areas. Studies are continuing to determine if the avoidance behavior exhibited by cows with calves will decrease following construction and reduced highway traffic. Roby (1978) also noted that caribou feeding close to the highway that might otherwise be considered habituated to it showed alert responses or discontinued feeding with each passing vehicle, thus decreasing forage intake rates during feeding bouts. Villmo (1975) reported similar behavior of domestic reindeer adjacent to roads in northern Norway and pointed out that this either led to extended feeding periods or reduced forage intake.

Caribou encounter the Dempster Highway during fall, winter and early spring when snow covers the terrain. The southward fall migration to the wintering grounds is normally initiated by the first snow storm of the season and crossing of the highway can be expected between early September and mid-November (Thompson 1979). Recrossing of the highway in spring by northbound animals occurs between mid-March and mid-May and appears to be related to improved travel conditions for caribou through reduced snow depths as the spring thaw commences. Observations of caribou approaching the Dempster Highway were reported by Surrendi and DeBock (1976). They found that caribou showed stronger avoidance to vehicular traffic than to the road itself. When approaching the highway in forested areas, caribou preferred to cross where visibility down the highway corridor was good, that is where the road was straight and level.

In open terrain caribou showed more hesitation in crossing the road where streams paralleled it and bands of riparian willow obscured vision and presumably provided cover for wolves or other predators. Caribou migrating through open terrain away from the road were observed to hesitate before crossing through willow patches and frequently broke into a fast trot or run once they entered the willows. Roby (1978) observed similar behavior along the pipeline haul road in Alaska. He also noted that wolves, which were protected from hunting and were attracted to the road through food handouts by truckers, soon learned to use the road, both as a vantage point in searching the landscape for prey and as a screen to aid them in stalking caribou close to the road.

Surrendi and DeBock (1976) reported that caribou approaching the Dempster Highway in open tundra did so in single file, while in forested habitat they usually approached the road in a broad front. They showed more apprehension of the road itself in forested areas than in open terrain. This may have been associated with the fact that in forested areas the road and cleared right of way represent a much greater visual change in the landscape than the road does in open terrain.

Slow moving vehicles were less disturbing to caribou than those travelling at high speeds and clouds of blowing snow behind fast-moving vehicles added to the intensity of the disturbance. Roby (1978) noted a similar effect from clouds of dust generated by vehicular traffic in summer in Alaska. Large trucks evoked a stronger avoidance response than autos or pickup trucks.

When caribou were observed to retreat from the Dempster Highway because of fast-moving traffic they usually moved back about 0.8 km, however, on occasion animals retreated 12 to 16 km before stopping (Surrendi and DeBock 1976). Disturbed caribou frequently delayed crossing the highway until night when the traffic ceased. The height of the road above the surrounding terrain also influenced the crossing bahavior of caribou. In open terrain caribou showed stronger avoidance to the road where it was raised appreciably above the ground surface. The road then presented a visual barrier and the steep embankments limited the ease of movement of the animals. High berms of plowed snow were also a hinderance to the movement of caribou.

Prior to the construction of the Trans-Alaska Oil Pipeline, Child (1973) carried out research at Prudhoe Bay to assess the reaction of caribou to obstructions designed to simulate oil field gathering pipelines and the Trans-Alaska Pipeline. Results of these studies, conducted in summer, showed that the majority of the caribou (78-85%) confronting the "pipelines" were either turned back in their movements or paralleled the obstructions until they could pass around the ends, rather than use the crossing facilities which were

provided. Among caribou confronting the simulated Trans-Alaska Pipeline, gravel ramps were used more frequently (18%) than underpasses beneath elevated portions of the pipe (5%). Crossing success was correlated with group size and composition and sex of group leadership. Individuals were successful in using the crossings more frequently than groups, and small groups more frequently than large groups. Groups under female leadership were more successful in using crossing facilities than those with male leaders. This observation, superficially, appears at variance with observations of female and young avoiding the haul road and pipeline during and subsequent to pipeline construction (Cameron and Whitten 1979). Important differences in the conditions of these observations were the absence of traffic and construction activity around the simulated pipelines and the fact that the simulated pipelines were close to the coast and intercepted movements of caribou to insect relief areas. Child found that under conditions of high density of biting insects, caribou made pronounced movements to coastal areas, showed less avoidance of the simulated pipelines and had a higher crossing success than when insect harassment was low or absent.

Another study of an experimental elevated pipeline, with crossing facilities, was carried out on the Seward Peninsula, Alaska with domestic reindeer (Child and Lent 1973). Reindeer were herded into the vicinity of the pipeline and their reactions to it were observed. The reindeer showed an avoidance of the pipeline during both winter and summer and used the crossings only during periods of insect harassment. Crossing of the pipeline also occurred during winter when drifting snow formed snow bridges over the pipe.

Johnson and Todd (1977) concluded that mountain caribou (R. t. montanus Thompson-Seton) in British Columbia, Canada had become habituated to a highway crossing their migration route 13 years after its construction. This is in a forested area where the caribou were unable to see the highway or traffic from a distance. However, some highway mortality has occurred, apparently associated with caribou being attracted to the highway edges seeking salt that is applied to the road surface in winter (Johnson 1976). Along with increasing highway traffic, a gas pipeline and powerlines have also been added to this transportation corridor and there is concern that the incremental effect of these developments may eventually interrupt the normal movements of caribou in this region.

Miller et al. (1972) observed that gravid female caribou in migration to the calving grounds were extremely persistent in attempting to overcome barriers constructed across their traditional migration route. When confronting pole barrier fences and drift fences of felled spruce trees, caribou maintained group cohesion by following the lead animals through, over or around the obstructions. Although the caribou followed snowmobile trails laid down in the snow to guide them toward the corral they were reluctant to move

from the traditional travel route on lake ice and showed strong avoidance of brushy areas through which the snowmobile trails passed.

The tendency of caribou to follow trails packed in the snow by oversnow vehicles has been previously reported. Klein (1971) and McCourt et al. (1974) noted that winter seismic lines in northwestern Canada caused deflections in the movement of migrating caribou. Geist (1975) estimated that on the basis of a typical deflection requiring an increased movement of from 0.64 to 2.38 km the increased daily energetic cost to the caribou would be 0.66 to 2.4 percent. Of course, multiple deflections could occur during the course of a day and the associated energetic costs would be additive. These estimations were based on the questionable assumption that the energetic cost of walking on a packed vehicle trail was the same as that of walking in undisturbed snow.

Villmo (1975) commented on the consequences for domestic reindeer of hydroelectric developments in Norway that included loss of rangelands, disruption of movements and increased difficulty and associated mortality in herding the animals across unfrozen water courses in winter. Reimers (viva voce) suggests similar consequences for wild reindeer where hydroelectric developments have taken place within their rangelands in southern Norway. Very little systematic research has been conducted, however, to assess the magnitude of these effects.

The disturbance of wild reindeer and temporary abandonment of their rangelands caused by hikers and skiers on recreational trail systems in Norway has been documented by Thomson (1972, 1977). He suggests that if wild Rangifer are hunted at least seasonally they will not readily adapt to the presence of non-threatening humans active within their habitat and Geist (1975) has postulated the same effect for ungulates in general. While this may be true as a generalization, among the largely unhunted caribou of the McKinley herd in Alaska, cows with calves show characteristic avoidance of the McKinley National Park highway in summer although bull caribou and other wildlife, such as grizzly bears, moose and mountain sheep have, for the most part, become habituated to highway traffic and people hiking nearby (R. Boertje viva voce).

Caribou of the currently reduced Nelchina caribou herd in Alaska confront elevated portions of the Trans-Alaska Oil Pipeline in open spruce forest on their winter range. Although there has been no systematic study of the reaction of caribou to the pipeline along this portion of the route, some observations are available (Sterling Eide viva voce). Caribou wintering in the vicity of the pipeline have been observed feeding through the snow under and immediately adjacent to the pipeline where the disturbed soil or gravel construction surface had been fertilized and revegetated with domestic grasses. These grasses remained green and apparently retain high forage quality into the winter. Other observations of

tracks of caribou moving perpendicular to the pipeline in winter show that although crossings under the pipe or via special buried sections occur frequently, some animals are deflected by the pipe for considerable distances and others turn back. These same caribou cross the Richardson Highway which runs parallel to the pipeline in this region, but which is generally several kilometers from it. Hunters often congregated along the highway and shot caribou as they approached the road in the past when the herd was larger, and hunting seasons and harvest limits were very liberal. Skoog (1968) reported that when hunters in the 1950's and 1960's congregated along the Richardson Highway, as well as the Taylor Highway that intercepts the migration of caribou of the Fortymile herd, caribou, frustrated in their attempts to cross through the line of hunters, often delayed crossing until after darkness. In spite of the past high level of disturbance associated with these highways, caribou from both herds have continued to cross these roads annually; although some alteration in movement patterns has occurred, it may be more closely associated with reductions in herd size than the obstruction to movements that the highways may represent (LeResche 1975; Bos 1975).

With the discovery of natural gas reserves on the islands of the Canadian High Arctic a new threat, that of the obstruction of inter-island movements of Peary caribou, is emerging. Miller and Gunn (1978) have emphasized the importance of inter-island movements to the continued existence of island populations of Peary caribou (R. t. pearyi Allen). They noted that channels in the sea ice between islands maintained by proposed liquified gas tankers would probably be barriers to the movement of caribou.

3. Discussion and Conclusions

Some conflicting observations appear in the literature and there are genetic differences in behavior exhibited between populations of Rangifer, but for the most part, when variations in environmental conditions are considered, similar patterns exist in the reaction of caribou and reindeer to obstructions and related disturbances associated with northern development. These can be summarized as follows:

1. Roads, railroads, pipelines, powerlines, artificial or altered water courses or other man-made linear features can, independent of other human activities, block, delay or deflect the movements of caribou and reindeer. The effect of such structures as obstacles to the movement of Rangifer is dependent upon the mode of construction and how much they alter the existing terrain either by presenting physical barriers to movement, or by visibly altering the landscape to create the appearance of physical barriers, or by creating visual scenes which appear threatening to the animals. Highways or railroad beds

elevated substantially above the surrounding terrain present both physical and visual barriers to moving large mammals, and deep construction cuts and associated obstacles such as snow fences or steep snow berms have similar effects. In open terrain, roads, railroads or pipelines are visible from a great distance, consequently approaching animals may react to them sooner and thereby be delayed longer in their movements than when approaching such features in forested terrain. On the other hand, cleared transportation right of ways in forested areas create sharp breaks in the habitat which may be reacted to with a high level of alarm. Caribou and reindeer appear to be less disturbed by elevated pipelines and powerlines in forested terrain and cross under them more readily than in open tundra. The strange substrate of road or railroad surfaces may cause deflection of moving animals either because of their reluctance to walk on it or, particularly in winter, because it offers an easy surface to travel on. The avoidance response shown by caribou and reindeer to man-made features is apparently partially associated with predator avoidance behavior. Therefore if such features provide cover or better visibility for predators, if they simulate natural features where predators may be more effective or if they are constructed adjacent to natural terrain features that may favor predators, avoidance by caribou and reindeer can be expected.

2. The level and type of vehicular traffic and other human activities associated with roads, railroads and other man-made features are major factors influencing the reaction of caribou and reindeer. Experience has shown that caribou and reindeer usually show much greater alarm and avoidance to traffic and other human activities than to the constructed features themselves. Generally, the larger the vehicle, the greater the disturbance, and blowing dust or snow increase the disturbance effect. The greater the frequency of traffic, the greater is the deterrence to moving animals. Caribou adapt more readily to infrequent, regularly spaced traffic than infrequent but irregular traffic. The sounds associated with traffic appear to accentuate the alarm reaction, although, sound in itself, if associated with fixed non-threatening objects or from nonvisible sources, such as oil drill rigs, simulated gas pipeline compressor stations or supersonic aircraft (Espmark 1972; McCourt et al. 1974) appears to be readily adapted to.

3. Caribou and reindeer react to obstructions and associated disturbances differently in relation to the season of the year. During spring and summer, females accompanied by young of the year show much stronger avoidance of

obstructions than during the winter. This behavior is apparently related to predator avoidance behavior in which this cohort, in tundra areas, also avoids stands of riparian willow which may hide wolves and other predators (Roby 1978). During summer, when levels of insect harrassment are high, caribou and reindeer seem preoccupied with seeking relief from insects, show strongly motivated movements to insect relief areas (in the case of mosquitoes and black flies) and seem less responsive to other disturbances. At this time they more readily cross roads, pipelines and other obstructions which may lie in the path of their movements to insect relief areas and in some cases seek relief from insects (particularly parasitic flies) by standing on elevanted, gravel road surfaces, pipeline pads and airstrips. During migration to the calving grounds by pregnant females in late winter and during fall migration to the wintering grounds the migratory urge is strong and movements are less likely to be impeded by obstructions than may be the case when animals are on summer or winter range areas when movements are primarily associated with feeding activities and less strongly directionally oriented. When caribou and reindeer are preoccupied with rutting activities, which usually coincides with fall migration to the wintering grounds, they are also less likely to be impeded in their movements by obstructions.

4. There are pronounced differences in response to obstructions in relation to sex and age of the animals involved and to group size. In addition to the avoidance behavior of females with young mentioned above, adult males in general appear more adaptable to man-made features and habituate more rapidly to their presence. They also usually show less alarm reaction to highway traffic and other human activities than females with young. Generally, the larger the group, the greater the likelihood of avoidance reaction or deflection when confronting obstructions. This appears related to the fact that group movement is the product of the majority of the animals in a group following intention movements of "leaders" or individuals that show alarm reaction or otherwise may be the first to respond to stimuli. Therefore, one would expect a linear response to obstructions and disturbances in direct relationship to numbers within the group. This generalization must be qualified. Single animals often appear strongly motivated toward rejoining a group and under such circumstances are particularly resistant to disturbance or deflection from their intended movement direction. Cow-calf pairs, during the immediate post calving period, show less group fidelity than other animals. During harassment by mosquitoes or by biting or parasitic flies,

caribou and reindeer become less responsive to other stimuli and therefore group size may be less important in influencing response to obstructions and disturbances.

5. Caribou and reindeer, as well as other ungulates, more readily adapt or habituate to obstructions and associated disturbances if they are resident in the area of the obstruction rather than being present only seasonally or during migration. Habituation to obstructions and disturbances occurs more readily in populations that are unhunted than in those that are hunted, as well as in populations free of large mammalian predators such as wolves and bears.

Variations in behavior exist between genetically distinct races of Rangifer which may lead to differences in response to obstructions and disturbances. Woodland caribou (R. t. caribou Gmelin and R. t. sylvestris Richardson), for example, as a rule have less extensive migrations and show less pronounced sociality than tundra forms. Consequently, they can be expected to be less strongly motivated to cross roads, railroads or other linear obstructions and to react more individualistically than tundra forms. Woodland caribou exist in relatively small herds and because they are locally resident they can be expected to be more adaptable to disturbances within their habitat. Svalbard reindeer (R. t. platyrhynchus Vrolik), in the absence of wolves and with restricted food availability in winter have evolved a pattern of extreme inactivity and docility (Ringberg, 1979) which presumably facilitates their adaptation to human disturbance. On Svaldbard, reindeer show little alarm to vehicles and people and graze within the developed area of the coal mining complex of Longyearbein. Peary caribou in the high arctic islands may share this characteristic, however, no comprehensive study of their behavior has been conducted.

The consequences for caribou and reindeer of northern development which creates roads, pipelines or other obstructions and associated disturbances on their rangelands will vary considerably according to the conditions which have been outlined above. Specific effects, however, can be anticipated.

Local overgrazing and trampling of winter range was a consequence of impeded movement of wild reindeer by a gas pipeline in Siberia. Range abandonment through disrupted movements has been documented where railroads cross Rangifer rangelands and similar patterns of discontinued range use can be anticipated where roads have sufficient traffic to discourage crossing by reindeer or caribou. Discontinued use of range components when it occurs because of such obstructions is not, however, instantaneous. Many years may be involved in the breakdown of movement patterns.

The effect on populations of caribou or reindeer of loss of use of a portion of their rangelands will vary depending on the relative importance of the lost component. Loss of a portion of the food resource of a herd may lead to a reduction in its numbers, if it was at carrying capacity, and associated overgrazing of the remaining range may occur. If below carrying capacity, although no herd reduction may occur, potential population increase may be precluded. If traditional calving areas are lost the consequences may be lowered calf survival through use of less favorable calving areas (i.e. increased threats to calf survival through unfavorable weather, increased predation and insect harassment and greater presence of other natural or man caused hazards as well as availability of poorer quality forage). Loss of access to insect relief areas may expose the animals to levels of harassment by insects which will reduce feeding opportunity and lead to increased energetic expenditure of the animals, thus reducing growth rates of young and curtailing deposition of body reserves in preparation for breeding and winter. Historically, fractured Rangifer ranges through human development activities have led to range abandonment, herd reduction or extinction, or alternatively, fracturing of herds into smaller but discrete components. In the latter situation the total number of animals in the smaller herds has apparently consistently been less than in the original herd they replaced.

The importance of interherd movements in the population dynamics of caribou in North America, although not well documented, has received recent emphasis in the literature (Walters et al. 1978). The opportunity for this occurrence, which may be essential to reverse the decline of large herds, will clearly be reduced through the construction of major transportation corridors such as the Trans-Alaska Oil Pipeline and associated haul road. Similarly the likelihood of the exchange of genetic material between herds and the establishment or reestablishment of herds in unoccupied habitat will also be reduced.

Geist (1975) estimated the energetic costs associated with deflection of movements of migrating caribou. There are additional energetic costs associated with all aspects of disturbance by vehicle traffic and other human activities. This has been discussed in the literature, primarily in relation to harassment of caribou and reindeer by low-flying aircraft, however, there has been virtually no research into the actual physiological consequences of such disturbance for the animals involved. It is possible to extrapolate from work with domestic animals including reindeer (see Zhigunov 1968) as Geist (1975) has done, however, there are obvious limitations to such an approach. This is clearly an area deserving high priority for future research.

The energetic costs and other physiological consequences of disturbance can be assessed with properly designed research. The capability of caribou and reindeer to accept these consequences and

to adapt to them will vary with the circumstances involved. Obviously the species has evolved along with natural disturbances such as predators, insect harassment and hunting by humans, however, these influences, where they occur, are compensated for in various ways. Reduced productivity may be a consequence of high levels of insect harassment and extensive seasonal migrations may be the outcome of moderate to high levels of predation. Archeological evidence suggests that historical methods of hunting, including the use of lead fences and stone or sod cairnes that simulate obstructions, have not led to the disruption of traditional movements of caribou or reindeer nor to the extinction of specific herds (Warbelow et al. 1975, Mølmen and Skogland, 1979). The location of these traditional hunting sites, however, has usually been along migration routes, rather than on the calving grounds, or wintering grounds where presumably hunting activities would have been more dispersed. The use of new technology in hunting, such as snowmobiles, may change this situation. Adding disturbance through other human activities will nevertheless lead to increased physiological costs to the animals. These costs may be met through increased forage intake (if this option is available), altered behavioral patterns (accomodation to the disturbance or abandonment of areas of disturbance), or reduced allocation of energy to other requirements (growth, reproduction and escape from predators).

Disturbances associated with pipeline construction, oil exploration or other major northern projects may be of a temporary nature and therefore of consequence to caribou or reindeer only during construction or exploration activities. What then are the consequences of temporary disruption in the traditional movement patterns of caribou or reindeer? Espmark (1970) showed that domestic reindeer movements are based on learned familiarity with terrain features and that disorientation of reindeer, especially young animals, may occur if movement over a traditional route is prevented for only one season. Pregnant cows, both reindeer and caribou, tend to return to the vicinity where they gave birth the previous year. Yearlings and young females pregnant for the first time tend to follow the older, experienced females thus maintaining the traditional use of a specific area for calving. If movements to the calving grounds are delayed or stopped so that calving occurs in a new area, presumably females calving for the first time will tend to home to the new area in subsequent years and older females will experience a weakened homing drive to the traditional calving grounds. There is some evidence from North America that when caribou herds are at low levels, their traditional movement patterns are more tenuous and therefore more subject to disruption than when population numbers are at or near the long term means.

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