Caribou - Bhp Environmental Assessment Panel
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Catalogue Number: 6-3-110

CARIBOU

Submission to the Wildlife Technical Session

BHP Diamond Mine Environmental Assessment Panel

Yellowknife, NT

Prepared by

Government of the Northwest Territories
Department of Renewable Resources

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EXECUTIVE SUMMARY

Industrial development on the scale of the NWT Diamond Project will affect caribou in the Bathurst herd. The proposed monitoring and mitigation measures need to be strengthened to ensure that the project will not constrain future harvesting options. This submission deals with possible effects on individual caribou and how those effects may accumulate at the population level. Environmental variation (high levels of insect activity, deep snow) and knowledge gaps introduce uncertainty to the risk assessment for the magnitude and probability of effects on caribou. That uncertainty and our understanding of cumulative effects is why the Government of the Northwest Territories is requesting that the Panel recommend co-operative monitoring and mitigation efforts based on a detailed plan.

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1.

1.0 INTRODUCTION

Industrial development on the scale of the NWT Diamonds Project will affect caribou in the Bathurst herd.

> *Project development may have some effect on wildlife such as barren-ground caribou. . . Mining activities, to some extent may cause habitat loss or alteration, interference with migration patterns, increased noise disturbance, hazards and altered ecology.*
>
> *[vol.1, Introduction, Project Description 1. 7]*

The purpose of this submission is to assist the Panel in developing recommendations for monitoring and mitigating the Project's effects on caribou. It supplies background information on caribou ecology and describes the NWT Diamonds Project's effects as justification for those recommendations.

The Department of Renewable Resources has long term information on caribou migration and seasonal ranges and so we can state when and where the caribou will interact with the proposed mine. But within the long term patterns there is unpredictability from year to year. Among factors that cause the unpredictability is annual variation in weather. Variability in movements and behaviour injects uncertainty into predicting and managing effects through monitoring and mitigation. This submission outlines environmental and other uncertainties as they may affect caribou responses to the proposed mine.

Experience elsewhere and our knowledge of caribou ecology is that caribou responses to industrial development may be subtle and take years to accumulate to the threshold of measurement at the population level. Although that may cause difficulty in initially recognizing effects, it by no means lessens their reality and underscores the importance of monitoring and mitigation. This submission will describe how effects accumulate in caribou.

1.1 Mandate

The Bathurst herd is one of the largest caribou populations in North America and has been part of the culture of aboriginal people for thousands of years. People from 8 communities share the herd and the Government of the Northwest Territories has a mandate to ensure the herd remains ecologically intact and at a size to provide for the needs of people.

The herd's cultural value is inestimable. We can, however, estimate the dollar value for the harvest from the meat replacement costs and annually it is $11.2 million. (Case *et al.* 1995).

1.2 Issues

The EIS states that predicted effects will, after mitigation, be minor.

> *"With appropriate mitigative measures in place, caribou will be largely unaffected by the NWT Diamonds Project. Based on the caribou response to development elsewhere, the overall impact on caribou of the NWT Diamonds Project is expected to be minor. "*
> *[Vol. IV, Section 3.3.4.5, p. 3.31]*

A minor impact (" *specific group of individuals within an ecosection affected during less than one generation. " Vol. /V, p 1.5)* could mean a loss of individual caribou. One of the principles of the GNWT's Sustainable Development Policy is that government will promote economic development which maintains harvestable resources at sustainable levels. Therefore, we recommend that monitoring and mitigation measures need to be strengthened to minimise impacts and we are willing to work with the Proponent.

This submission will supplement the Proponent's information to help the Panel to evaluate effects and recommend mitigation. The technical use of a few words is unavoidable but they are used sparingly and are explained in Table 1. Specific comments on the caribou sections in the Environmental Impact Statement are in Appendix 1. Selected background papers (Appendices 2,3 and 4) and a resume (Appendix 5) are also attached.

Table 1. Biological Terms (Bathurst Caribou Management Plan 1994)

Calving Grounds

The specific area on the tundra that the pregnant females of a caribou herd occupy when giving birth; usually the same place each year but the boundaries may vary slightly.

Caribou Herd

All adult female caribou associated with a particular calving area, plus all males and young animals associated with those adult females. Herds are named after the location of their calving areas.

Disturbance

All stimuli resulting from human activities.

Habitat

Place where a plant or animal normally lives; includes both the physical environment (e.g., soils, landforms) and the biological environment (e.g., food, cover).

Migration

Periodic movement (usually twice a year) of animals from one region to another.

Photographic Survey of the Calving Ground

A survey during which some of the calving ground is photographed from 2000 feet above ground and all caribou on the photographs are counted. That count is used to estimate the number of caribou on the calving ground.

Population

A group of interbreeding animals, usually occupying a particular space separate from other such groups. The basic unit of management, as a "population" is the same as a "herd".

2.0 **ASSESSING THE RISKS**

The first step is to state what we are protecting. The GNWT recognises sustainable development as the way to manage resources . For caribou this means no reduction in a herd's well being that would affect harvesting. This generalised goal is restated as objectives which describe the level of risks (Table 2).

Table 2. Environmental Assessment Goals and Objectives for the Bathurst Caribou Herd

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Goal

Sustainable development - to ensure that exploration or development activities on or near the Bathurst range do not threaten the distribution, quality or productivity of the herd or its habitat.

(Source: Bathurst Caribou Management Plan, May 1994 draft, Department of Renewable Resources, Government of the Northwest Territories, Yellowknife)

Objectives

1. Individual caribou deaths or injuries are unacceptable risks and should be minimized to the maximum degree possible.

2. Behavioral responses and energetic costs are acceptable risks but have to be reduced by separating caribou from human activities especially in years when caribou are already environmentally stressed.

Unlike the goal, which refers to the population, the objectives are at the individual level and the reasoning for this is that measures at the population level are relatively imprecise (sensitive only to large changes in the factors being measured (such as calf survival and herd size). Even when changes are measured it can be difficult to attribute them to any one cause. Any effects from exposure to industrial development may also be masked or accentuated by natural factors (changes in wolf predation, insect harassment). The objectives are thus related to the individual level.

The second step is to evaluate the likelihood of where and when Bathurst caribou will interact with the NWT Diamonds Project. Traditional knowledge identifies the proposed mine and winter road as being on spring and fall migration routes and summer range. Over decades, caribou use the same routes and seasonal ranges but annual movements vary in response to weather such as snowfall and spring melt. That means that although there is long term predictability in the use of migration corridors and seasonal ranges, annual movements are less predictable.

The third step is to list and evaluate the probability and magnitude of effects including environmental influence. Industrial activities may startle or frighten caribou to interrupt feeding or move away. The extreme end of the caribou responses is injury or death. The probability for those different responses depends on the disturbance intensity (for example, a truck's speed), the caribou's sex and age and on ecological variables. Cows with calves are more responsive to disturbance than bulls (Miller and Gunn 1979). Severe mosquito harassment may make caribou stand on a road to escape insects and seem unresponsive to trucks. In a winter with deep snow, caribou will likely select the energetically less cost of walking along the packed road surface despite traffic rather than flounder through deep snow. That would increase the probability for traffic collisions and caribou injury or death.

These three steps depend on understanding caribou ecology and population dynamics and a brief review follows to establish the background and explain the likelihood of caribou interacting with the Project's activities. In the following text, the word 'uncertainty' is frequently used. Uncertainties stem from knowledge gaps, environmental variation and human error. In a leading text on adaptive environmental assessment and management, the "one key issue for design and evaluation of (economic) development policies is how to cope with the uncertain, the unexpected, and the unknown. . . The appropriate concept for both assessment and policy design is a recognition of the inevitability of uncertainties and consequent selective risk-taking." (Helling 1980).

2.1 Caribou Ecology and Behaviour

The Bathurst Herd

This caribou herd is one of the largest herds in North America and is accessible to more people than other NWT herds. Its present range (250,000 km^2) extends from below the treeline as far west and south as Wha Ti and Yellowknife across the barrens to the arctic coast and Umingmaktok. Herd size estimates have fluctuated. This reflects both real changes in herd size and uncertainties in technical measurement. In the 1980s, immigration from other herds was advanced as one possible explanation for changes in herd size but subsequent analyses suggest that, that is an unlikely explanation. In 1990, estimated herd size was 352,000 +/- 78,000 caribou based on a photographic survey. The trend in herd size is that the herd's increase in the early 1980s has ended (Figure 1). Based on the 1990 estimate, the herd can sustain the annual harvest (14,500 to 18,500).

Caribou herd size is not stable but fluctuates over decades. The reasons are controversial but shifting interactions among predators, weather and forage are the likely causes. Two points stand out in assessing the NWT Diamonds Project effects. First, the Bathurst herd may no longer be increasing and if it starts to decline, even a relatively minor adverse factor can accelerate a decline.

Second, evidence about the mechanisms for a decline suggest a declining population may be less resilient to disturbance. The George River caribou herd (Quebec and Labrador) has increased to a level where forage is insufficient on calving and summer ranges (Huot *et a/. 1995)* and fewer calves are born or survive (Crête *et* a/. 1995). Fat reserves are lower than when the herd was increasing. This suggests that caribou may have less ability to buffer themselves against energetic costs of responding to disturbance. If Bathurst caribou start to decline during the Project's 25 year-span and suffer forage limitations, disturbance may be more serious than if the herd were increasing.

Late Winter and Spring

In winter, snow conditions largely influence how caribou avoid predators and balance the energy costs of foraging against the energetic gain from forage. Traveling and feeding in deep snow is energetically costly and caribou avoid those costs as far as possible. Crusted snow that would almost support the caribou's weight before collapsing raises the energetic cost of walking by about 570% (Fancy and White 1985). Caribou select the hardest surface with the shallowest snow and this becomes more important in years with above average snow depths. Below the treeline, caribou rest and travel on the wind-packed snow on lakes where they are less vulnerable to wolves. Echo Bay winter road's route is also 72% over lakes *(Vol. /, p. 3.22)*. This suggests (and could be confirmed during monitoring and mitigation) that caribou are more likely to use the winter road when and where snow is deep.

When caribou are migrating, the snow forces them to follow each other along heavily used trails. The urge to reach the calving grounds is strong and the caribou are not easily diverted. In contrast, caribou wintering in an area make local movements and may be more easily displaced or interrupted by traffic.

Summer

In summer caribou balance between obtaining food to rebuild body reserves and avoiding insect harassment. As well as supporting a calf, a cow has to feed to reach a threshold level of condition to conceive during the October rut (Cameron *et al. 1993)* and to survive the winter. As the summer passes, the caribou feed on different plants according to whether the plant is flowering or has new leaves. Caribou are highly selective and attempt to feed on the most nutritious plants (summarised in Klein 1990).

Biting insects are an affliction for caribou in summer. Caribou lose foraging time and expend energy trying to escape mosquitoes (*Culicidae*) and warble flies (*Hypoderma tarandi*). Summer temperatures and wind speed largely determine the insect's activity (Russell *et al. 1993).* If the harassment is severe, the caribou lose condition. For example, warm summers (and more insects) correlate with lower calf weights in the fall (Helle and Tarvainen 1984). Lighter calves are less likely to survive the winter especially if the snow is deeper than average (Eloranta and Nieminen 1986).

Fall

Fall brings relief from insect harassment and the caribou gain weight: males may increase their weights 20% and females 10%. The caribou feed on sedges and grasses and seek out mushrooms. Timing of and movements during fall migration and what factors influence them are uncertainties in our current knowledge. The southward migration is usually underway in September.

2.2 Interactions **between NWT Diamonds Project and Caribou**

Echo Bay Winter Road

Caribou numbers on the winter road will vary annually as caribou sometimes winter along the road and migrate across it. The only information on caribou annual winter distribution is from the Department of Renewable Resources' late March surveys which estimate calf survival (Figure 2). The surveys do not systematically survey the entire winter range but are designed to find concentrations. Those surveys suggest high numbers (1000s to 10s of 1000s) were close to the road 5 out of 10 years surveyed and in 9 years large numbers were west of the road (Figure 2).

Spring migration starts in late March and early April which, when compared to road closure (latest being 14 April, 1983-95), suggests that migration would frequently occur after road closure. The later the road closes, the more likely it is that migrating caribou will encounter traffic but our knowledge is uncertain about migration timing and its annual variation. We are uncertain too, about the probability of caribou in the vicinity of the winter road from January to March.

The road is not a physical barrier. The snow berms are pushed back and would not hinder caribou or reduce the visibility of trucks to caribou and caribou to truck drivers except on the narrower and twisting portages in the treed areas.

Truck density along the road is projected to increase at least six times over current use when BHP is in its 10th operational year (not including any other road users). The road is open between 50 and 78 days/year (average 62). That annual variation means that traffic density could vary from 100 to 157 trucks/day *(Estimated from BHP's information vol. /, p.* 2.*1* 86).

The Proponent's speed limit (30-40 km/h; *Vol.1,* 2.182) on the lakes lessens the probability for collisions with caribou. But caribou rely on their speed to escape predators and faced with a perceived threat (a truck) a caribou may try and outpace it by remaining on the road's hard packed surface or cutting across the road. Thus caribou behaviour (running on the road) and frequent poor visibility (blowing snow and darkness) increase the probability of caribou deaths and injury. Frequent truck passage will interrupt caribou resting on lakes but there are uncertainties as to when this would occur and its significance to the caribou. Prevailing snow conditions will largely influence those possible effects.

Lac de Gras Mine

Annual predictability for the timing and numbers of caribou in the Lac de Gras mine's vicinity is currently low. We can say that most use will occur in the summer and fall. We can also predict temperature and wind conditions when insect harassment will be severe (Russell eta/. 1993) and the caribou can be expected to seek insect relief habitat. At that time bare surfaces especially those slightly elevated (airstrip, roads) or with shade (when warble flies abound) will attract caribou. The roads have a <3m drop-off and are 10-30m wide which will provide insect relief and an easy traveling surface compared to boulder fields. Caribou seeking insect relief could impede mine operations and expose caribou to traffic accidents. Caribou may also be attracted to vegetation growth where dust has advanced the spring melt and then later in the summer to plants growing in the seepage line along road berms.

During mine operation, the scale of mine activity can be appreciated from the average 1,000-1,300 aircraft/year *(Vol. /,. p* 2.*190)*, an unknown number of helicopters and 184,000 truck loads of ore and waste rock/year *(Estimated from BHP information, Vol.I, p.2.37).* The Proponent's baseline information indicates that a few thousand caribou could be exposed to aircraft and trucks but the timing and pattern of caribou movements is uncertain. Caribou were in the vicinity of the Misery Access road (29km) especially in May and September 1994.

The extent to which mine activities will cause energetic costs for caribou from avoidance of activities and changed foraging opportunities is unknown. Our only experience of how caribou will respond in summer is from the Prudhoe Bay oilfield where the level of vehicle activity is comparable and where cows and calves in mid-summer avoided roads (Appendix 2- Dau and Cameron 1986, Cameron *et. al. 1992,* 1994).

Experience of how caribou will respond during spring or fall migration is mixed. The worst case scenario is disruption and this is recorded in Norway and Russia (Appendix 3). The Russian Taimyr herd was initially faced with a railway and road then subsequently a pipeline. In 1967, reindeer were killed crossing the railway and deflected or held up. The Norwegian case-history (the Snohetta herd) occurred between the 1920s and 1980s as a road and powerline were added to parallel an existing railway. Migration was partially disrupted apparently more by human activity than the structures themselves. The situations were quite different from a mine supplied by a winter road. We include them because they make the point that disruption can occur and in Section 3.0 we will refer to how the Russians used fencing to deflect the migration away from the railway and pipeline.

2.3 **Cumulative Effects**

There are two levels at which effects accumulate. The first level is the individual. A caribou may learn not to respond (habituate) or its responses may intensify. Behavioral responses use energy and if repeated often enough those energy costs reduce body reserves. Thin caribou are less likely to survive and a cow has to have sufficient body reserves to conceive and raise a calf (Cameron 1994).

The second level of cumulative effects is the population. Caribou population effects from exposure to industrial development is controversial partially because even if individual caribou respond, effects are not often detectable at a population level. There are reasons why failure to detect effects at the population level is not evidence that no effects occurred. First, is the scale of measurements. This includes both the time for effects to accrue and the precision of population measures. It has taken more than 15 years for the effects of the Prudhoe Bay oilfield on caribou productivity to be measurable (Cameron 1995). Secondly, most studies have only looked at short term behavioral responses. One exception is the research on caribou and low-level military flights in Labrador. The flights startled the caribou and that led to reduced calf survival during calving and insect harassment (Barrington and Veitch 1991, 1992).

We have mentioned how industrial activities disrupted migration in the Russian Taimyr herd and the Norwegian Snohetta herd. The population consequences were that the former herd increased and the latter declined. But the relationship between the disrupted migrations and changes in herd size is essentially unknown and open to different interpretations. This is because some details are lost in time and others were not recorded. In contrast, information on the cumulative effects from Prudhoe Bay oilfield or the low-level military flights over caribou in Labrador was systematically collected.

Reporting the cumulative effects from Prudhoe Bay oilfield or the low-level military flights over caribou in Labrador raises the question as to how comparable either is to a diamond mine in the NWT. Superficially one mine does not appear to replicate the activity of an oilfield. But we are uncertain at what level of activities or frequency of caribou exposure may cause effects to accumulate and under what environmental conditions. Bathurst caribou are now exposed to Lupin and Colomac mines, exploration and other human activities. Those effects must be considered as cumulative even though they may be beyond the responsibility of any one development.

3.0 MONITORING AND MITIGATING

Monitoring (measuring aspects of caribou behaviour and ecology) will describe the Project's effects on caribou and thus reveal mitigation effectiveness. This concerns effects rather than surveillance (compliance) monitoring. Monitoring and mitigation should not themselves cause additional disturbance. And they should be based on traditional and scientific knowledge of caribou ecology.

Effects monitoring has two parts. First is to monitor caribou distribution and selected environmental factors as 'early warning'. The environmental factors include those conditions (deep snow, late springs, severe insect harassment) which stress caribou and thus intensify human disturbance. Caribou proximity and the rating for the environmental factors should then trigger pre-determined mitigative actions whose stringency would be geared to caribou numbers and environmental stress.

Second, monitoring will identify residual effects which is then an evaluation of mitigation. This can be achieved by observational studies which do not have to be extensive but they do have to be rigorously designed.

The Proponent's monitoring and mitigation plans were vague and so in this submission we offer examples to illustrate. We will be available to work with the Proponent on details.

Echo Bay Winter Road

Caribou and trucks should be separated to avoid injuries and deaths. The greatest risk is in winters with deep snow and when caribou are present in high numbers along the road. Monitoring to identify when caribou are present along the road will be necessary. One possible model for monitoring and mitigation is from the all-weather haul road for the Red Dog mine (Alaska) which crosses the Western Arctic caribou herd's fall migration routes and wintering range. Between 30-70 concentrate trucks use the road daily and, in some years, thousands of caribou. Cominco has a monitoring and mitigation plan (Appendix 4) which relies on traffic restrictions to allow free caribou passage.

Traffic restrictions to separate caribou and trucks may only be practical for brief intervals given the short time that the road is open. Variations could include the selective use of temporary (snow) fencing to insure that caribou crossings are at predictable locations for the truck drivers. Alternatives to keep caribou off the road will need testing. Although there are many papers on reducing wildlife and road traffic problems using fences, reflective mirrors and lights, they were developed for moose and deer in different environments. Drivers should be educated to anticipate why caribou on the road may try to out run or cut in front of a truck.

Lac de Gras Mine Site

The emphasis for mitigation is to prevent injuries and deaths to caribou and operational delays by keeping caribou from using roads and the runway. This will involve temporary fencing to direct caribou to cross roads at specific points and the experimental testing of traditional methods and other devices (one-way gates, cattle grids). Those measures will be especially necessary during summer weather conducive to insect harassment.

Mitigation through separating caribou from activities will reduce the caribou's energetic costs of responding to disturbance. Disturbance from aircraft can be reduced by altitude restrictions and flight corridors. A review of caribou responses to aircraft concluded that " . . . aircraft maintaining altitudes of 660 m (above the ground) caused little or no disturbance to caribou during any season, and flight altitudes above 300 m (above the ground) caused few strong responses by caribou." (Shideler *et* a/. 1986, p.46).

Approaching and departing aircraft to the landing strip should use flight corridors. Other areas caribou should be kept away from are reclamation areas where vegetation is being established - caribou will likely select new growth. And fencing will be needed to keep caribou away from unconsolidated tailings.

Directing caribou movements through fencing is a traditional hunting method with several different techniques. We suggest that both traditional and contemporary techniques be investigated as fencing will have to be adapted to the seasons and levels of caribou motivation. Migrating caribou are more resistant to changing their direction than caribou foraging in an area but even migrations on a large scale have been redirected. The Russians used a 60km fence to direct wild reindeer away from a railway and pipeline (Appendix 3). Care will be needed with choice of where the caribou are being directed and provision of contingencies to ensure that the fences do not themselves become a problem.

Other steps to mitigate effects are educational. Education will include explaining to mine staff about caribou's need for uninterrupted foraging, their strategies for avoiding predators and the consequences of insect harassment.

Cumulative Effects

Caribou exposed to the winter road will likely be, in some years, the same individuals exposed to the mine at Lac de Gras as well as other developments. This increases the need to minimise behavioral changes and energetic costs. Mitigating individual effects will, in turn, mitigate cumulative effects. Environmental variation, knowledge gaps and possible failures or errors in mitigation and monitoring are sources for uncertainty in mitigating cumulative effects. Energetic modelling to predict and evaluate cumulative effects are possible with the type of model developed for Porcupine caribou herd (Russell eta/. 1993). That modelling would usefully guide developing priorities for monitoring and mitigation.

Our only previous experience with this scale of development on caribou ranges is the effects of the Prudhoe Bay oilfield on caribou in the Central Arctic herd. The evidence over 15 years is increasingly indicating that behavioral avoidance of roads is accumulating as an effect on cow productivity and calf survival. The evidence is not, yet, irrefutable but is sufficiently strong that management of industrial activities and caribou must remain conservative until it can be demonstrated that cumulative effects do not constrain the herd's well being.

4.0 RECOMMENDATIONS TO THE PANEL

1. The Proponent should work with the Department of Renewable Resources and traditional users to develop specific monitoring and mitigation programs to manage interactions between the NWT Diamonds Project and caribou. Those programs should be firmly built on science and traditional knowledge. The operating conditions for the Project should require monitoring and mitigation plans.

2. Interactions between the NWT Diamonds Project and caribou should be managed with the objective that caribou deaths and injuries are unacceptable risks and should be minimised to the maximum degree possible. Behavioral and energetic costs are only acceptable if minimised. Those assessment objectives have to be stringent because of environmental uncertainties and knowledge gaps. The only experience elsewhere for this scale of project on caribou ranges (Prudhoe Bay) indicates that cumulative effects are likely at the population level unless mitigation is effective.

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APPENDIX 1

Comments on NWT Diamonds Project Environmental Impact Assessment

The sections on caribou and environmental assessment could have been more rigorous and scientific. Other methods to acquire baseline information would have given more useful information and been less intrusive. Well designed sampling to describe numbers and behaviour of caribou and environmental factors that influence their behaviour are essential baseline data to measure effects and plan mitigation.

Volume II:
Section 3.3.2.2 Previous research (on the Bathurst herd)

The caribou section does not sufficiently explain caribou ecology as it relates to the Project. Relevant literature on caribou is absent with reliance on general articles. Information from the few reports cited is poorly integrated. For example, the Proponent cites Urquhart's report that the Bathurst herd has calved at Bathurst Inlet since 1960 even though there is information in another cited report (Fleck and Gunn 1982) which summarises the pre-1960 knowledge on calving distribution.

The paragraph on food habits fails to explain caribou ecology and how it might predict caribou's response to development. The only paper cited is a popular summary (Urquhart 1989) rather than primary research or review papers (for example Klein 1990 and Russell eta/. 1993). And it seems remiss not to cite the research published on the Bathurst herd's feeding behaviour on the summer range 1. Understanding why caribou select certain foods in spring and summer especially their selection for fresh growth explains why caribou will be attracted to some structures. Dust in spring will accelerate snow melt and plant growth and seepage in summer along roads may also attract caribou.

The description of insect harassment would have been enhanced by using the relevant literature. The distinction between caribou responding to mosquitos or warble flies is not made although it determines how they would interact with the Project. It is misleading to state that caribou" seek out human developments" (p.3. 164) without pointing out that bulls differ from cows (with calves) in their responses. Russell *et* a/. (1993) describe the conditions under which either mosquito or warble fly harassment are likely. As the Proponent has the weather data for the site, it would have been useful to have estimated the number of days when insect harassment would have been severe.

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[1](Melton, **D. and D. Heard. 1992. Ungulate** behaviour **and habitat quality: insights from Africa and the** Arctic. Pages 185-188 *In*: Ungulates 91, Proceed. Internat. Symp, SFEPM/IRGM,

The paragraph discussing the Bathurst herd's size would have been more useful if the Proponent had used current estimates and background information on previous estimates including an explanation of how herd size is estimated. The most recent estimate is from 1990 (352,000 +/- 78,000).

Section 3.3.2.3 Methods

No rationale for the methodology is given and data presentation is scanty without descriptive statistics. Using a Twin Otter at 200 kmph and 300-400 m above the ground in May is not the best survey technique. Even under reasonable conditions observers will miss seeing caribou, so at that speed and altitude with the small windows in the Twin Otter many caribou would be missed.

The subsequent survey design (local study area), using a helicopter at low speed (44-50 kmph) and a low altitude (30m above ground level) every 2 to 4 days (1000/o coverage) would have made for accuracy (seeing all the caribou) but at the cost of disturbing them. Miller and Gunn (1979) for example, recorded extreme responses, i.e. galloping, to helicopter flights <200 m agl. The weekly helicopter flights over the larger wildlife study area are too low and slow to avoid unnecessary disturbance. It is misleading, without footnotes, to give the Twin Otter high level fast flights with the low and slow helicopter flights in the same table. It is not clear why there were no survey flights in June or early July 1994

In 1995, methods improved using a Cessna 185 in spring" to avoid disturbance to migrating pregnant cows" (p. 1-5, 1995 Baseline Study Update). But helicopter flights in summer and fall were still low enough (61-91 m above the ground) to be disturbing especially as large groups were circled (p. 1-7). It is not explained how the observers determined strip width for the helicopter surveys.

Given the three survey aircraft types and the variation in survey altitude and strip width, comparisons between months and years are not feasible.

The differences between how bulls respond compared to cows and calves should have alerted the researchers to the importance of sex-age composition. In 1994, only 13% of all caribou sighted were classified and most (61 %) were cows which was attributed (p. 176) "to the ease of identifying sex in the small post-calving aggregations". In 1995, the methods indicate sex-age information was collected but it was not reported. At the low altitudes of most flights, it is unusual that the observers did not classify more animals.

Those aerial surveys only reveal caribou numbers in the mine's vicinity. They tell nothing about how long caribou remained and what their activities were (foraging, resting, seeking relief from insects). Given the intensity and frequency of the low level flights, information on caribou responses should have been collected. Specific information on habitat use, plant phenology, insect harassment, timing and rates of snow melt are all factors whose measurement would have contributed to understanding caribou behaviour and thus contributing to the development of mitigation and monitoring plans.

Vol. IV, Impacts and Mitigation, Section 3.3.4 Bathurst caribou

The Proponent notes, correctly, that there is a large body of literature on caribou and disturbance but neglects to point out that it is also a controversial topic with dovided opinions. The paper cited (Bergerud *et* a/l 984) provides one side of the issue and triggered published letters of disagreement to the journal's editor. The paper cited for the effects of Prudhoe Bay was published 12 years ago and more recent publications present evidence that the Central Arctic herd's productivity is decreasing. An especially useful paper for the Proponent and Panel would have been Shidler *et al.*(1 986) review of caribou and disturbance.

The examples of herds crossing roads are unhelpful to the Panel without details. The key points would have been to describe the amount and type of traffic and the season and extent of caribou interaction with the roads. Examples such as the Qamanirqauq herd crossing the Churchill railway (no reference given) are misleading because so little information was collected. The Proponent is correct in that the caribou did cross the **railway but neglects to mention that even though there were only two trains a week, caribou were killed.**[2]

Section 3.3.4.1 Habitat loss

The statement that "Lac de Gras does not represent major wintering or summering areas and consistently high densities of caribou do not exist" should be substantiated by data or references.

Section 3.3.4.2 Habitat degradation

The statement that "In general, habitat degradation will not affect caribou use of habitat" should be substantiated by data or references.

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[2]Banfield A.W. F. 1954. Preliminary investigation of the barren ground caribou. Canadian Wildlife Service, **Wildlife Management Bulletin Series 1, No.** 10B.

Section 3.3.4.3 Disturbance

Many terms are undefined and supporting data for statements are absent. For example: "They (caribou) did not exhibit extreme reactions or evidence of disturbance to the noise or activity at the site."

Section 3.3.4.4 Mitigation

The proposed mitigative steps are few and vague, for example, high-use caribou habitats will be "protected from disturbance if possible";"behavioral responses of caribou to visual barriers may be used to deflect them from open pits"; aircraft traffic "will be controlled during spring and fall migrations"; and "historical experience could be used to divert caribou from the Long Lake tailings pond". All these mitigative actions are identified as conditional but the conditions under which they are implemented are not identified. The list is not exhaustive when compared to possible effects.

APPENDIX 2

Background Papers on Prudhoe and Low-flying Aircraft in Labrador

Effects of a road system on caribou distribution during calving

J. R. Dau[1] and R. D. Cameron[2]

Abstract: In winter 1981-82, a 29-km road system was built in a high-use caribou (*Rangifer tarandus granti*) calving area near Milne Point, Alaska. Aerial surveys of this area were conducted annually during the calving period for 4 years before and 4 years after road construction. Effects of the road system on the distribution of caribou were investigated by comparing survey data obtained during these two periods. The 41400-ha study area was partitioned into 40 quadrats; after construction (1982 - 85), significantly fewer caribou were observed within quadrats encompassing the present road system than before construction (1978-81). The area within 6 km of the road system was stratified into six 1-km intervals, and differences in the distribution of caribou among those strata were examined using linear regression analysis. After construction, the density of maternal females was positively correlated with distance, whereas no such relationship was apparent before construction. Density of nonmaterial adults was unrelated to distance during both periods. The results suggest that a local displacement of maternal caribou has occurred in response to roads and associated human activity.

Key words: caribou, calving, roads, disturbance.

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Rangifer, Special Issue No. 1, 1986:95-101

Introduction

The Central Arctic Herd (CAH) is a distinct subpopulation of ca. 13 000 caribou (*Rangifer tarandus granti*) (as of 1983; W. Smith, unpublished data) that ranges the Arctic Slope of Alaska between the Canning and Colville Rivers. Seasonal movements are principally north-south between wintering areas in the Brooks Range and calving grounds/ summer range on the Arctic Coastal Plain (Cameron and Whitten, 1979).

In winter 1981-82, CONOCO, Inc. built 29 km of gravel road as the initial phase of petroleum development within the Milne Point Production Unit (Fig. 1). This complex is approximately centered on one of two known CAH calving concentration areas (Whitten and Cameron, 1985). In winter 1984-85, a single pipeline 35 cm in diameter and approximately 1.8 m above ground was erected adjacent to the Milne Point Road, and a 300-person housing facility was constructed. Human activity and traffic levels near Milne Point were low in June 1983 and 1984 (<10 vehicles per day; 1 active drill rig), moderate in 1982 (10 - 100 vehicles per day; 2 active drill rigs), and high in 1985 (>200 vehicles per day; 3 active drill rigs).

The objective of this study was to determine the effects of roads and associated activity on the local distribution of caribou, especially maternal females, in this high-use calving area. We compared the distribution of caribou within this region during the four years before construction of the road system (1978 - 81) with that during the four years after construction (1982 - 85).

Methods

The study area is ca. 45 km northwest of Prudhoe Bay, lying north of the West Sak Road between the Oliktok Road and Kuparuk River

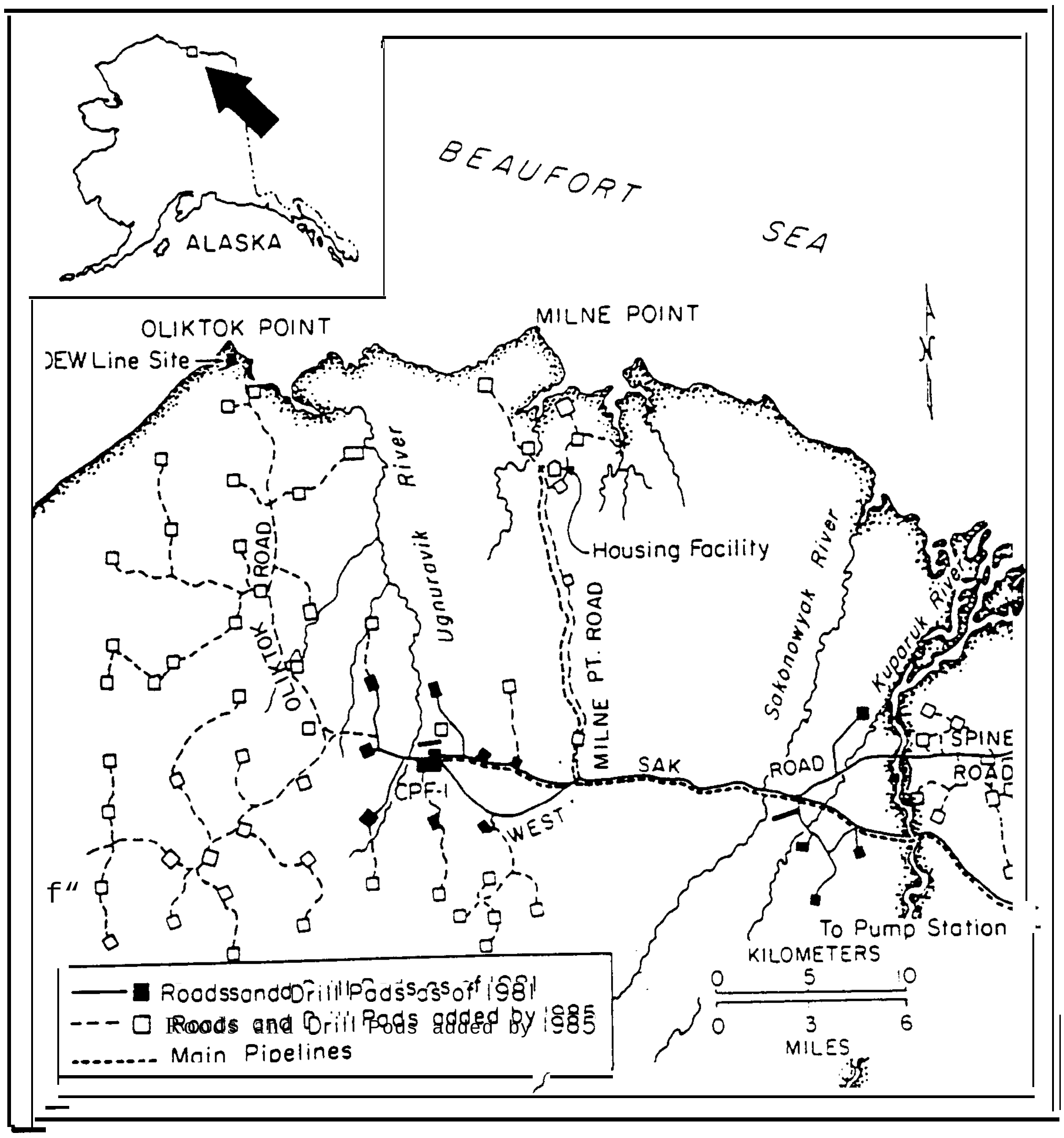

Fig. 1. The Milne Point study area and surrounding region, with roads and gravel pads as of 1981 and 1985.

(Fig. 1). Terrain ranges from sea level to 25 m elevation. Veneration is typical of the Arctic Coastal Plain (Wahrhaftig, 1965) and similar to that described for the Prudhoe Bay region (Neiland and Hok, 1975; Webber and Walker, 1975).

Aerial surveys of the study area (Whitten and Cameron, 1985; Cameron *et al.*, 1985) were conducted annually between 10 and 14 June 1978 - 85, within a few days after the majority of CAH calving had occurred. North-south strip transects spaced at 3.2 km were flown by helicopter, and observers searched within 1.6 km of the transect center line. For each group of caribou observed, we recorded map location, group size, and sex/age composition.

The study area was partitioned into 40 quadrats of 1036 ha each (Fig. 2). Median percentages of caribou observed within the seven quadrats that include the present road system (i.e., «road quadrats») were compared between the pre- and postconstruction periods using the

Mann-Whitney test: the Z test statistic is reported when ranks were tied (Conover, 1980).

The area within 6 km of the present roads was then stratified into six 1-km distance intervals, excluding portions of strata that were closer to the West Sak Road (Fig. 1), and the data were examined to determine whether the assumptions for linear regression analysis were satisfied (Neter and Wasserman, 1974). Square root transformations eliminated the correlations between means and variances of caribou density within strata. Linear regressions describing caribou density as a function of distance from roads were fit using the full and reduced model approach (Neter and Wasserman, 1974) to examine differences within and between the two four-year periods. Linear models for 1978 - 81

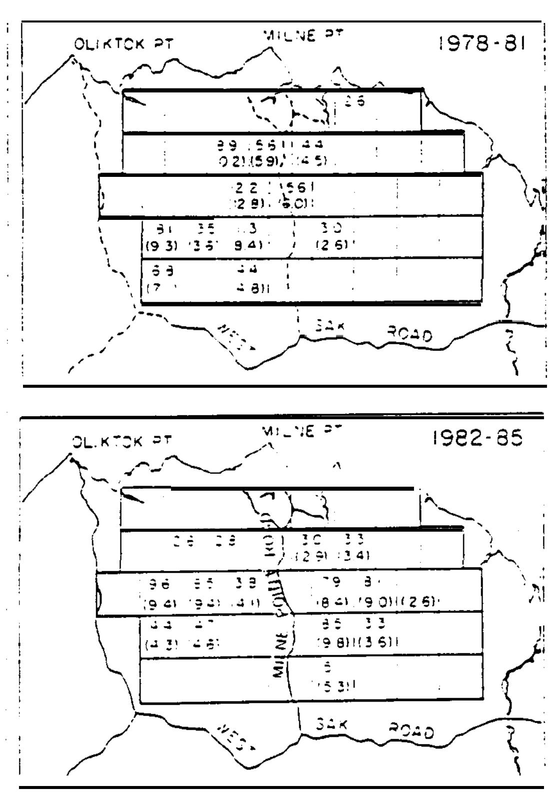

Fig. 2. Distribution of 1036-ha quadrats in the study area (see Fig. 1) preferred by caribou (calves, in parentheses) during calving, 1978 - 81 and 1982 - 85. The occurrence of caribou is expressed as a percentage of the total observed in all 40 quadrats; only those percentages exceeding 2.5% (the percentage of the total area for each quadrat) are shown.

and 1982 - 85 were fit simultaneously and compared through analysis of variance (ANOVA).

During the surveys, we did not distinguish between maternal and nonmaternal females. Therefore, to describe the distribution of maternal females, the above analyses based on total number of caribou were repeated using number of calves (i. e., neonates). In addition, stratification and ANOVA were used to compare the responses of maternal groups (i. e., ≥25% calves) and nonmaternal groups (i. e., <25% calves) to roads. It should be noted that the latter is an *a posteriori* analysis, and the results should not be granted the same level of objectivity as other results presented here.

All statistical operations were performed using a Compaq Deskpro computer system and SPSS/PC statistical software (Norusis, 1984). Alpha levels (P-values) ≤0.05 were considered statistically significant.

Results

Fewer caribou were near the present road system after construction than before construction. The median percentage of caribou in the seven road quadrats was significantly different between 1978 - 81 and 1982 - 85 (8.5 vs. 2.0%, T = 26.0, P = 0.03). Before construction, 17% of all caribou observed in the study area (465 of 2806) were within these seven quadrats, compared with only 2% (90 of 5424) after construction.

Differences between periods for calves were not clear. Even though the median percentage of calves in the road quadrats was higher during 1978 - 81 (10.5%) than during 1982 - 85 (0.0%), the difference was not statistically significant (z = -1.69, P = 0.09). However, the disparity between pre- and postconstruction periods in the percentage of all calves observed in the seven quadrats was greater than that for all caribou. Before construction, 17% of all calves observed (190 of 1150) were within these quadrats, compared with <1% (,6 of 2339) after road construction.

Linear relationships between caribou density and distance from roads were significantly different between 1978 - 81 and 1982 - 85 for all caribou, and for calves (Table 1). The annual variability in these relationships within each four-year period was not significant for all caribou, but was nearly significant for calves (P = 0.053). The latter may have resulted from yearly differences in levels of human activity in the study area after 1981. Nevertheless. differences in these relationships were greater between periods than among years within periods (Table 1).

During 1978 - 81. there was no delectable linear relationship between the density of either total number of caribou or number of calves, and distance from roads. In 1982- 85, however, both density parameters were correlated with distance (Fig. 3). This further suggests that the between-period difference in the relationship between calf density and distance (see above) was *real* and not attributable to within-period variation.

The similar results obtained for total number of all caribou and number of calves (Fig. 3) indicate that the distribution of maternal caribou was not appreciably different trom the distribution of all caribou. This is not surprising considering that most adult (≥2 years) caribou in the study area during June were maternal females (minimum mean = 69%; SD = 15).

The relationships between number of maternal groups per km² and distance from roads differed significantly between 1978 - 81 and 1982 - 85, a difference that cannot be attributed to within-period variability (Table 2). No such difference was found for nonmaterial groups, either between or within the pre- and postconstruction periods. Furthermore, there was no linear correlation between the number of maternal or nonmaterial groups per km² and distance during 1978 - 81; nor was there any correlation for nonmaterial groups during 1982 - 85. In 1982 - 85, however, the number of maternal groups per

Table 1. Analysis of variance examination of the relationships between numbers of all caribou, and calves, per km², and distance from roads. Milne Point. Alaska. June 1978 - 85.

Density parameter	Model[a]	Source of variability	Sums of squares	df	Mean square	F	P	Entering F value	P
All caribou		Total	25.26	47					
	Basic[b]	Regression	3.43	1	3.43	7.23	0.01	7.23	0.01
		Error	21.83	46	0.47				
	Reduced[c]	Regression	8.84	3	2.95	7.89	<0.01	7.24	<0.01
		Error	16.42	44	0.37				
	Full[d]	Regression	15.69	15	1.05	3.50	<0.01	1.91	0.07
		Error	9.56	32	0.30				
	Test[e]	Periods	8.84	3	2.95	5.15	0.02		
		Years/Periods	6.86	12	0.57				
Calves		Total	4.63	47					
	Basic[b]	Regression	2.07	1	2.07	7.58	<0.01	7.58	<0.01
		Error	2.56	46	0.27				
	Reduced	Regression	5.38	3	1.79	8.51	<0.01	7.85	<0.01
		Error	9.26	44	0.21				
	Full[d]	Regression	9.40	15	0.63	3.83	<0.01	2.05	0.03
		Error	5.24	32	0.16				
	Test[e]	Periods	5.38	3	1.79	5.35	0.02		
		Years/Periods	4.22	12	0.34				

[a] Each model tests simple linear relationship(s), where the dependent variable is the square root of caribou density (numbers/km²) and the independent variable is distance from the road site (km).

[b] Fits a linear model with data pooled across all years: H_0: the eight relationships are not significantly different. The Entering F value tests for the significance of this model beyond the significance of the Basic model.

[c] Fits a separate linear model for each period; H_0: the two relationships are not significantly different. The Entering F value tests for the significance of this model beyond the significance of the Basic model.

[d] Fits a separate linear model for each year within each period: H_0: the four relationships are not significantly different. The Entering F value tests for the significance of this model beyond the significance of the Reduced model.

[e] Tests H_0: the variation in linear models between periods is not significantly greater than the variation in linear models among years within each period.

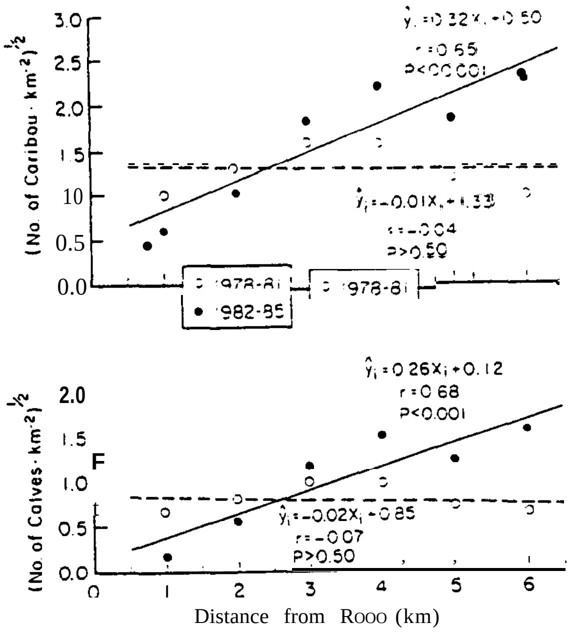

Fig. 3. The relationships between caribou density and distance from roads for all caribou, and calves (i.e., neonates), during June 1978 — 81 and 1982 - 85, Milne Point, Alaska. Data points shown are strata means for each 4-year period: however, linear models were fit using data for individual years.

km' was highly correlated with distance from roads (Fig. 4).

Discussion

Results of the quadrat analysis for calves are probably misleading. The absence of a statistically significant difference between 1978 - 81 and 1982 - 85 in the median percentage of calves in the seven road quadrats may be attributable to the small sample size (n = 8), tied ranks, and the large effect on ranks of the slightly greater percentage of calves observed during 1985 (1%) vs. 1980 (0%).

Linear regression analyses clearly show significant differences between 1978 - 81 and 1982-85 in the relationships between caribou density and distance from roads, differences that are not artifacts of annual variability. Apparently, displacement of maternal females from areas near the Milne Point road system account for this change.

Extrapolating these local effects to a regional level requires some speculation. The logical implication is that an extensive, dense network of roads will result in widespread, partial displacement of maternal caribou from calving

Table 2. Analysis of variance examination of the relationships between numbers of maternal and nonmaternal groups per km² and distance from roads, Milne Point, Alaska, June 1978-85.

Density parameter	Model	Source of variability	Sums of squares	df	Mean square	F	P	Entering F value	P
Maternal groups		Total	0.875	47					
	Basic	Regression	0.144	1	0.144	9.09	<0.01	9.09	<0.01
		Error	0.730	46	0.016				
	Reduced	Regression	0.363	3	0.121	10.40	<0.01	9.39	<0.01
		Error	0.512	44	0.012				
	Full	Regression	0.507	15	1.050	2.94	<0.01	1.04	0.44
		Error	0.368	32	0.012				
	Test	Periods	0.363	3	0.121	10.10	<0.01		
		Years, Periods	0.144	12	0.012				
Nonmaternal groups		Total	0.742	47					
	Basic	Regression	0.026	1	0.026	1.66	0.20	1.66	0.20
		Error	0.716	46	0.016				
	Reduced	Regression	0.111	3	0.037	2.58	[illegible]	2.97	0.06
		Error	0.631	44	0.014				
	Full	Regression	0.273	15	0.018	1.24	0.29	[illegible]	0.54
		Error	0.469	32	0.015				
	Test	Periods	0.111	3	0.037	2.74	0.10		
		Years, Periods	0.162	12	0.013				

See footnotes to Table 1.

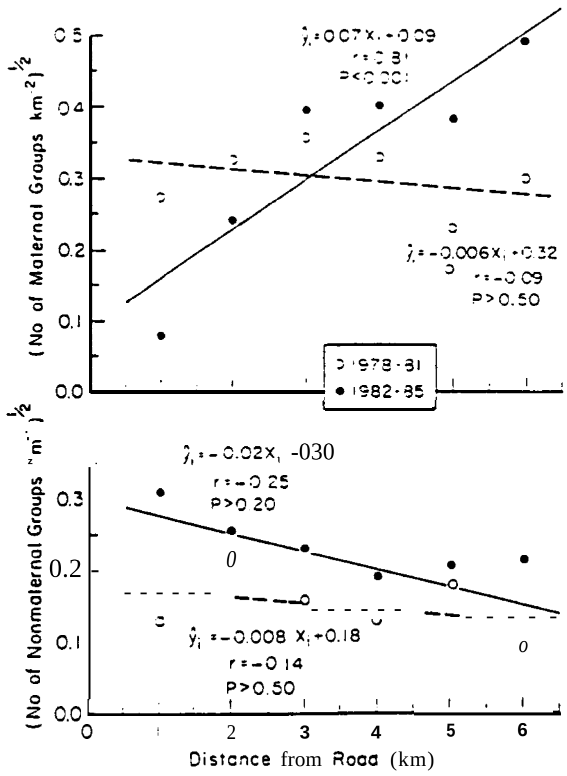

Fig. 4. The relationships between the number of maternal groups (i. e., ≥25% calves) and nonmaternal groups (i. e., <25% calves) per km², and distance from roads during June 1978-81 and 1982-85, Milne Point, Alaska. Data points shown are strata means for each 4-year period; however, linear models were fit using data for individual years.

grounds unless they begin to tolerate these structures and associated activities (Cowan, 1974). Unfortunately, there is no evidence for habituation by maternal caribou. On the contrary, numbers of CAH females calving within the Prudhoe Bay oil field have remained consistently low (Whitten and Cameron, 1985, unpublished data), despite nearly a decade of exposure to manmade structures.

The fidelity that most caribou herds show to calving grounds suggests that these areas may be more important than other seasonal ranges which are used less predictably (Skoog, 1968). Bergerud (1974) stated: "The basic question is .... why the same areas, limited in extent, are used year after year as calving sites." Valkenburg et al. (in press) discuss some of the factors that could influence the affinity of caribou to calving areas.

The CAH has continued to grow despite the loss of calving habitat. However, this apparent inconsistency does not preclude the possibility that traditional calving areas confer an advantage to caribou. Thus far, displacement of CAH maternal females has been relatively minor, and the low density of this herd on its calving grounds has allowed use of suitable alternative areas (Whitten and Cameron, 1985).

To our knowledge, this study is the first to systematically and quantitatively address the effects of development within a high-use calving area. If petroleum development continues to expand across the central Arctic Coastal Plain, we should have more opportunities to evaluate the importance of calving areas to the CAH. Other seasonal ranges have been only slightly affected by man, losses to predation are thought to be low, and the annual human harvest is small. The absence of these confounding factors provides a unique opportunity to evaluate the consequences of habitat loss to the productivity of a barren-ground caribou herd.

Acknowledgements

Funding was provided by grants from CONOCO, Inc., Continental Pipeline Co., ARCO Alaska, Inc., Exxon Co., U. S.A., and Sohio Petroleum Co. Additional support was obtained from Federal Aid in Wildlife Restoration, and from the Division of Habitat, Alaska Department of Fish and Game. The senior author's travel to the Fourth International Reindeer/Caribou Symposium was provided in part by a grant from the Jack R. Luick Memorial Travel Fund. W. T. Smith and K. R. Whitten were instrumental in the collection of much of the aerial survey data; additional assistance was provided by P. Bente, R. R. Rice, R. G. McAllister, D. Masiak, and R. M. Stearns. We thank W. L. Regelin, W. T. Smith, S. R. Peterson, D. R. Klein, S. G. Fancy, and M. C. S. Kingsley for critically reviewing the manuscript. We are particularly grateful to D. J. Reed for statistical assistance.

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Abundance and movements of caribou in the oilfield complex near Prudhoe Bay, Alaska

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Abstract: We examined the distribution and movements of 141 radiocollared female caribou (*Rangifer tarandus granti*) of the Central Arctic Herd during summer, 1980-1993. Numbers of caribou locations within each of 5 quadrats along the arctic coast were totalled separately for days during which insects were active and inactive, and numbers of east-west and west-east crossings of each quadrat mid-line were determined from sequential observations. Both abundance and lateral movements of radiocollared females in the quadrat encompassing the intensively-developed Prudhoe Bay oilfield complex were significantly lower than in other quadrats ($P < 0.001$ and $P < 0.00001$, respectively). Avoidance of, and fewer movements within, the complex by female caribou are ostensibly in response to the dense network of production and support facilities, roads, above-ground pipelines, and the associated vehicular and human activity. Impaired access to this area constitutes a functional loss of habitat.

Key words: arctic, disturbance, pipeline, *Rangifer tarandus*

Rangifer, 15 (1): 3-7

Introduction

Barren-ground caribou (*Rangifer tarandus granti*) of the Central Arctic Herd (CAH) inhabit the Arctic Slope between approximately the Colville and Canning Rivers. Seasonal movements occur between calving and summer ranges on the coastal plain and wintering areas in the northern foothills of the Brooks Range (Cameron & Whitten, 1979).

Summer distribution and movements of CAH caribou are influenced strongly by insects. During warm, calm days in July when mosquitoes (*Aedes* spp.) and oestrid flies (*Hypoderma* (= *Oedemagena*) *tarandi, Cephenemyia trompe*) become active, caribou aggregate and move to the coast of the Beaufort Sea; when cooler conditions prevail, insect activity abates, and caribou return inland (Dau, 1986). These oscillatory movements periodically bring numerous caribou into contact with oilfields in the coastal zone (*e. g.*, Smith & Cameron, 1985a, 1985b; Murphy & Curatolo, 1987; Smith *et al.*, 1994).

Petroleum-related activity near Prudhoe Bay spans nearly 25 years. Following the discovery of oil there in 1968, development increased steadily, from little more than a staging area near Deadhorse Airport to a large, dense network of roads, pipelines, processing facilities, and assorted commercial enterprices. The present complex occupies much of the coastal zone between the Kuparuk and

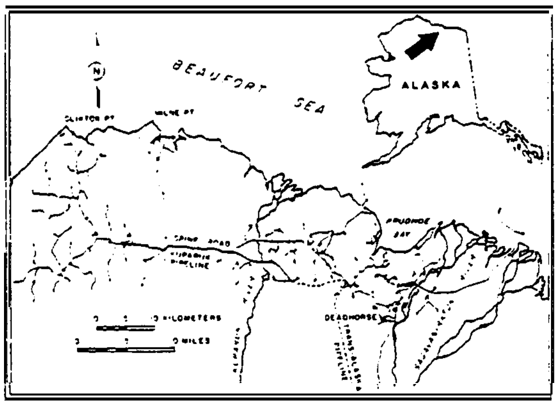

Fig. 1. Roads and facilities in the Prudhoe Bay region. Alaska, ca. 1990. Note: One or more pipelines (stippled) are adjacent to most roads.

Sagavanirktok Rivers. During the 1980s, additional oilfields were developed west of the Kuparuk River and in the Sagavanirktok Delta (Fig. 1).

For 14 summers. we monitored che distribution and movements of radiocollared caribou. in part to identify any changes that might occur wirh increasing development in the Prudhoe Bay region. In rhis paper, we rest rhe following hypothesis (HO): Neither overall abundance nor frequency of east-west and west-east movements of radiocollared females within the area encompassing rhe Prudhoe Bay oilfield complex differed from similar areas elsewhere within the summer range of the CAH.

Methods

From 1980 through i 995, we relocated 141 different radiocollared female caribou (range, 6–40 caribou/yr) by fixed-wing aircraft at least once each during the period 25 June - 10 August. Locations were marked on topographic maps (U.S. Geological Survey, 1:250,000) and later converted to UTM coordinates, or coordinates were recorded directly from a LORAN or GPS receiver: most were accurate to < 2 km, and all < 5 km, judging from our ability to relate caribou observations co identifiable map landmarks or based on position errors of airborne navigation equipment.

Analyses were restricted to locations within ca. 20 km of the coastline. The area was subvided at 1° intervals of longitude from 146°W co 15 1'W, yielding 5 quadrats, each ca. 850 km². The central quadrat encompassed the Prudhoe Bay oilfield complex north from Deadhorse Airport. while the other quadrats included less-developed areas west of the Kuparuk River and undeveloped areas east of the Sagavanirktok River (Fig. 2).

Insect activity was classified as present or absent for each survey day by applying hourly temperature and wind data recorded at Deadhorse Airport to the

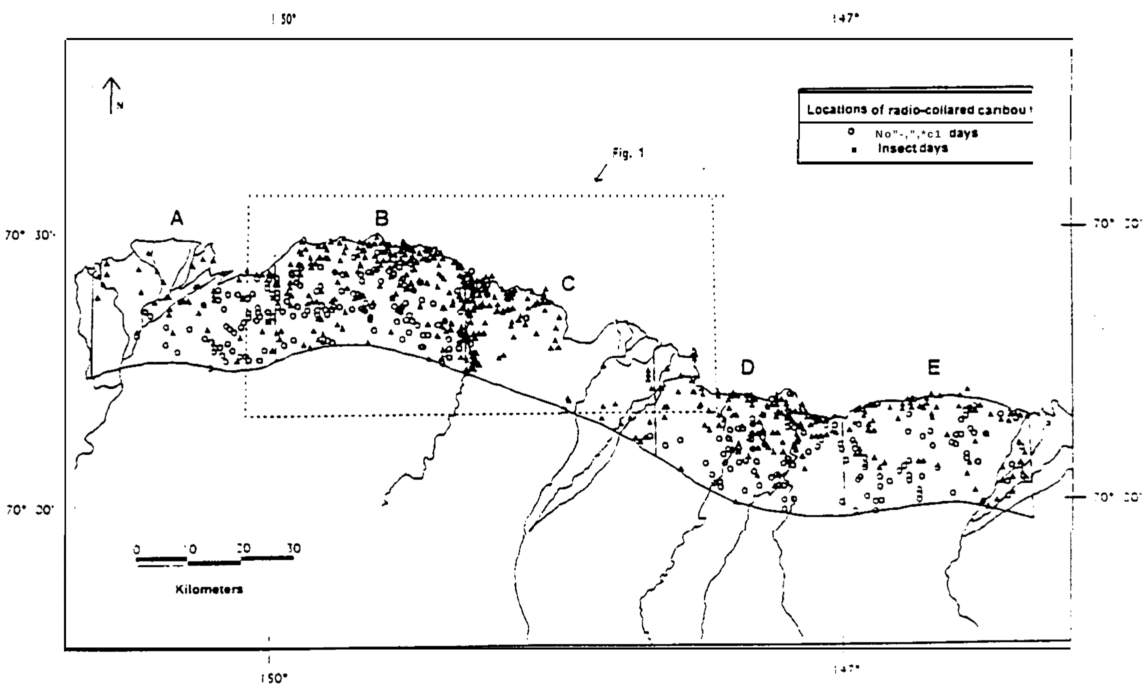

Fig. 2. Locations of radiocollared female caribou within ca. 850-km² coastal quadrats in relation to insect activity. Central Arctic Herd, Alaska, summer 1980–1995. Note: Some points represent > 1 female in a single group.

predictive models of Russell *et al.* (1993). If temperature and wind velocity met the criteria for predicted mosquito or oestrid fly activity for ≥ 4 hours, that entire day was classified as an «insect» day; all other days were classified as « non-insect. »

The entire summer range of the CAH seldom was surveyed for radiocollared females on a single day, and, in some years, coverage of quadrats (Fig. 2) to the west (A and B) or east (D and E) was not equal. Quadrat C, however, was overflown regularly during departure and arrival in the Deadhorse area, our base of operations. Nonetheless, bacause radio-tracking effort was not always spatially uniform, we assessed distribution of radiocollared females among quadrats by comparing ratios of non-insect: insect observations. We compared ease-wesr movements of females within quadrats from a subset of sequential locations of 115 individuals, from which ratios of inferred: potential crossings of each quadrat mid-line were calculated. Standard errors were computed (ratio formula; Cochran, 1977), with female-year as the sample unit, and differences between ratios of means were evaluated using t-tests. P-values < 0.05 were considered significant.

Results

We obtained 1220 point locations for radiocollared females within the study area. Despite use of a simple categorical estimate of insect activity for each full day, there was a clear tendency for caribou to be nearer the coast on insect days than on non-insect days (Fig. 2), a direct reflection of movements that occur in response to changing mosquito and oestrid fly harassment.

The ratio of non-insect:insect observations of female caribou within Quadrat C was significantly lower than those for the ocher 4 quadrats ($P <$ 0.001, Table 1). Similarly, the relative frequency with which radiocollared females crossed the mid-line of Quadrat C was significantly lower then for other quadrats ($P <$ 0.00001, Table 1).

Discussion

Abundance

The data indicate reduced use of Quadrat C by radiocollared female caribou, at least during non-insect days, apparently in response to the presence of the Prudhoe Bay oilfield complex. An inspection of caribou locations (Fig. 2, with reference to Fig. 1) clearly demonstrates that few were in the general area of the complex. Even during insect harassment, most females were along or near the Kupurak flood-plain, a major movement corridor for caribou (Smith *et al.*, 1994), or within a few kilometers east of rhe Kuparuk Delta, an area of little surface development. Clearly, avoidance is far more extensive than reported previously for the central portion of the oilfield (Cameron *et al.*, 1979; Smith & Cameron, 1985).

Table 1. Ratios of non-insect::insect observations of radio-collared female caribou within each quadrat (Fig. 2), and inferred:potential crossings of quadrat mid-lines, Central Arctic Herd, summer 1980–1993.

Quadrat	Observations, non-insect:insect (n)	Crossings, inferred: potential (n-)
A	0.60 (154)	0.46 (192)
B	0.55 (382)	0.43 (408)
C	0.08[b] (186)	0.05[c] (222)
D	0.43 (305)	0.41 (269)
E	0.61 (193)	0.49 (168)

[a] Number of potential crossings breed on sequential locations, including those resumed for interjacent quadrats.

[b] Significantly lower than ratios for Quadrats A, B, D, and E (r-zest, $P < 0.001$); all other differences not significant, except for Quadrats B vs. E ($P < 0.01$).

[c] Significantly lower than ratios for Quadrats A, B, D, and E (t-test, $P <$ 0.00001); all ocher differences not significant.

The comparative paucity of female caribou in Quadrat C during non-insect vs. insect days (Table 1) cannot be attributed to a unique habitat composition, specifically, a greater occurrence of sparsely-vegetated riparian areas used principally for insect relief. Figure 2 shows that Quadrat C comprised more riparian habitat than Quadrat B, D, or E, but less rhan Quadrat A, yet rhe non-insect: insect ratio for the latter was among the highest computed (Table 1).

Determining rhe exact area that female caribou avoid is difficult, owing to the gradual progress of oilfield development and the accompanying net growth of the CAH from ca. 9000 in 1981 (Whitten & Cameron, 1985a) to ca. 23,000 in 1992 (Whitten, unpubl. data). A *minimum* area, however, can be estimated. Assuming, conservatively, that abundance of radiocollared females during insect days did not decline, reduced use of Quadrat C can be calculated as the product of the total number of locations there during insect days (171) and the second lowest ratio reported (0.55, Quadrat B; Table 1). Thus, at least 60 females should have been present in Quadrat C, wherein only 13 were observed, a decrease of 78 % or an equivalent area of 660 km^2.

Movements

Our observation of infrequent lateral movements of female caribou within Quadrat C reinforces earlier evidence for low rates of crossing the Trans-Alaska Pipeline corridor, including its extension through the complex (Whitten & Cameron, 1983b). In contrast, caribou apparently were abundant, and major movements were not uncommon. in this same area during the 1970s (Child, 1973; White *et al.*, 1975; Gavin, undated).

Obvious attempts by large groups of caribou to penetrate the oilfield complex have been observed in recent years. On several occasions (e.g. Smith *et al.*, 1994), insect-harassed aggregations moved eastward across the Kuparuk Delta, contacting the roads and pipelines west and south of Prudhoe Bay (Fig. 1), but apparently were unable to continue to the west channel of the Sagavanirktok River. Moreover, in our 14 years of radiotracking, not a single collared caribou is known to have passed entirely through the main oilfield in either direction. The 10 inferred crossings of the Quadrat C mid-line (Table 1) may have occurred near Deadhorse Airport. the southern boundary of the complex.

Although predevelopment data are unavailable. there is no reason to believe that previous movements of caribou in Quadrat C were substantially different from those in similar areas of the CAH summer range. Insect-induced movements are ostensibly more opportunistic than repetitively site-specific. Given unimpeded access. the exact routes caribou take to and from the coast depend largely upon their location at the onset and cessation. respectively. of insect harassment; although riparian areas. when available, are selected as corridors (Smith *et al.*, 1994). Hence. just as weather events tend to be random. so are the associated movements. If mid-line crossing ratios for Quadrats A. B. D, and E accurately reflect a random process. then the frequency of lateral movements within Quadrat C has decreased by nearly 90 % (Table 1).

Implications

Underuse of. and reduced movements within. the Prudhoe Bay oilfield by caribou are apparently due to the cumulative effects of intensive and extensive surface development. high levels of vehicular traffic. and widespread human activity. Very likely, avoidance is exacerbated by numerous pipelines < 1.0 m above ground level, which constitute physical barriers to movement.

By comparison, more recent oilfields west of the Kuparuk River (i.e. within Quadrat B) have a lower density of production-related facilities (Fig. 1), and nearly all pipelines are elevated ≥ 1.5 m. Numerous caribou continue to occupy these areas in summer. albeit with notable shifts in distribution (Smith *et al.*, 1994). Nevertheless, as development within the Kuparuk region continues to expand and intensify, additional changes can be anticipated.

The avoidance process, we suspect, is quite subtle and therefore difficult to detect. Unlike the extreme sensitivity noted during calving (Dau & Cameron, 1986; Cameron *et al.*, 1992), female caribou evidently will tolerate considerable surface development in summer, especially when passage under (or over) pipelines is possible (Smith *et al.*, 1994). However. if structural complexity increases to a point at which the environment becomes unacceptable, caribou may largely abandon an area. perhaps abruptly. Withdrawal is probably sustained by new movement patterns that emerge through learning and trial-and-error. Both rate of egress and the eventual level of use might also vary to an unknown degree. depending upon local habitat types and regional landscape features. Our inability to quantify this complex interaction of man-made and natural stimuli renders critical levels of disturbance elusive and accurate predictions of the timing of abandonment virtually impossible.

Barren-ground caribou are indeed adaptable (Bergerud *et al.*, 1984), but there are limits. Exceeding their tolerance for adverse stimuli will influence distribution and may preclude access to an area. And inaccessible habitat is habitat lost.

Acknowledgements

Primary funding was provided by Federal Aid in Wildlife Restoration and the Alaska Department of Fish and Game. Division of Wildlife Conservation. We are grateful to R. A. DeLong, L. A. McCarthy, and staff from Alaska Biological Research. Inc. for technical assistance. Pilots D. C. Miller and R. D. C. flew all radiotracking surveys. Thanks to D. R. Klein and an anonymous reviewer for their constructive comments on our earlier draft of the manuscript.

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Manuscript accepted 27 January, 1995

ARCTIC
VOL. 45, NO. 4 (DECEMBER 1992) P. 338-342

Redistribution of Calving Caribou in Response to Oil Field Development on the Arctic Slope of Alaska

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(Received 8 November 1991; accepted in revised form 23 March 1992)

ABSTRACT. Aerial surveys were conducted annually in June 1978-87 near Prudhoe Bay, Alaska, to determine changes in the distribution of calving caribou (*Rangifer tarandus granti*) that accompanied petroleum-related development. With construction of an oil field access road through a calving concentration area, mean caribou density (no./km²) decreased from 1.41 to 0.31 (*P* = 0.05) within 1 km and increased from 1.41 to 4.53 (*P* = 0.04) 5-6 km from the road. Concurrently, relative caribou use of the adjacent area declined (*P* < 0.02), apparently in response to increasing surface development. We suggest that perturbed distribution associated with roads reduced the capacity of the nearby area to sustain parturient females and that insufficient spacing of roads may have depressed overall calving activity. Use of traditional calving grounds and of certain areas therein appears to favor calf survival, principally through lower predation risk and improved foraging conditions. Given the possible loss of those habitats through displacement and the crucial importance of the reproductive process, a cautious approach to petroleum development on the Arctic Slope is warranted.

Key words: Alaska, calving, caribou, disturbance, oil field

RÉSUMÉ. Des photographies aériennes ont été prises au mois de juin chaque année de 1978 à 1987 près de la baie Prudhoe en Alaska, en vue de déterminer les changements dans la distribution des caribous (*Rangifer tarandus granti*) qui mettaient bas, changements accompagnant les projets de mise en valeur reliés au pétrole. Avec la construction d'une route d'accès à un champ pétrolifère à travers une zone importante de mise bas, la densité moyenne du caribou (nombre d'individus/km²) diminuait de 1,41 à 0,31 (*P* = 0,05) à moins d'1 km de la route et augmentait de 1,41 à 4,53 (*P* = 0,04) à une distance de 5 à 6 km de la route. En même temps, l'utilisation relative de la zone adjacente par le caribou diminuait (*P* < 0,02), apparemment en réponse à l'augmentation de la mise en valeur de surface. On suggère que la perturbation de la distribution associée à la construction de routes diminuait la capacité de la zone environnante à supporter des femelles parturientes et qu'un espacement insuffisant des routes aurait pu faire chuter l'activité générale de mise bas. L'utilisation de terrains traditionnels de mise bas ainsi que de certaines zones à l'intérieur de ces terrains semble favoriser la survie des veaux, en particulier grâce à une baisse de la prédation et à de meilleures conditions de pâturage. Étant donné que le caribou pourrait être évincé de cet habitat et vu l'importance cruciale du processus de reproduction, on recommande une approche prudente à l'exploitation du pétrole sur le versant arctique.

Mots clés: Alaska, mise bas, caribou, perturbation, champ pétrolifère

Traduit pour le journal par Nésida Loyer.

INTRODUCTION

For more than 20 years, barren-ground caribou (*Rangifer tarandus granti*) of the Central Arctic Herd (CAH) have been exposed to petroleum-related activity on a portion of their calving grounds. Aerial surveys from 1978 through 1984 revealed that the area encompassing the Prudhoe Bay oil field supported the lowest caribou densities within the calving grounds of the herd (Whitten and Cameron, 1985), suggesting a causal relationship between oil field presence and low caribou abundance; however, comparable pre-development observations were lacking, and the data remained equivocal.

With expansion of surface development west of the Kuparuk River in the late 1970s came an opportunity to monitor changes in the distribution of calving caribou that accompanied placement of roads (and later, above-ground pipelines). Aerial strip-transect observations by Dau and Cameron (1986) during the four years before road construction near Milne Point (i.e., control period) indicated that mean caribou density was unrelated to distance within 6 km of future roads, whereas during the four years following construction (i.e., treatment period) density increased significantly with distance within 6 km of roads. However, neither the actual pre- and post-construction caribou densities nor the associated changes in local distribution were reported. Here we test for significant differences in caribou density at 1 km distance intervals based on ten years' data, estimate the relative magnitude of alterations in habitat use, and discuss the implications of future petroleum development on the Arctic Slope.

STUDY AREA

The CAH inhabits that portion of the Arctic Slope between approximately the Colville River on the west and the Canning River on the east. Seasonal movements are oriented north-south between winter range in the northern foothills of the Brooks Range and calving grounds/summer range near the coast of the Beaufort Sea (Cameron and Whitten, 1979). From 1978 through 1983, the herd increased from approximately 6000 to 13 000 caribou (Whitten and Cameron, 1983; W. Smith, unpubl. data) and in 1991 was estimated at 19000 caribou (D. Reed, unpubl. data).

Approximately 45 km west of Prudhoe Bay is the Kuparuk Development Area (KDA) (Fig. 1), which lies within one of five calving concentration areas of the CAH (Whitten and Cameron, 1985; W. Smith and R. Cameron, unpubl. data). Terrain relief and vegetation communities are typical of the Arctic Coastal Plain Province (Spetzman, 1959; Wahrhaftig, 1965).

In winter 1977-78, the Spine Road was extended across the Kuparuk River (Fig. 1). By 1981, a construction camp, office/living quarters, rudimentary production facilities, and an airstrip were in place at ARCO's first central processing facility (CPF-1) pad. As well, the Kuparuk Pipeline had been constructed between CPF-1, with its small network of production wells and above-ground flow lines, and the origin station of the Trans-Alaska Pipeline, 40 km east. During winter 1981-82, Conoco built the Milne Point Road from the Spine Road north to the future site of a central facilities pad, and ARCO extended road access to Oliktok Point. Between 1982 and 1987, ARCO

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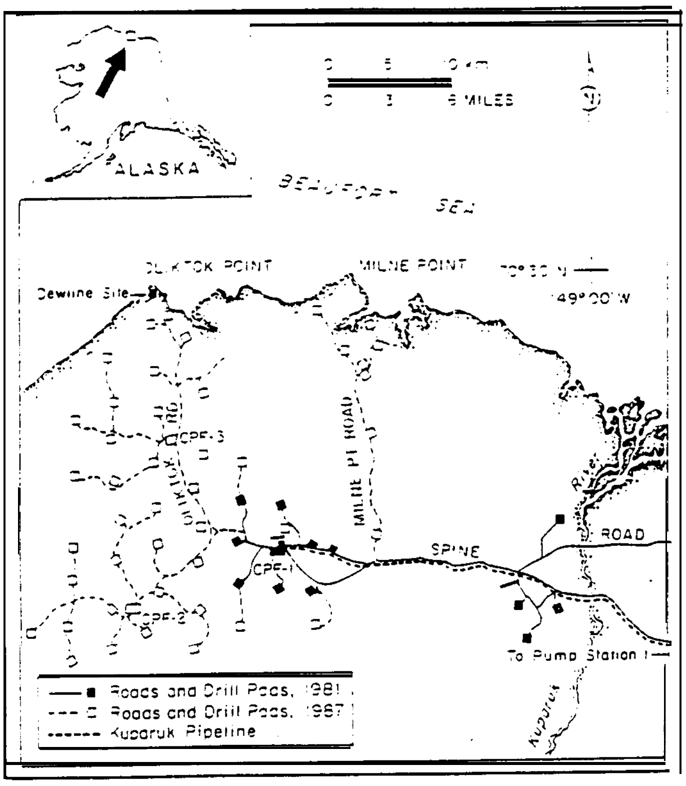

FIG. 1. The Kuparuk development area as of 1981 and 1987.

enlarged the administrative/support facilities at CPF-1: expanded the network of access roads, well pads, and elevated pipelines: commissioned two additional CPFs: constructed dock facilities at Oliktok Point: and installed a system of seawater pipelines for tertiary recovery of crude oil. Conoco built a central camp and processing facility, several drill pads, a modest system of production flow lines, and a main transport pipeline southward, along the Milne Point Road, to the Spine Road where it joins the Kuparuk Pipeline.

Each year, during breakup in late May or early June, the Spine Road was breached at the Kuparuk River, and access to the KDA was possible only by air until after mid-June. Consequently, road traffic was greatly reduced during the period in which our surveys occurred (see below). Mean traffic levels estimated during ground surveys along the Milne Point Road in June 1982-87 were generally < 200 vehicles/day and more commonly < 100 vehicles/day (Dau and Cameron, 1986; J. Dau and W. Smith, unpubl. data).

METHODS

On 10-14 June 1978-87, approximately one week after the peak of calving, we conducted low-level aerial surveys of the study area by helicopter (Cameron *et al.*, 1985; Whitten and Cameron, 1985; Dau and Cameron, 1986). In brief, a pilot and three observers in a Bell 206B or Hughes 500D searched within 11 contiguous north-south strip transects (10 transects in 1978), each 3.2 km wide. For each group of caribou, we recorded total number, sex/age composition, and map location (USGS 1:63 360) where first observed.

The zone within 6 km of the present Milne Point road system was apportioned into 1 km distance strata, and numbers of caribou within each stratum (excluding groups closer to the Spine Road) were totaled for each of the ten surveys. Mean caribou densities for each stratum were compared between pre- and post-construction periods (1978-81 and 1982-87 respectively) using Student's t-tests; degrees of freedom were adjusted for unequal population variances (Satterthwaite, 1946). To assess shifts in caribou distribution within the overall study area, we evaluated changes in the occurrence of caribou between the Oliktok and Milne Point roads (expressed as a percentage of all caribou north of the Spine Road) by Spearman's rank correlation. In all cases, P values < 0.10 were considered statistically significant.

RESULTS

Numbers of caribou observed within 6 km of the Milne Point road system varied more than fivefold during the ten years of study, from 232 in 1980 to 1259 in 1984 (Table 1). Despite this wide range in total counts, densities of caribou within the six distance strata differed between pre- and post-construction periods. After construction, caribou were significantly less numerous within 1 km of roads and significantly more numerous 5-6 km from roads (Table 2). Differences in caribou density for other strata, although statistically insignificant, were intermediate in degree, indicative of the functional relationships reported previously by Dau and Cameron (1986). Data for all caribou and calves were similar, reflecting a predominance of cow-calf pairs.

These changes become clearer when caribou densities are expressed in relative terms and the means for control and treatment periods compared. Following construction, relative abundance (i.e., percent distribution among strata, adjusted for differences in area) declined proportionally by 0.86, 0.59, 0.27, and 0.30 within the first four distance strata respectively, but increased by 1.88 and 1.34 within the last two strata respectively (calves: declined by 0.95, 0.73, 0.33, and 0.21, increased by 2.10 and 1.50 respectively) (Fig. 2).

Associated with the locally perturbed distribution of caribou was a decline in relative use of a portion of the study area. From 1979 through 1987, caribou numbers between the present Oliktok and Milne Point roads, expressed as a percentage of total observations north of the Spine Road (Fig. 1), decreased significantly, independent of total counts (Fig. 3).

TABLE 1. Numbers of caribou observed within 6 km of the Milne Point road system during aerial strip-transect surveys, and snow-melt status in the study area (Fig. 1), 1978-87

Years	No. observed: All caribou	No. observed: Calves	Snow melt*
1978	485	187	L
1979	648	281	E
1980	232	72	L
1981	720	325	E
1982	305	112	L
1983	771	328	E
1984	1259	559	E
1985	532	224	L
1986	455	160	L
1987	266	115	L

*Relative timing: L = late (moderate to complete snow cover or extensive flooding); E = early (little or no snow cover or standing water).

TABLE 2. Mean (SE) caribou density (no./km²) observed within each of 6 intervals of distance from the Milne Point road system, pre-construction (1978-81) vs. post-construction (1982-87)

Sample unit	Years	Distance interval (km) 0-1	1-2	2-3	3-4	4-5	5-6
All caribou	1978-81	1.41(0.35)	1.93(0.49)	3.08(1.26)	3.82(1.11)	1.39(0.82)	1.41(0.40)
	1982-87	0.31(0.13)	1.10(0.40)	2.48(0.73)	3.34(1.11)	5.49(2.12)	4.53(1.17)
	P:*	0.05	0.24	0.70	0.77	0.12	0.04
Calves	1978-81	0.60(0.16)	0.76(0.23)	1.31(0.61)	1.60(0.60)	0.57(0.38)	0.56(0.20)
	1982-87	0.04(0.02)	0.34(0.18)	1.01(0.35)	1.45(0.53)	2.49(1.04)	2.03(0.54)
	P:	0.04	0.19	0.68	0.85	0.13	0.04

*t-test, degrees of freedom adjusted for unequal variances (Satterthwaite, 1946).

DISCUSSION

Annual variation in the numbers of caribou observed near Milne Point (Table 1) is primarily an effect of spring snow conditions. In years of early snowmelt and runoff, calving caribou occupy the immediate coastal zone in abundance, whereas if snowmelt is late or flooding widespread, distribution tends to be skewed inland (Whitten and Cameron, 1985). The stage of snow ablation also influences caribou sightability and, therefore, the total count. Survey conditions are best when snow is either absent or continuous, as caribou are easily discernible against consistently light or dark backgrounds; however, sightability decreases if snow cover is discontinuous. An additional complication was herd size, which continued to increase during the tenure of this study. Thus, for a given year, the number of caribou observed may have been influenced by measurement error, as well as population variability, but the relative distribution of caribou among distance strata was unaffected.

The data strongly suggest that calving caribou were displaced outward after construction of the Milne Point road system. Relative abundance within 2 km decreased by more than two-thirds, while that beyond 4 km nearly tripled (Fig. 2). Though opposite in direction, these dual effects are additive or synergistic from the perspective of habitat use. Underutilization adjacent to roads and resultant overutilization elsewhere effectively diminish the capacity of the area to support caribou,

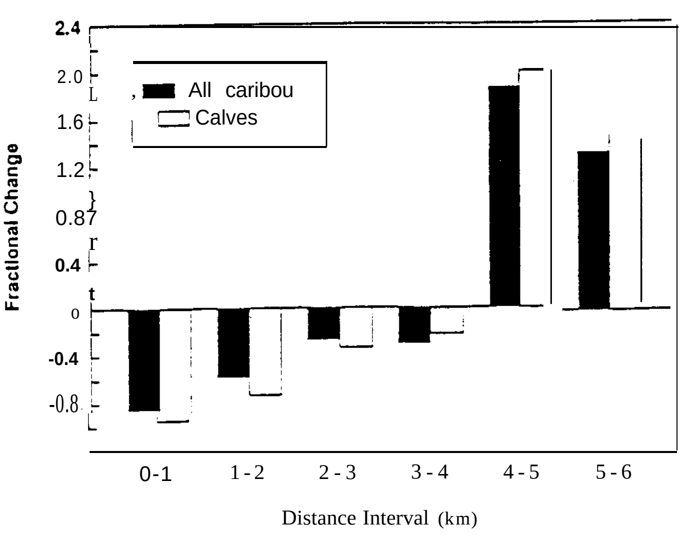

FIG. 2. Mean fractional changes in relative caribou abundance (i.e., percent distribution among strata, adjusted for differences in area) for 1 km distance intervals from the Milne Point road system, 1982-87 vs. 1978-81.

particularly in years of early snowmelt when absolute densities are high (Table 1).

Another implication is that overall caribou use could be greatly reduced if roads are routed too closely. Owing to a sensitivity to disturbance (de Vos, 1960; Lent, 1966; Skoog, 1968; Bergerud, 1974), most females with calves might then be

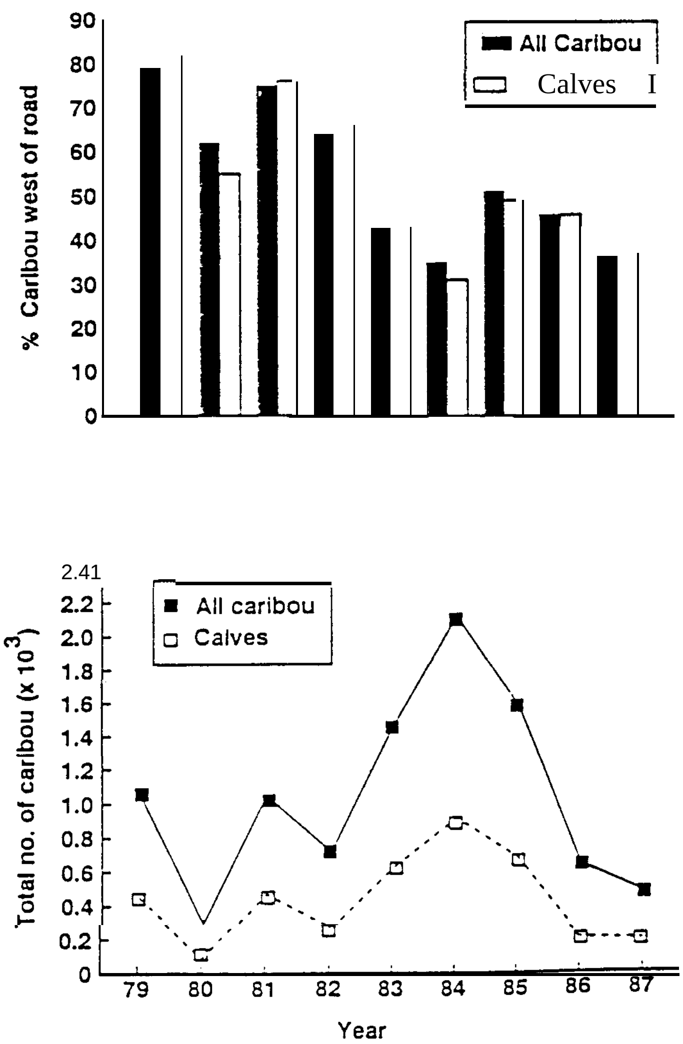

FIG. 3. Decline in percent abundance of caribou west of the Milne Point Road (Spearman's Rank, $P < 0.02$), and changes in total numbers of caribou observed north of the Spine Road (see Fig. 1), 1979-87. Note: In 1978, one transect in the vicinity of the Oliktok Road was not flown.

unable to maintain an acceptable distance from adverse stimuli, triggering a general withdrawal. In retrospect, this may have occurred within the Prudhoe Bay oil field complex (Whitten and Cameron, 1985) as it grew from a remote exploration outpost to a hub of development activity, with numerous support facilities, roads, and pipelines (Shideler, 1986).

Likewise, displacement of calving caribou from the KDA may occur as overlapping and contiguous oil reserves are exploited. Indeed, those changes appear to be in progress, judging from the declining percentage of caribou within the heavily developed area north of the Spine Road (Fig. 3). Construction of the Oliktok Road and its associated pipelines and pads, expansion of processing facilities, and increasing Milne Point development ostensibly have contributed to a gradual redistribution of calving activity. Either some caribou shifted into areas east of the Milne Point Road, or relatively fewer entered the western portion of the study area from the south. That such a change occurred independent of total caribou abundance constitutes circumstantial evidence that it was disturbance-induced and not simply a response to stochastic weather variables.

Repeated use of calving grounds by the CAH (Whitten and Cameron, 1985; Cameron *et al.*, 1986) appears to reflect an ecological compromise whereby net benefits are maximized. Rather than remain on inland winter range (Cameron and Whitten, 1979), where newly emergent forage is abundant during the calving period, parturient females, unlike most bulls and nonparous females, precede the northward progression of plant phenology (Whitten and Cameron, 1980), moving to coastal regions, which generally have fewer wolves (*Canis lupus*) (Stephenson, 1979) and grizzly bears (*Ursus arctos*) (Reynolds, 1979; Young *et* al., 1990; D. Young, pers. comm. 1991) and where mosquito emergence occurs later (Roby, 1978). By doing so, however, they forego nutritional compensation for the additional metabolic demands of late gestation and early lactation (Robbins and Moen, 1975; Oftedal, 1985). Hence, females that consistently calve near the arctic coast reduce predation risk to their newborn calves, but at the expense of access to high-quality forage.

In contrast, recurrent area-specific calving concentrations (Whitten and Cameron, 1985) are related to the occurrence of dry tundra (Bishop and Cameron, 1990) with abundant *Eriophorum vaginatum* (Walker and Acevedo, 1987), a nutrient-rich forage species (Kuropat and Bryant, 1980) that flowers immediately after snow ablation (Chapin *et al.*, 1979). Also, the better-drained habitats comprising these plant communities are probably superior as birth sites, especially in years of persistent snow cover.

To summarize, it appears that fidelity of the CAH to its calving grounds involves predator and insect avoidance, whereas calving concentrations *within* that broad region correspond to areas characterized by the best habitats. The relative occurrence of caribou among those areas for a given year is influenced primarily by snow conditions and, therefore, forage availability. In essence, then, nutritional factors define calving distribution, but within the spatial constraints imposed by predators and insects.

Preference for a calving environment, be it a broad landscape class or specific vegetation type, implies long-term dependence on those resources to the extent that sustained access is *required* for persistence of the population (Ruggiero *et al.*, 1988). Moreover, particularly adverse conditions (e.g., in weather, predator abundance, insect activity) might periodically render unpreferred — and, presumably, suboptimal — areas totally unfavorable, underscoring the importance of those occupied selectively. Patterns of habitat use, like metabolic adaptations, may play a role in minimizing the consequences of extremes (Levins, 1968) that might otherwise be detrimental to individuals and, ultimately, to the population. If, on the other hand, caribou are not subjected to adverse conditions that approach the limits of their adaptive capability, the constraints inherent in heterogeneous habitats will not become apparent, and the options available will seem more numerous than is actually the case. As a result, the loss of preferred areas might be erroneously viewed as inconsequential.

In view of the probable importance of calving grounds to the long-term reproductive performance of caribou, our data on the CAH indicate a need for discretion in developing petroleum resources elsewhere on the Arctic Slope. The much larger Porcupine Herd (Fancy *et al.*, 1989) is similar to the CAH in terms of fidelity to coastal calving grounds (Skoog, 1968; Hemming, 1971; Clough *et al.*, 1987) that favors calf survival (Fancy and Whitten, 1991); and calving concentration areas (Clough *et* al., 1987; Fancy and Whitten, 1991) are characterized by beneficial snow conditions (Lent, 1980; Eastland *et al.*, 1989) and a greater abundance of highly digestible *Eriophorum* (White *et al.*, 1989; Christiansen *et al.*, 1990). U.S. legislation is now pending to open a portion of the Arctic National Wildlife Refuge (ANWR) coastal plain to oil exploration. If ANWR leasing is authorized and production follows, extreme care must be exercised to ensure that individual actions adversely affecting calving caribou on a local level do not cumulatively result in major impacts on a regional or population level.

Beyond direct changes in the geobotanical environment (Walker *et al.*, 1987), progressive expansion and intensification of surface development will, at some stage, reduce the totality, diversity, and quality of calving habitats on the Arctic Slope. Our short-term frame of reference and relative inexperience should give rise to caution when we contemplate the exploitation of these ecosystems.

ACKNOWLEDGEMENTS

This work was supported by Federal Aid in Wildlife Restoration and the Alaska Department of Fish and Game, Divisions of Wildlife Conservation and Habitat; by the Alaska Fish and Wildlife Research Center, U.S. Fish and Wildlife Service; and by grants from ARCO Alaska, Inc., Exxon Co. U.S.A., Sohio Petroleum Co., Conoco, Inc., and Continental Pipeline Co. We thank K.R. Whitten, R.T. Shideler, L.M. McManus, R.A. DeLong, J.M. VerHoef, and E.A. Lenart for technical assistance. B.M. Barnes, R.T. Bowyer, W.L. Regelin, J.W. Schoen, R.T. Shideler, D.B. Stone, R.G. White, and K.R. Whitten offered helpful comments on the manuscript, as did referees S.G. Fancy and A. Gunn.

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Alaska Department of Fish and Game
Division of Wildlife Conservation

Federal Aid in Wildlife Restoration
Research Final Report
1 July 1987-31 August 1994

Distribution and Productivity of the Central Arctic Caribou Herd in Relation to Petroleum Development: Case History Studies with a Nutritional Perspective

by
Raymond D. Cameron

Grant W-23-1, W-23-2
W-23-3, W-23-4
W-23-5, W-24-1
W-24-2, W-24-3
Study 3.35
December 1994

CONTENTS

BACKGROUND

Reduced local use of calving and summer range by the Central Arctic herd (CAH) with progressive oilfield development on the Arctic Coastal Plain occurred (Cameron et al. 1979; Cameron and Mitten 1980; Smith and Cameron 1983; Whitten and Cameron 1983*a*, 1985; Dau and Cameron 1986). Habitat loss is, in itself, an undesirable consequence of petroleum development, but there is an additional major concern that such proximate impacts, operating cumulatively, will eventually reduce productivity of the herd. Specifically, displacement of adult females from preferred areas could adversely affect foraging success and therefore growth and fattening (Cameron 1983; Elison *et al.* 1986; Clough *et al.* 1987), which in turn might depress calf production (Dauphinè 1976;

FINAL REPORT (RESEARCH)

State: Alaska

Cooperator: ~~U.S. Fish and Wildlife Semite.~~ Universi~~ty of Alaska Fairbanks~~

Project NO.: W-23-1. W-23-2, W-23-3. W-23-4, W-23-5. W-24-1 W-24-2. W-24-3 Project Title: Wildlife Research and Management

Study No.: 3.35 Study Title: Distribution and Productivity of the Central Arctic Caribou Herd in Relation to Petroleum Development: Case History Studies With a Nutritional Perspective

Period Covered: 1 July 1987-31 August 1994

SUMMARY

As of July 1992, the Central Arctic caribou (*Rangifer tarandus granti*) herd numbered approximately 23,400 head, confirming a decline in growth rate: low calf production in recent years was a contributing factor. Aerial survey data obtained during the calving period demonstrate maternal females and their calves were displaced outward after construction of the Milne Point road system. Similar abnormalities in caribou distribution associated with oilfield development were observed in mid-summer. Data on radiocollared female caribou indicate the likelihood of producing a calf is directly related to female body weight during the previous autumn, wherein both the incidence of early calving and the probability of calf survival are correlated with postpartum weight. During summer lower weight gain among lactating than among nonlactating females substantially decreases parturition rate. The high frequency of reproductive pauses among females exposed to disturbance may be attributable to their relative inability to compensate for the metabolic costs of milk production.

Key Words: Alaska, body weight, calving, caribou, Central Arctic herd, disturbance. nutrition, oilfield, reproduction

Thomas *1982;* Reimers 1983; Eloranta and Nieminen 1986; Lenvik *et al.* 1988; Thomas and Kiliaan 1991) and survival (Haukioja and Salovaara 1978; Rognmo *et al.* 1983; Skogland 1984; Eloranta and Nieminen 1986; Adamczewski *et al.* 1987).

Such concerns, though justified from a theoretical point of view, lack empirical support. As industrial development in the Attic is virtually unprecedented, there is little basis for predicting the extent and duration of habitat 10SS, much less the secondary short- and long-term effects on the well-being of a particular caribou herd. Furthermore, despite a general acceptance that female body condition and fecundity are functionally related, it is unlikely that any single model would apply to all subspecies of *Rangifer*, and perhaps not even within a subspecies for different geographic areas. We therefore possess neither adequate foresight as to the probable behavioral responses of Arctic caribou to industrial development, nor an understanding of the mechanisms by which changes in habitat use might translate into measurable impacts on population dynamics.

These uncertainties form the basis "of the present two-component study: (1) assessments of CAH productivity and distribution in relation to oilfield development; (2) an investigation of the influence of female body condition on reproductive performance. Here I summarize, extract, or update results from various reports and publications in addressing study objectives. Applicable methods, where not described, are detailed in the sources cited.

Under the auspices of this study and through a companion program at the University of Alaska Fairbanks, 8 manuscripts have been published, and 10 others are currently in preparation (Appendix A). During the past year, a paper on predicting parturition rate of caribou was accepted by the Journal of Wildlife Management (Appendix B), another on abundance of radiocollared caribou near Prudhoe Bay was submitted to *Rangifer* (abstract, Appendix C), and a note on measurements of weight vs. mass was accepted for publication in the fall 1994 issue of the Wildlife Society Bulletin (Appendix D).

OBJECTIVES

- To monitor the size, calf production, and recruitment of the CAH.
- To describe changes in the distribution and movements of CAH caribou in relation to oilfield development on the Arctic Coastal Plain.
- To determine the relationship between body condition and reproductive performance of female caribou of the CAH, including comparisons of

the body condition, reproductive success, and offspring survival of females under disturbance-free conditions (i.e., east of the Sagavanirktok River) with the status of those exposed to oil-related development (i.e., west of the Sagavanirktok River); and

- the rates of summer weight gain and subsequent reproductive performance of lactating vs. nonlactating female caribou.

RESULTS AND DISCUSSION

Status of the Central Arctic Caribou Herd

A July 1992 photocensus of the CAH yielded a total count of 23,400 (K. Whitten, unpubl. data), in general agreement with a point estimate of 19,000 made by extrapolation in June 1991 (D. Reed, unpubl. data). Both estimates indicate the growth rate of the herd has declined from that noted in the late 1970s and early 1980s. In fact, had the CAH continued to increase at that previous rate, it would have numbered about 48,000 by 1992, roughly twice the observed total (Fig. 1). A reduced rate of growth is consistent with low calf cow ratios estimated from transect surveys of the calving grounds (range, 48-74 calves/100 cows: Fancy et *al.* 1992; Cameron, unpubl. data) and a downward trend in the reproductive success of radiocollared females (Fig. 2). Preliminary analyses of weather data indicate the inferred decline in female body condition (Cameron *et al.* 1993) cannot be attributed to increasing trends in either insect activity or snow depth. The CAH apparently has reached or exceeded carrying capacity (Cameron and Bowyer, in prep. [B.S., Appendix A]).

Development-related Changes in Caribou Distribution

Changes in the distribution of calving caribou associated with the Kuparuk Development Area (KDA), west of Prudhoe Bay (Fig. 3), have been quantified using strip-transect surveys flown by helicopter (Fig. 4). As a follow-up to an earlier paper by Dau and Cameron (1986), Cameron *et al.* (1992*a*) showed that, after construction of a road system near Milne Point, mean caribou abundance declined by more than two-thirds within 2 km and nearly tripled 4-6 km from roads (Fig. 5). Such perturbed distribution reduces the capacity of an area to support females and their calves. Logically, roads comprising an oilfield complex that are, on average, <3 km apart may depress area-wide calving activity; and, in fact, percent occurrence of caribou in the heavily-developed western portion of the KDA declined significantly from 1979 through 1987, independent of total abundance (Fig. 6). The probable consequences of perturbed distribution is reduced access to preferred habitats (Cameron *et al.* in prep. [B.4. Appendix A]; Nellemann and Cameron. in prep. [B.6., Appendix A]).

That outward displacement of caribou from the Milne Point road system has occurred is corroborated by the regional changes in caribou distribution accompanying construction. Prior to road placement, caribou were found in a single, more-or-less continuous concentration roughly centered on the Milne Point Road; whereas a bimodal distribution, with one concentration east and *west* of the road, was clearly apparent after construction (Fig. 7; Smith and Cameron 1992).

A companion investigation conducted from the KDA road system has been completed (Smith *et al.* 1994). During spring and summer 1978-90, the Spine and Oliktok Roads (Fig. 3) were surveyed systematically by light truck to monitor the influence of oilfield development on caribou distribution and movements. Caribou increasingly avoided zones of intensive activity, especially during the calving period. In addition, crossings of the road transect by large, insect-harassed groups shifted away from the central portions of the complex to areas of lower disturbance near Oliktok Point and the Kuparuk floodplain. Clearly, patterns of caribou use have changed considerably in recent years.

Female Caribou Bodv Condition vs. Reoroductive Performance

Body weights of CAH female caribou are closely related to their reproductive success (Cameron *et al.* 1993). For radiocollared females, the probability of producing a caif varied directly with body weight during the previous autumn, in contrast to calving date and perinatal survival, which were more closely related to maternal weight shortly after parturition (Fig. 8). Probably the likelihood of conceiving is determined by body condition at breeding, whereas parturition date and calf survival are linked to maternal condition during late gestation. Body fat content. specifically, is highly correlated with fecundity (Gerhart *et al.*, in prep. [B.8., Appendix A]).

Several data sets suggest reduced nutritional status and reproductive success of radiocollared females exposed to oil development west of the Sagavanirktok River. July and October body weights, oversummer weight gain, the incidence of successive 2-year pregnancies. and perinatal calf survival were all lower for females to the west than for those under disturbance-free conditions to the east, although differences were not significant at the 95% confidence level (Cameron *et al.* 1992*b*). A recent longitudinal analysis of fecundity, however, showed the frequency of reproductive pauses was significantly higher for western (36'?0) than for eastern (19%) (*t*-test, *P* c 0.02). *This* is the subject of a future paper (Cameron, in prep. [B.1O., Appendix A]).

Mid and late lactation exacts a substantial cost on summer weight gain which, in turn, influences the probability of conceiving that autumn (Cameron and White 1992). Weights of lactating CAH females averaged 9 kg less than for nonlactating females (Fig. 9), resulting in a projected 28% reduction in parturition rate (Fig. 10). Thus, declining calf production of the herd in general (Fig. 2), and among females west of the Sagavanirktok River in particular, may be a consequence of repeated failure to compensate for the metabolic burden of milk production (i.e., through increased forage intake or lower energy expenditure), thereby depressing body condition and evoking more frequent reproductive pauses (Cameron and Ver Hoef 1994, Appendix B).

ACKNOWLEDGMENTS

I am particularly grateful to W. T. Smith for his advice and support in all phases of this study, and to C. S. Gewin for skilled technical assistance in both field and office. S. G. Fancy, K. L. Gerhart, and R. G. White collaborated on several aspects of the field research and on manuscripts that are now published or in preparation. For additional technical assistance, I thank S. C. Bishop, G. M. Carroll, B. Griffith, R. G. Hunter, T. R. McCabe, R. T. Shideler, M.D. Smith, N. E. Walsh, K. R. Whitten, and J. F. Winters. I also thank pilots D. C. Miller, R. K. Friedrich, and R. M. Warbelow for their skilled support. Special recognition goes to L. A. McCarthy and L. M. McManus for their invaluable assistance in preparing various reports and publications, and to R. A. DeLong, E. A. Lenart, D. J. Reed, and J. M. Ver Hoef for their efforts in data management, graphics, computer programming, and statistical analyses. Finally, thanks to T. R. McCabe, D. J. Reed, and W. L. Regelin for the dealing with the assorted administrative matters that I so deeply despise.

Financial support was provided by Federal Aid in Wildlife Restoration by the Alaska Department of Fish and Game, Divisions of Wildlife Conservation and Habitat Restoration; and by the U.S. Fish and Wildlife Service, Alaska Fish and Wildlife Research Center. Numerous staff of the Alaska Department of Transportation and Public Facilities assisted frequently with field logistics.

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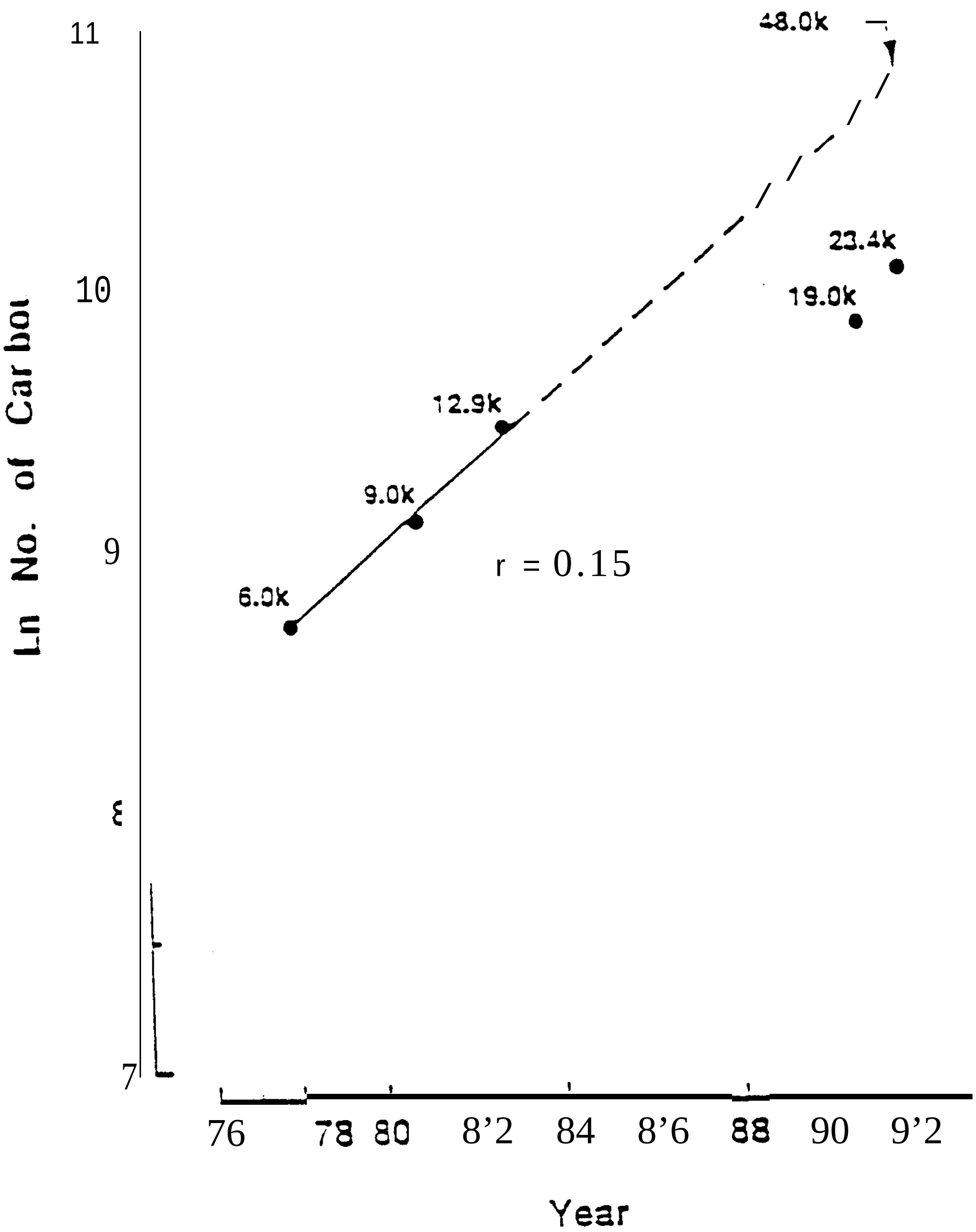

Fig. 1. Growth of the Central Arctic Caribou Herd, 1978-92. Census estimates by Whitten and Cameron (1983*b*), D. Reed (unpubl. data), and K. Whitten (unpubl. data). From Cameron (1993),

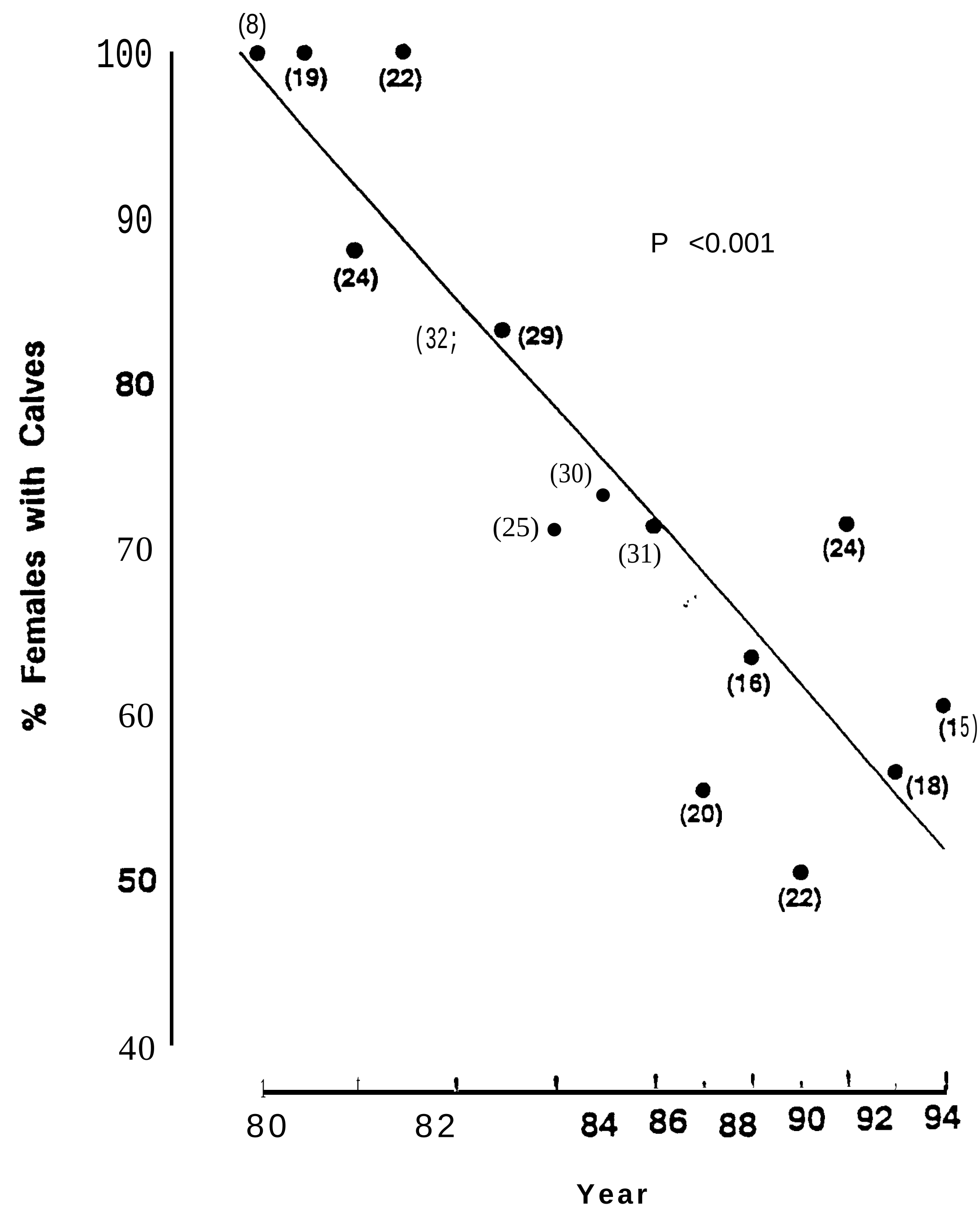

Fig. 2. Decline in calf production of the Central Arctic Caribou Herd, 1980-93. Estimates based on observations of radiocollared adult (i.e., sexually mature) females (n) from 10 June through 15 August. Note: Data not adjusted for east-west differences in herd productivity. Adapted from Cameron (1993).

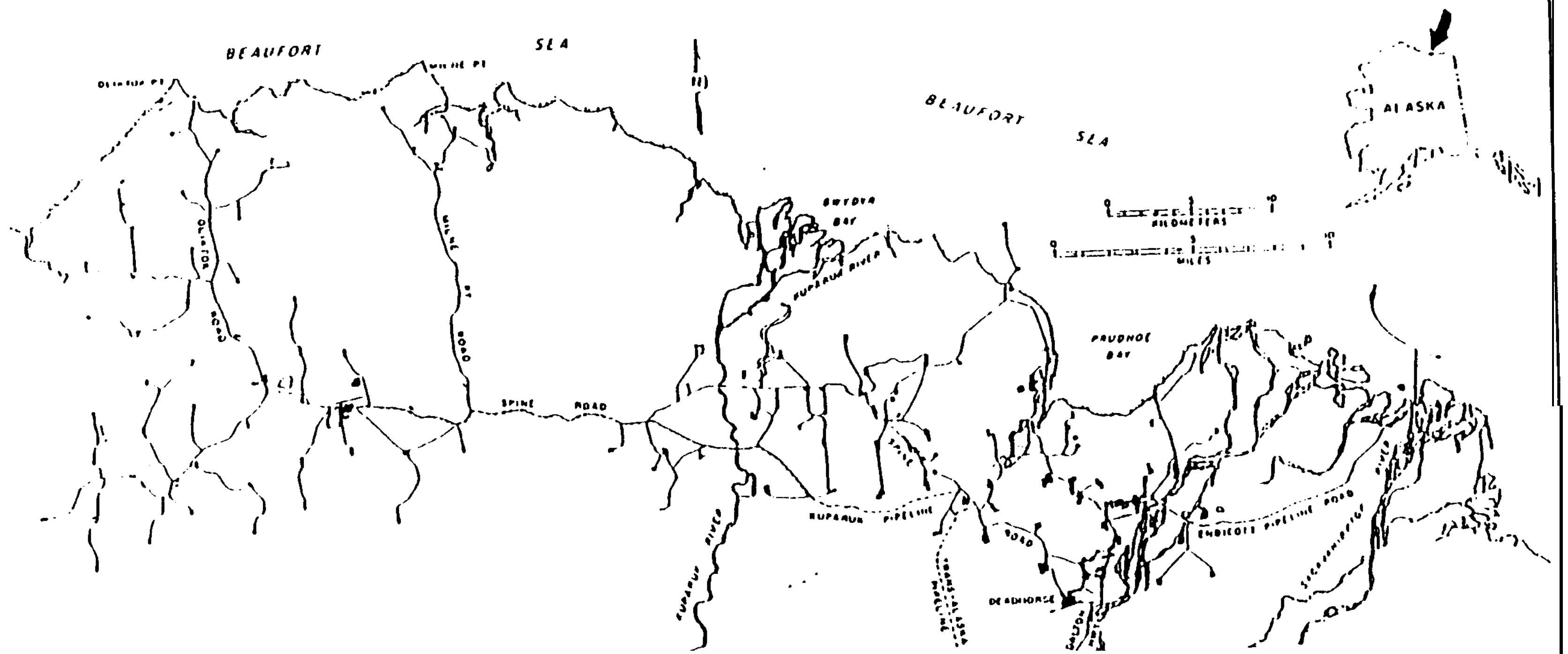

Fig. 3. Development in the Prudhoe Bay region, Alaska, ca. 1990. From Cameron *et al.*, in prep (B. ., Appendix A).

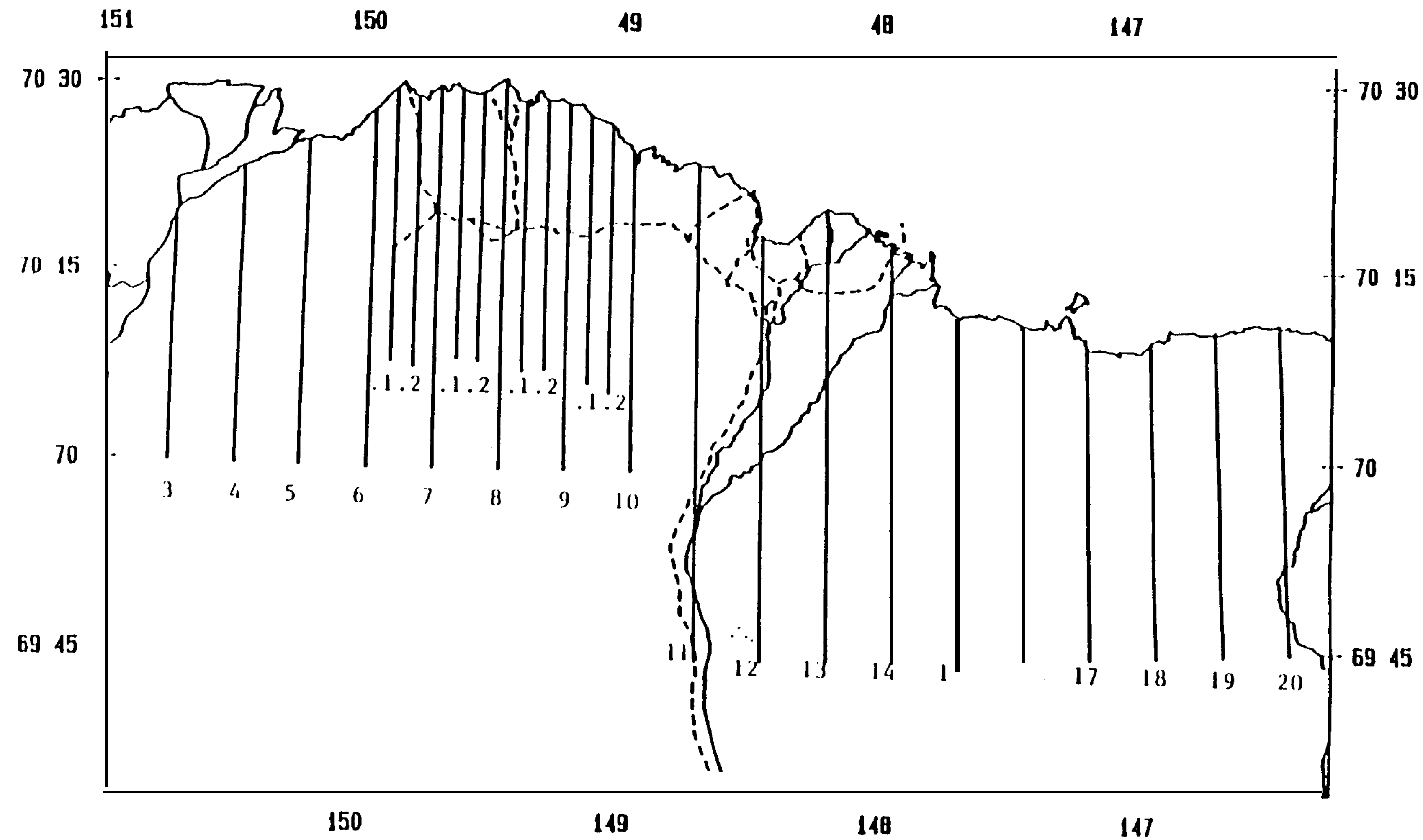

Fig. 4. Center lines of transects surveyed by ıelicopter during calving within he range of the Centra A ctic Herd. From Smith and Cameron 1992.

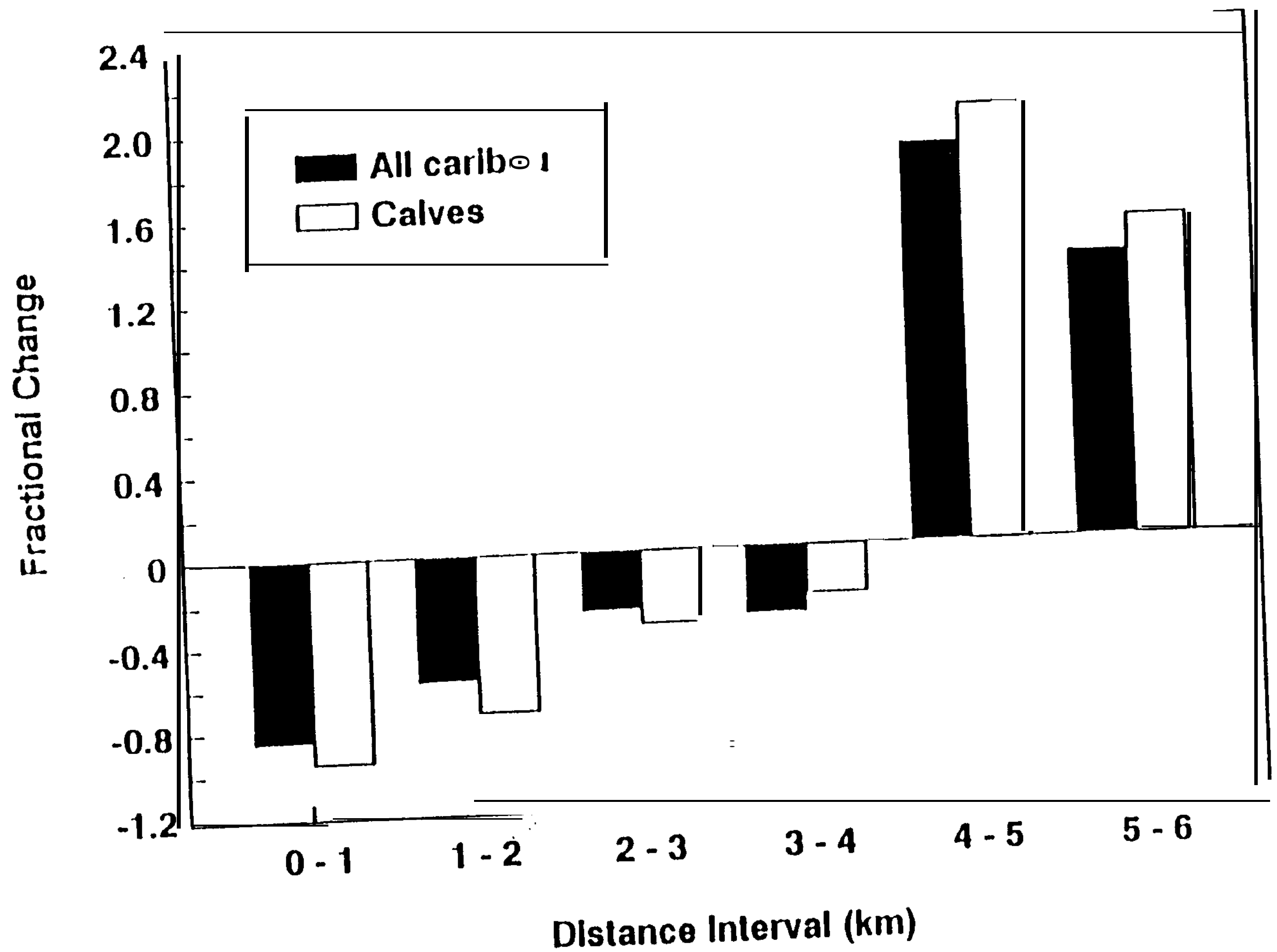

Fig. 5. Mean fractional changes in relative caribou abundance (i.e., percent distribution among strata, adjusted for differences in area) for 1 km distance intervals from the Milne Point road system, 1982-87 vs. 1978-81. From Cameron *et al.* (1992*a*).

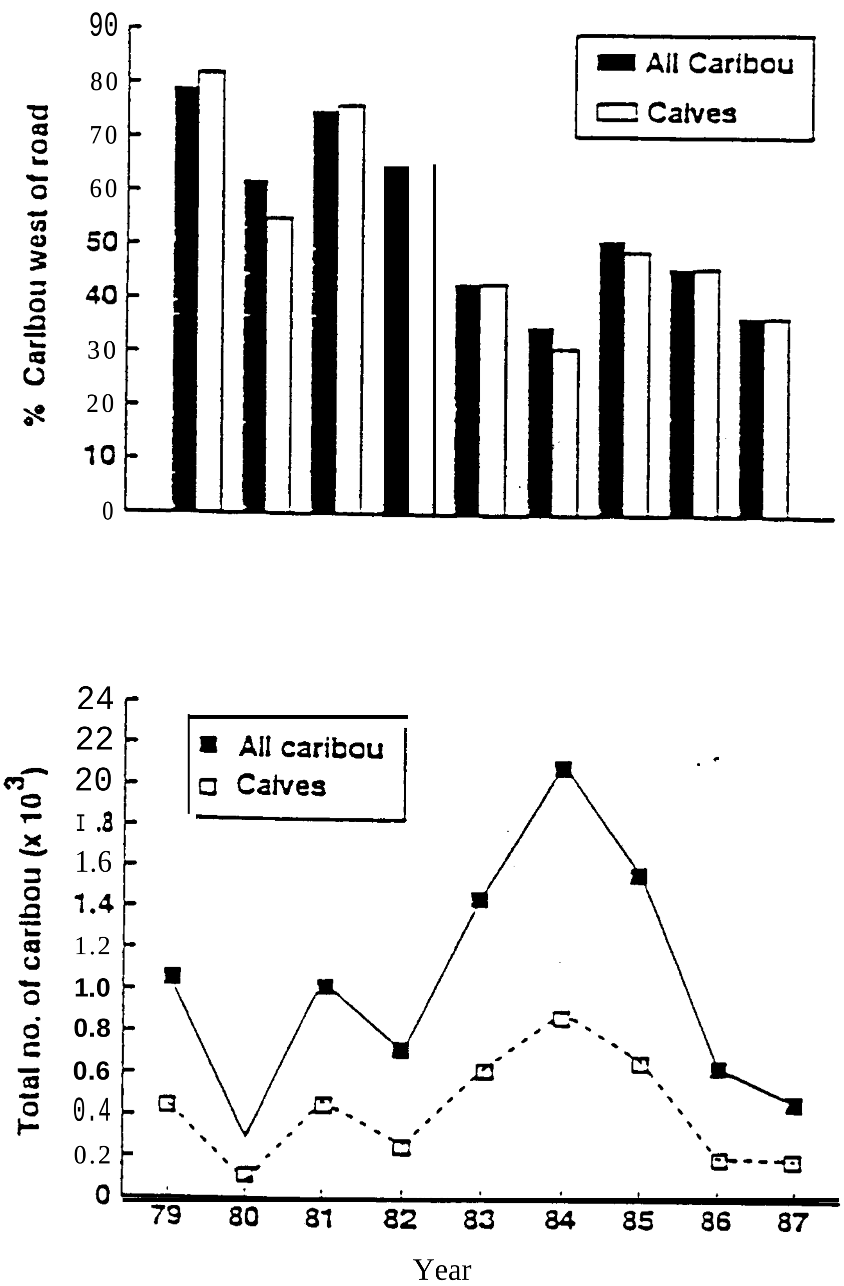

Fig. 6. Decline in percent abundance of caribou west of the Milne Point Road (Spearman's Rank, $P < 0.02$), and changes in total numbers of caribou observed north of the Spine Road (see Fig. 3, 1979-87. From Cameron *et al.* (1992*a*).

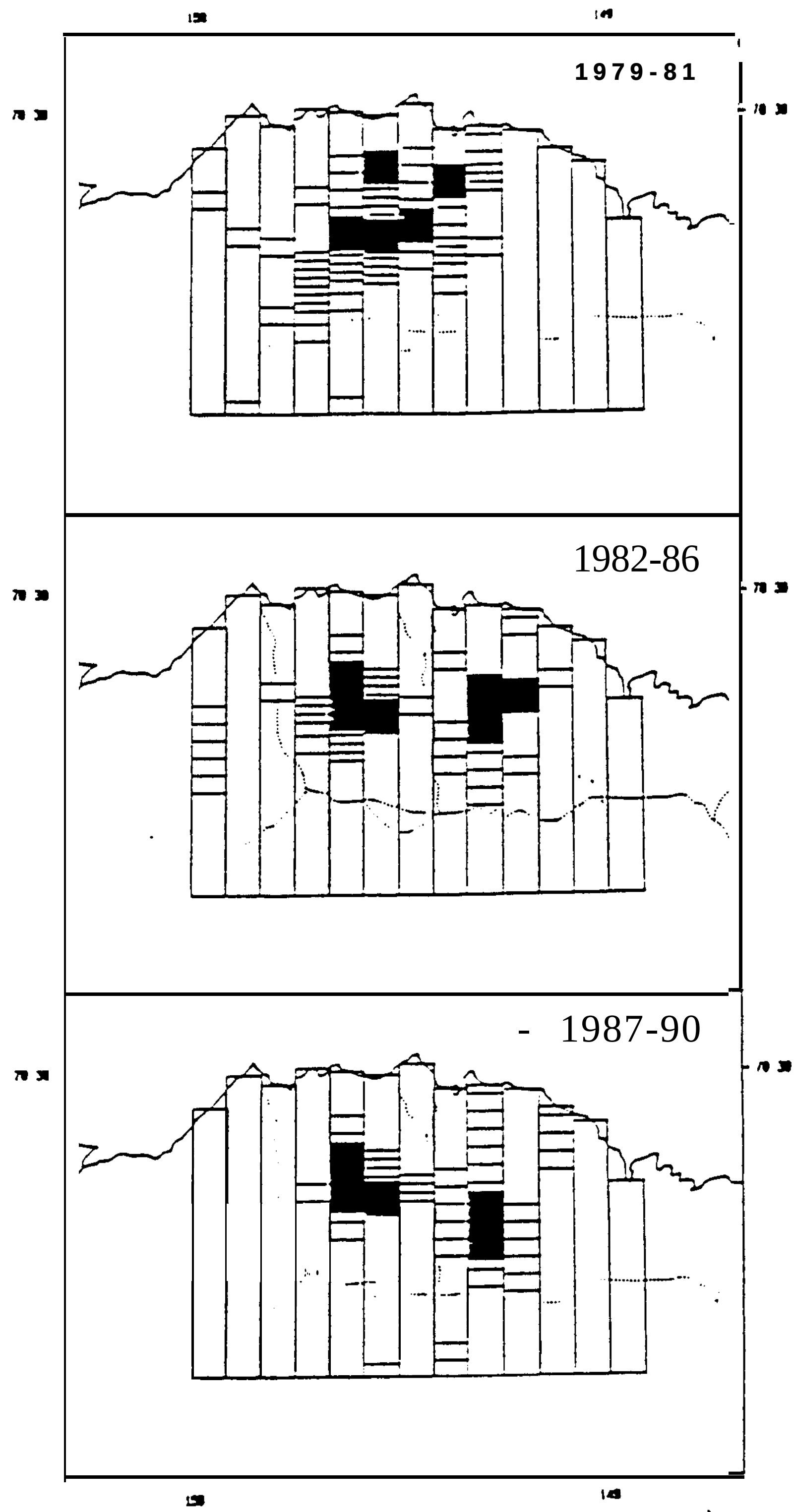

Fig. 7. Changes in mean relative distribution of Central Arctic Herd caribou in the Kuparuk Development Area during calving: 1979-81, 1982-86, and 1987-90. Shown only are those 10.4 km^2 transect segments in which the occurrence of caribou exceeded the area contribution to total coverage (1.9%). Gradations in line spacing depict multiples of observed use relative to availability: wide, <3X; narrow, >3X-5X; solid, >5X. From Smith and Cameron (1992).

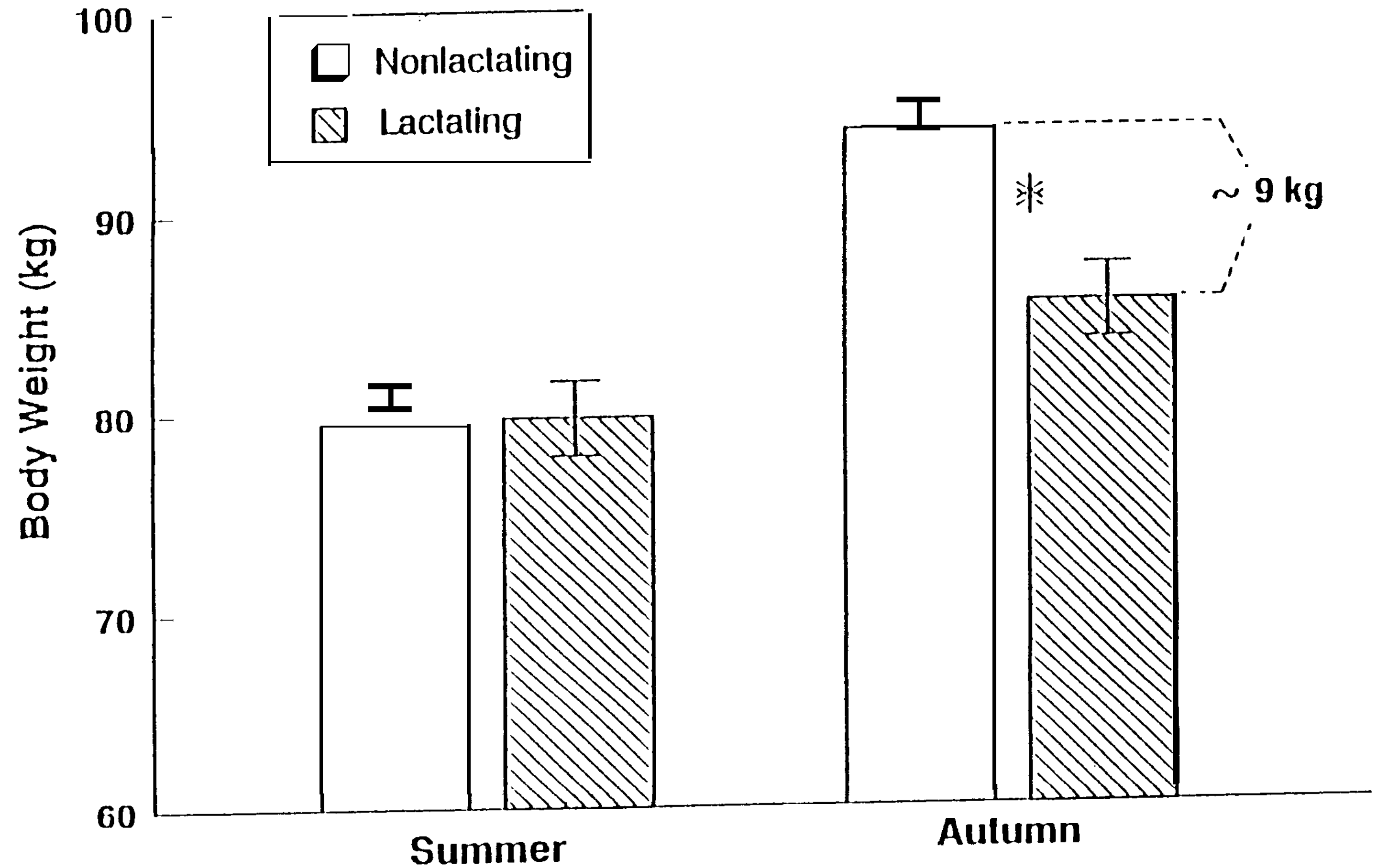

Fig. 9. Mean (± SE) body weights of lactating and nonlactating female caribou in summer (July) and au umn (October). From Cameron and White (1992). *Significant at $P < 0.001$.

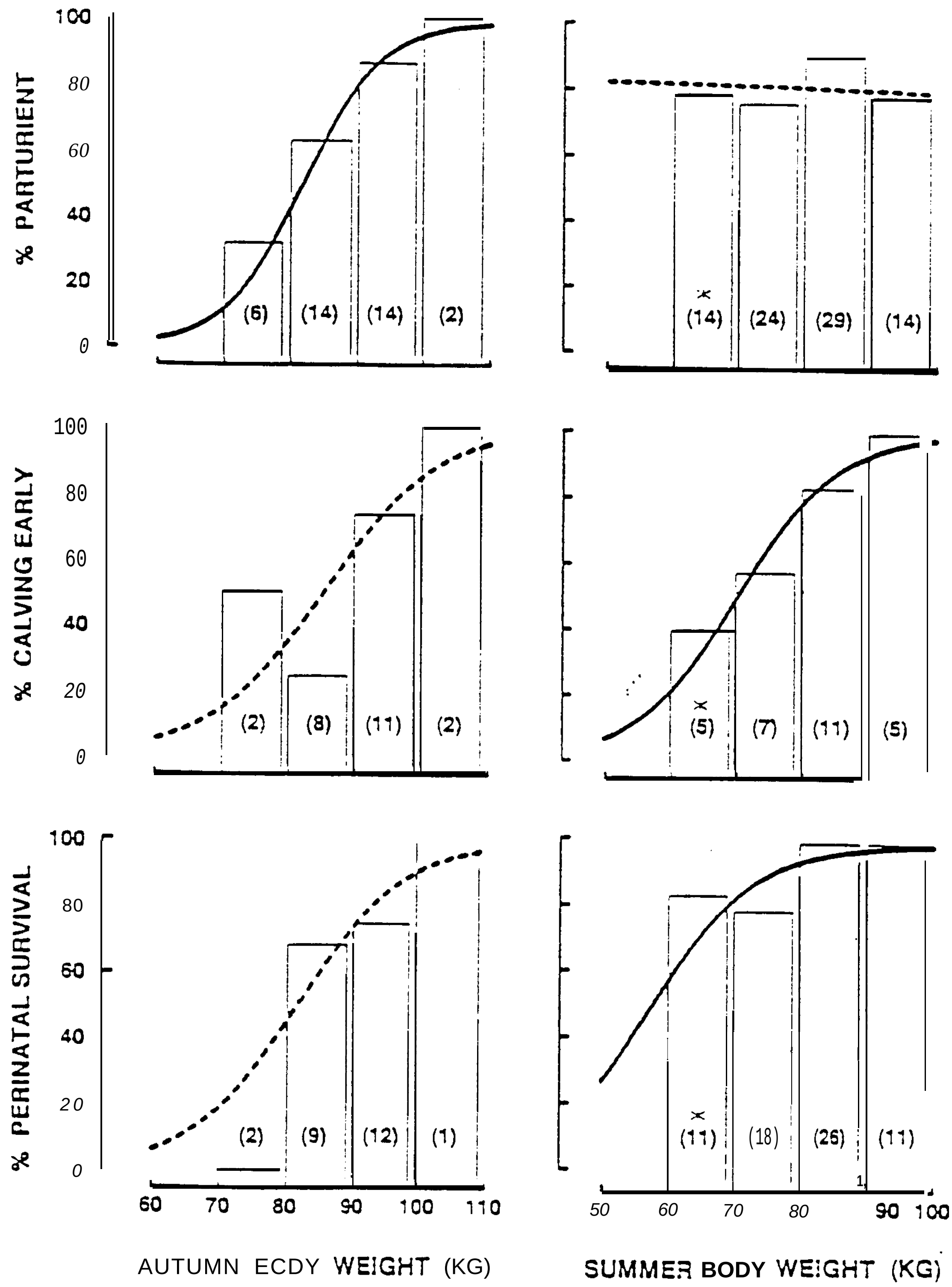

Fig. 8. Logistic regressions (solid lines are significant at $P < 0.05$) of parturition rate. incidence of early calving (i. e., on or before 7 June), and perinatal (>2 days post partum) calf survival on autumn and summer body weights of female caribou, Central Arctic Herd, 1987-1991. The empirical percentages are shown at arbitrary 10-kg intervals of body weight; numbers in parentheses are sample sizes: the asterisk indicates inclusion of one female weighing 57 kg. From Cameron *et al.* (1993).

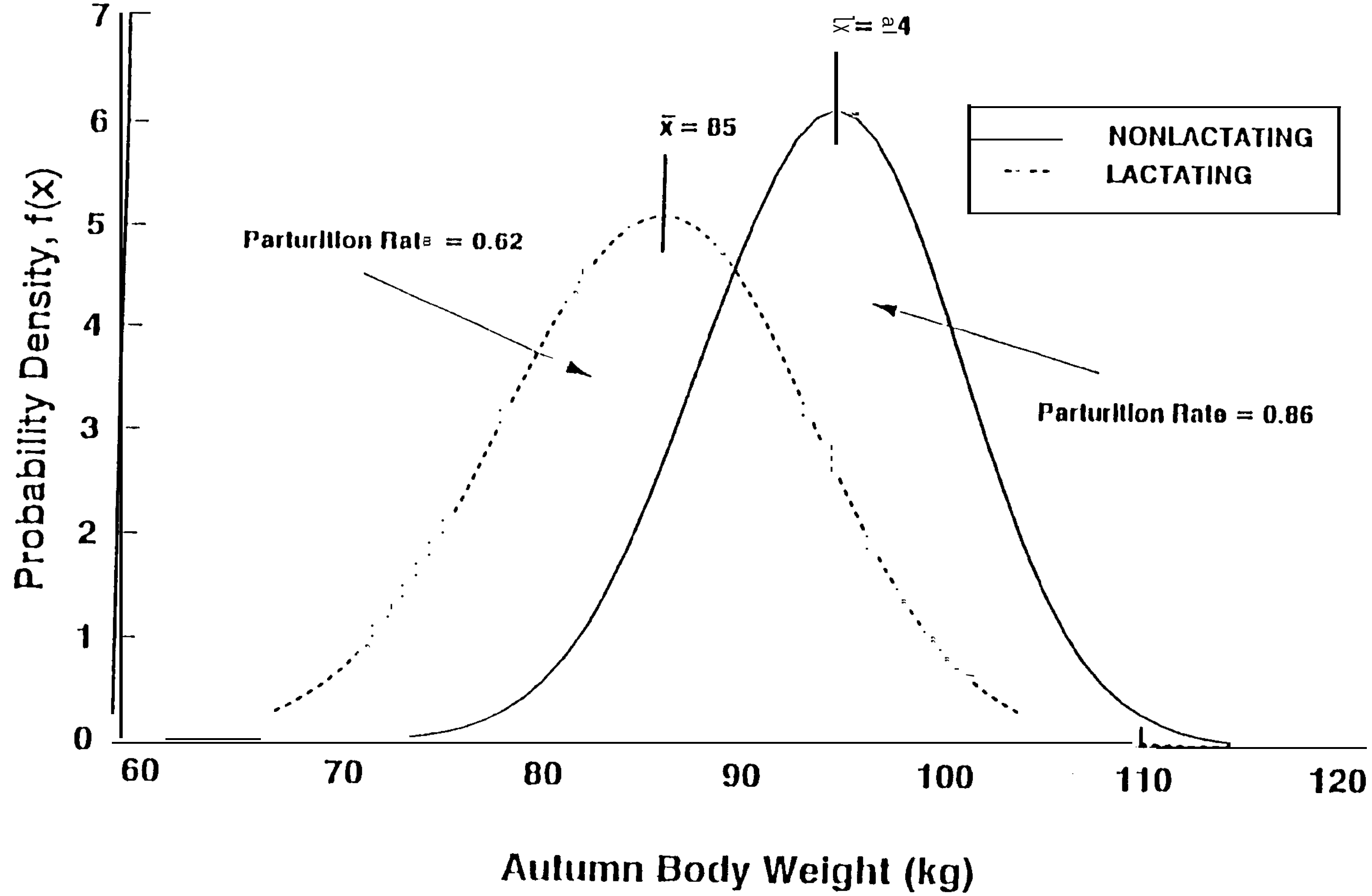

Fig. 10. Distributions of observed autumn (October) body weights for lactating and nonlactating female caribou. The associated parturition rates are integrated estimates derived from the logistic model (Fig. 8). From Cameron and White (1992).

Appendix A. Publication status, Study 3.35.

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6. Nellemann, C., and R. D. Cameron. Terrain preferences of calving caribou exposed to oil development. For Arctic.

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IMPACTS OF HUMAN DEVELOPMENTS AND LAND USE ON CARIBOU: A LITERATURE REVIEW
Volume II: Impacts of Oil and Gas Development on the Central Arctic Herd

by

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Technical Report No. 86-3

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EXECUTIVE SUMMARY

1. Although oil exploration on the North Slope has occurred since the 1920's large scale oil development did not begin until the Prudhoe Bay discovery in 1968. Since that discovery, oil development has spread westward into the Kuparuk oilfield, and is continuing with the development of the Milne Point field. Intensive exploration is occurring in the Colville River delta, and in several offshore locations east of Prudhoe Bay. In general the majority of the Central Arctic Caribou Herd (CAH) winter range is in the foothills and summer range (including concentrated calving areas) is on the coastal plain. Movements between these ranges are predominately north-south, whereas movements within the summer range are east-west along the coast and are dependent in part on the intensity of mosquito harassment. Oil development on the summer range could directly contact calving and coastal mosquito relief habitat, as well as affect movements to these habitats. Oil development in the foothills could directly contact CAH winter range, as well as affect movements between summer and winter range.

2. There is ample evidence to demonstrate that the term "herd" can be correctly applied to the CAH. Historic data suggested, and current data has confirmed, that the vast majority of caribou that are found on the CAH summer range belong to the CAH. Calving concentration areas near the coast and in proximity to Oliktok and Milne points, and Bullen Point to the Canning River delta, have been identified since the early 1970's. Although the overall density of calving on the coastal plain has varied from year to year, apparently due to weather and snow ablation during spring migration and early calving, these two areas have consistently been used by more parturient females than have other areas. Data from visual- and radio-collared animals indicate that there is strong fidelity of CAH cows to the CAH summer range and conversely few animals collared in adjacent herds have been re-located on the CAH summer range.

3. Two categories of habitat receive intensive use by CAH caribou—the sedge meadows comprising the calving concentration areas on the coastal plain, and coastal beaches, promontories, and river deltas that are used intensively as mosquito relief areas. The use of coastal sedge meadow habitat by calving caribou is contra-intuitive in that at calving time the availability and nutrient content of forage is greater in the foothills than on the coastal plain. Several hypotheses for the use of the coastal plain during calving have been advanced. These include the hypotheses that calving areas are located where predator densities are lower, or that calving areas are located in proximity to mosquito relief habitat; however, no single explanation for the apparent fidelity of parturient caribou to their calving ground appears to be justified. The potential significance to CAH caribou of continued access to coastal

mosquito relief habitat is discussed. These mosquito relief areas do not appear to provide adequate forage during mosquito harassment bouts, however they do provide habitat where caribou can avoid continual harassment and reduce the amount of energy expenditure that would be likely if such habitat were not available.

4. Our definition of impact is an effect on the ecosystem of caribou such that there has been a reduction in habitat quality, quantity, or the animal's ability to utilize that habitat that has been caused by oil or gas development. The emphasis on habitat-related effects as opposed to demographic effects (e.g., reduced population numbers, reduced calf recruitment) is due to the recognition that the effects of oil and gas development on caribou habitat and its utilization by caribou are spatially extensive and long-term (essentially irreversible). Impacts on CAH caribou that are caused by oil and gas activities on the North Slope include direct habitat loss; avoidance of developments; and disruption of movements. Potential impacts include harassment by aircraft and ground vehicles, and by pedestrians; and an increase in predation or human harvest.

5. The amount of habitat loss directly due to oil and gas development in the Prudhoe Bay, Kuparuk, and Milne Point oil fields was approximately 3,200 ha (8,000 ac) as of 1983. This is a conservative estimate because it includes only habitat covered by gravel or stripped for gravel mining, and does not include additional vegetation losses due to fugitive dust or ponding along roads and drill pads. However, direct habitat loss is an insignificant impact when compared to habitat that becomes unavailable to caribou because of their response to facilities and human activity that are associated with oil and gas development.

6. Harassment of caribou by aircraft can potentially cause injury or mortality to individuals (especially calves), disruption of the cow/calf social bond that could affect a young calf's ability to survive, and an increase in the amount of energy-consuming activities that a caribou engages in (e.g., from walking to running) or a decrease in feeding. Caribou in some herds appear to be sufficiently habituated to aircraft that they do not respond to overflights; caribou in other herds may react to a similar overflight with panicked running. Caribou in other herds appear to be most reactive to aircraft during calving and mosquito season. Overflights of higher than 660 m (2,000 ft) AGL during these sensitive periods, and 330 m (1,000 ft) at other times apper to cause little or no overt reaction. Harassment of caribou by off-road vehicles and pedestrians especially when herds are hunted, appears to cause a stronger reaction than most aircraft harassment; however, comparative observations in the CAH have not been made.

7. Caribou can react to linear developments (e.g., roads, pipelines) and point developments (e.g., drill pads) by avoiding areas around these developments. Avoidance has been measured by the distribution of caribou occupancy. The strength and longevity of the avoidance response by

caribou appear to vary depending on the composition of the caribou group, season of the year, type of development, amount of human activity associated with the development, species and degree of harassment by insect pests present, and the type of topography between the development and caribou as they approach a development.

8. Caribou of the CAH have been observed to avoid "point" developments such as an isolated, active drill rig during summer totally up to 1,200 m (4,000 ft) and partially up to 2 km (1.2 mi). Peary caribou have been observed to avoid an active seismic camp in winter by 2 km (1.2 mi) when the camp was located in flat terrain, but to approach similar camps which are located in hilly terrain.

9. Maternal groups of caribou in the CAH have been shown to avoid the TAPS corridor during all seasons, with the possible exception of the fall rutting period; the Prudhoe Bay oil field during summer; the Spine Road/Kuparuk Pipeline complex and the Milne Point Road during calving; areas of intensive human activity along the Spine Road during mid-summer; and the Milne Point Road during mid-summer. Maternal groups almost totally avoid the Prudhoe Bay oil field, and the area within 4 km (2.4 mi) of the Spine Road during calving. Maternal groups avoid linear developments during the remainder of the summer in direct (but not necessarily linear) proportion to the group's distance from the developments, up to a distance of a few kilometers.

10. Caribou summer movements through and within the oil fields have been reported from the viewpoint of broad scale movements within a subregion (e.g., within or around the Prudhoe Bay and Kuparuk oil fields), or from specific investigations of the behavior of caribou as they attempt to cross linear developments. Caribou movements into the Prudhoe Bay oilfield during mosquito harassment periods have virtually ceased, presumably due to the low clearance (often less than 1 m [3 ft]) of feeder lines and the intensity of human activity there. Caribou movements into and within the Kuparuk oil field have been disrupted by developments and human activity within the field; however, some of these disruptions may be short-term responses to localized areas of intensive human activity, and some return to pre-development patterns may be occurring.

11. The success of caribou in crossing linear developments appears to be dependent on several factors including size of the crossing group, type of development (e.g., isolated road, isolated pipeline, or road and pipeline in proximity), season of the year, type and density of insect pests, amount of human activity associated with the development, and presence of special features to enhance caribou crossing (e.g., ramps, buried sections, elevated pipe).

12. The rate of success by CAH of crossing linear developments varies according to the type of development. In order of decreasing success of crossing by caribou, the following linear developments occur in the CAH

range: buried pipeline, road without traffic, elevated pipeline alone (1.5 m, 5 ft, above the ground), road with traffic, pipeline and adjacent road without traffic, and pipeline and adjacent road with traffic. Traffic levels averaging 15 vehicles/hr have caused a significant decline in crossing success of caribou attempting to cross the Spine Road/Kuparuk Pipeline complex during mosquito season. Traffic levels averaging 6 vehicles/hr have not apparently affected crossing success of a road/pipeline complex. These data should not be interpreted as actual ranges of traffic frequency that can affect crossing success, but do reflect qualitatively the importance of traffic in affecting crossing success. The distribution of traffic during the day (and night) is as important as the average number—for example, if a high frequency of vehicles is concurrent with the approach of mosquito-harassed groups to a road/pipeline, these groups will probably be unable to cross the complex.

13. Although almost all quantitative studies of CAH crossing success have been conducted between late May and August, there have been changes in crossing success over the summer period. These changes in crossing success may be in response to changes in season, but it is difficult to isolate changes in season from other variables such as type of insect pests and intensity of harassment by these pests. The success of crossing linear developments is generally lower during periods of little or no insect harassment in midsummer and during calving. Because most calving occurs north of the Kuparuk Pipeline/Spine Road and parturient females are generally more sedentary, caribou may be less "motivated" to cross the complex then, as opposed to periods of mosquito harassment when their motivation to cross and reach insect relief habitat is greater. On the other hand, during oestrid fly harassment, group size is smaller and the reactivity of caribou to structures and human activity is much lower--caribou will approach and even utilize structures such as roads or under buildings as fly relief. These changes in reactivity to developments and human activity markedly affect crossing success.

14. Group size also affects the success of CAH caribou in crossing linear developments—larger groups have a lower success in crossing developments than do smaller groups. However, often large groups apparently occur in response to increased mosquito harassment; therefore, the effects of mosquito harassment can not be readily isolated from the effects of the social dynamics of large groups per se.

15. Buried sections of the Kuparuk Pipeline have been preferentially used by CAH caribou for crossing the pipeline. Ramps which have been constructed specifically to facilitate caribou passage are preferred over adjacent sections of elevated pipeline—this preference appears to be especially noticeable in areas where there are high levels of traffic along the road associated with the pipeline. Ramps may be a very important structure for enhancing the success by large, mosquito-harassed groups in crossing above-ground pipeline and especially road/above-ground pipeline complexes.

16. It is possible that CAH caribou are adjusting to the oil/gas development in the Kuparuk oil field. Caribou crossing success of some of the structures has increased slightly in 1983 and 1984 from that of earlier years. During midsummer 1984 maternal group occupancy along the Spine Road increased from that of several previous years. Large groups of caribou that moved southward from the coast as mosquito harassment declined then crossed the Spine Road/Kuparuk Pipeline complex directly between the Kuparuk River and Central Processing Facility (CPF-1), rather than paralleling the complex westward and "end-running" the developed area as they had done the three previous summers. These data reflect only one year however, and should not be considered definitive evidence. There are no such indications from data concerning the TAPS corridor or the Prudhoe Bay field, or concerning partutient caribou avoidance of the Milne Point Road.

ARCTIC
VOL. 44, NO 4 (DECEMBER 1991) P 318-327

Short-Term Impacts of Low-Level Jet Fighter Training on Caribou in Labrador

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(Received 19 September 1990; accepted in revised form 1 Y March 1991)

ABSTRACT. The short-term impacts on caribou (*Rangifer tarandus*) of low-level jet fighter training activity at Canadian Forces Base Goose Bay (Labrador) were investigated during the 1986-88 training seasons (April-October). Visual observations of low-level (30 m agl) jet overpasses indicated an initial startle response but otherwise brief oven reaction by woodland caribou on late-winter alpine tundra habitat. Between 1986 and 1988, daily effects of jet overflights were monitored on 10 caribou equipped with satellite-tracked radiocollars, which provided daily indices of activity and movement. Half the animals were exposed to jet overflights; the other 5 caribou were avoided during training exercises and therefore served as control animals. In 1988, the control caribou were from a population that had never been overflown. Level of exposure to low-level flying within the exposed population did not significantly affect daily activity levels or distance travelled, although comparison with the unexposed population did suggest potential effects. The results indicate that significant impacts of low-level overflights can be minimized through a program of avoidance.

Key words: caribou (*Rangifer tarandus*), low-level flying, jet aircraft, helicopters, disturbance, activity, movements, Labrador

RÉSUMÉ. Durant les mois de la saison d'entraînement (d'avril à octobre), de 1986 à 1988, on a étudié les retombées à court terme sur le caribou (*Rangifer tarandus*) de l'entraînement à basse altitude des avions de combat à la base des Forces Armées canadiennes de Goose Bay au Labrador. Des observations visuelles du vol des avions à réaction à basse altitude (à 30 m du sol) ont indiqué que, vers la fin de l'hiver, dans son habitat de toundra alpine, le caribou des bois avait une réaction initiale de surprise, nettement perceptible mais qui ne durait pas. Entre 1986 et 1988, on a surveillé les effets quotidiens du vol des avions sur 10 caribous équipés de colliers-radios suivis par satellite, qui fournissaient quotidiennement des indices de l'activité et du déplacement des animaux. La moitié de ces derniers étaient exposés au vol des avions, les cinq autres étant évités à dessein au tours de l'entraînement pour pouvoir servir d'animaux témoins. En 1988, les caribous témoins provenaient d'un groupe qui n'avait jamais été survolé. Le niveau d'exposition aux vols à basse altitude n'a pas affecté de façon significative le niveau d'activité ou la distance parcourue quotidiennement par la population exposée aux vols, bien qu'une comparaison avec la population non exposée aux vols ait laissé entrevoir des effets potentiels. Les résultats indiquent que des retombées significatives de vols à basse altitude peuvent être minimisées si l'on adopte un programme visant à éviter les animaux.

Mots clés: caribou (*Rangifer tarandus*), vol à basse altitude, avion à réaction, hélicoptères, perturbation, activité, déplacement, Labrador.

Traduit pour le Journal par Nésida Loyer.

INTRODUCTION

The continuation and expansion of military low-level flight training activities in northern Canada have increased concern regarding their impact on caribou (*Rangifer tarandus*). Northwest of Goose Bay, Labrador, NATO forces stationed at Canadian Forces Base (CFB) Goose Bay started the present era of low-level jet fighter training in 1981. The number of aircraft flights (sorties) has increased from approximately 1500 in 1981 to over 6000 in 1988 and is projected to reach a maximum of 18 000 per year by 1996.

The potential effects of this training can be conveniently divided into two classes: short-term behavioural responses that indicate the energetic costs and the potential for injury resulting from individual overflights, and long-term population responses that indicate the cumulative effects of overflights on population demographics and habitat use. The impacts of jet aircraft have only been assessed indirectly through the demographics and habitat use patterns of caribou frequently exposed to jet activity (Davis *et al.*, 1985). The short-term effects of jet activity have not been systematically investigated.

The present study was designed to investigate the potential short-term effects of low-level flying activity by fighter-type jet aircraft on caribou. It was hypothesized that disturbance due to low-level flying would be reflected in increased activity levels and by greater daily distances travelled, as animals engaged in escape-related behaviours (running, walking) more frequently following overflights. These effects were measured by watching the behavioural reactions of caribou to low-level overflights and by determining the relationship between an animals daily exposure to low-level flying activity and its daily movement and activity levels, remotely monitored by satellite telemetry. Our adoption of satellite telemetry — a relatively new technology in wildlife studies (Fancy *et al.*, 1988) — is one of its first applications to remotely monitor caribou behaviour and movements.

STUDY AREA

Within the two areas currently used for low-level training (Fig. 1), flights to within 30 m above ground level (agl) are permitted. Training exercises consist of navigation, evasion and simulated attacks on ground targets, using terrain features to provide cover from radar. Flight speeds are subsonic (typically 775-825 km·h^{-1}). The two training areas and CFB Goose Bay are connected by transit corridors, where minimum altitudes of 80 m agl are permitted. The exposure of different sites to low-level flying activity varies substantially within the training areas, ranging from up to 250 flights per month in the southeastern section of the northern low-level training area (LLT1) to fewer than 10 sorties per month in the outer two units.

Our study area included the ranges of three woodland caribou (*R.t. caribou*) populations (Fig. 1). Two small, sedentary populations inhabit the southern portion of the study area. The Red Wine Mountain (RWM) population of about 700 animals inhabits a 23 000 km^2 area, which includes the heavily overflown southern portion of LLT1, as well as range to the south. During winter, most members of the population can be found within LLT1, whereas a portion of the population migrates out of LLT1 prior to calving and remains to the south or west of

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the training area until after the fall rut. The Mealy Mountain (MM) population of about 2000 animals inhabits a 22 000 km² area east of Goose Bay, which is far from both training areas. Topography, climate. vegetation and other range characteristics are similar for both populations. Both ranges have rounded. barren hills supporting alpine tundra, which provide for late-winter forage when deep snow in the surrounding heavily forested plateau limits foraging opportunities and impedes travel (Brown. 1986).

The George River (GR) population of more than 500000 caribou uses the northern and northwestern sections of LLT 1 on a periodic basis, usually during the post-calving period between June and August. Since 1984. the calving grounds have expanded to the south-southwest. Thus, the southernmost 5-10% of the calving ground is now within the northwest corner of LLT1.

VETHODS

Study Design

Two criteria constrained the methods chosen. First. [he caribou's exposure to low-level flying (number of overflights) had to be manipulated reliably, as low-level flying over any individual animal was expected to be unpredictable and sporadic in nature. Second. the methods for measuring exposure and response had to be unobtrusive. as disturbance from monitoring overflights and responses could be greater than that caused by low-level flying. The two methods chosen. direct visual observations conducted on late-wintering areas and remote monitoring using satellite telemetry, seemed to best fulfill these requirements.

Visual observation of directed overflights allowed us. to record the type and level of response by caribou and to test the

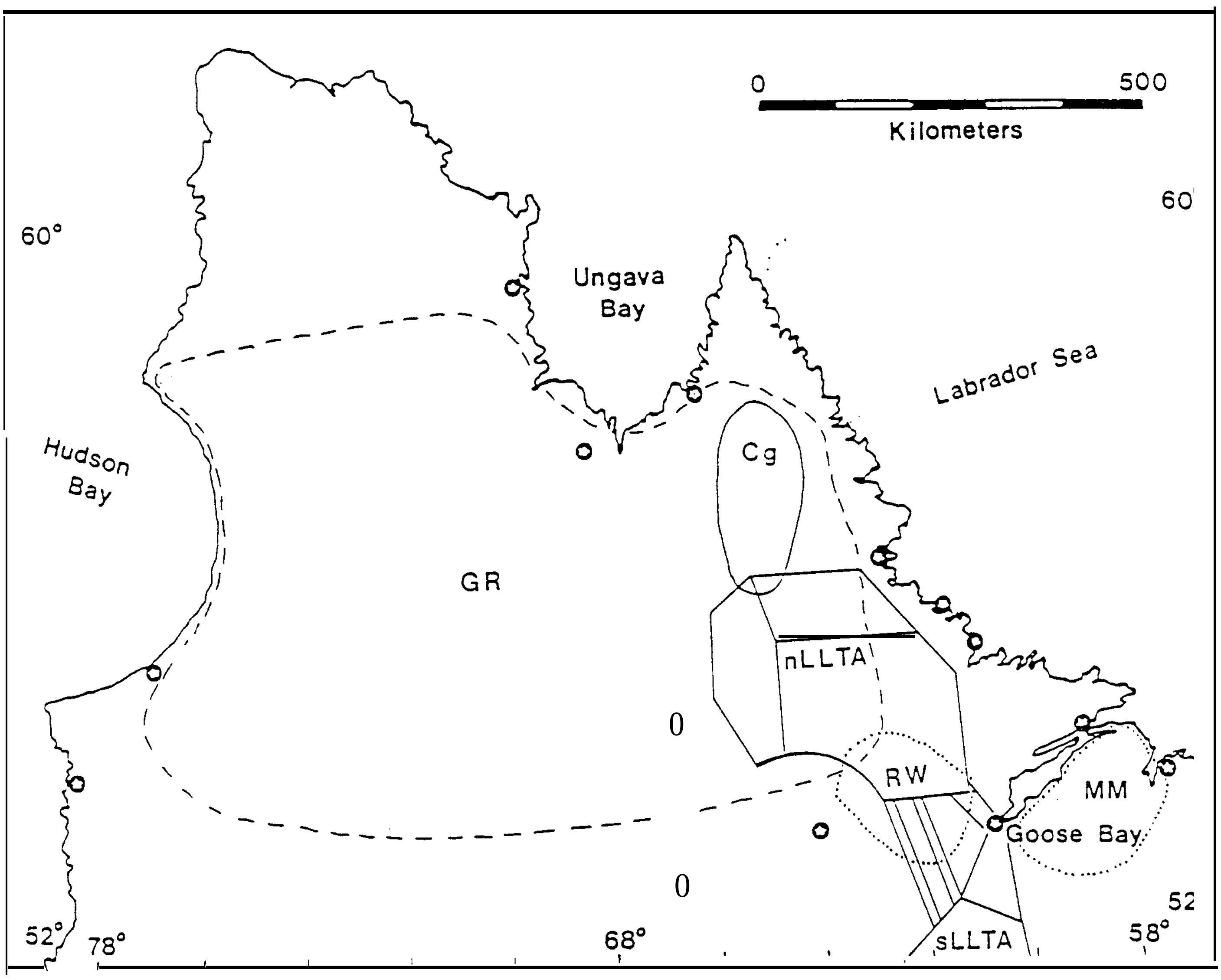

FIG. 1. Map of the study area and approximate ranges of three caribou populations in Labrador and northern Quebec. The George River (GR) population range is indicated by the dashed line. Cg = calving grounds of the GR population. The ranges of woodland caribou are denoted by dotted lines: RWM = Red Wine Mountain population; MM = Mealy Mountain population; nLLTA = the northern low-level training area (LLT1); sLLTA = the northernmost portion of the southern low-level training area. The three units of the nLLTA are indicated, as are the corridors between the LLTAs and CFB Goose Bay. Permanent communities are indicated by circled stars.

flexibility of directing overflights remotely over specific caribou. The use of satellite telemetry permitted us to remotely direct aircraft to specific caribou and non-intrusively monitor their responses on a daily basis. which could be compared to a control group consisting of caribou deliberately avoided by aircraft or individuals from a herd not exposed to overflights.

Observational Approach — Directed Overflights: Visual observations were attempted in late winter. when caribou were in open habitat where they could be observed without influencing their behaviour. Jets (F-4. F-5. F-16. F-18 and Tornado aircraft) were deliberately directed to fly over the caribou. The field crew. including a forward air controller from CFB Goose Bay. flew by helicopter to the observation area. where they located a suitable group of caribou and vantage point. When a jet neared the rendezvous point. the forward air controller guided the pilot to fly directly over the caribou at normal operational speed (775-825 $km \cdot h^{-1}$) and at minimum altitude (30 m·agl). Usually several jets arrived together and flew over the animals at internals of less than one to several minutes.

Observations were videotaped using a Panasonic WV-3250 (18X) video camera with a Panasonic AG-2400 video cassette recorder (1987-88) and a Panasonic AG-160 (6X) camcorder (1988). A spotter kept the camera operators appraised of the jet's approach and recorded the moment of overpass. altitude and distance of the jet to the animals. type and air force of jet. and other pertinent data. Caribou responses to overpasses by helicopters also were observed for comparative purposes. These were done before departing the observation site after the last jet overpassed. Helicopter overflights were conducted at typical cruising speed (150 $km \cdot h^{-1}$) and altitudes of 50-150 m.

Videotapes were analyzed using a Panasonic AG-1830 VCR. For the RWM caribou. the time of first response relative to [he moment of overpass was determined. Initial responses included: standing (for lying caribou): head-up (for lying or feeding caribou): and changes in movement (for feeding. standing or walking caribou). If [he animals moved or accelerated their movements. [he duration and distance or' movement were measured until movement either stopped or returned [o pre-overflight levels. Distances were estimated in body lengths (BL = 1.5-2.0 m), as an independent measure w3s not available. Duration and distance data were log-transformed before multiple regression analyses were performed. Group identity. composition (cows plus 11-month-old calves only. bulls only and mixed sex/age groups). size and behaviour prior [o overflight were used as independent variables. For [he GR caribou. distances (BL) moved by randomly selected samples of 20-40 caribou were determined for each 5 s period. beginning 5-20 s before and ending up [o 20 s after the overpass. For each period. half [he animals were taken from a 100 m wide strip under the jet's flight path. while the other halt' came from beyond this region.

Remote Monitoring of Overflights: We used satellite telemetry (Fancy *et al.* 1988) to manipulate and measure the daily level of exposure and responses to low-level flying of each study animal. Satellite telemetry remotely provided daily relocations and an index of the animal's total activity level during the preceding day. Using the locations. we could remotely direct jet aircraft either toward or away from an animal's location. By manipulating exposure levels among animals. we could then evaluate the relationship between exposure to aircraft and a caribou's subsequent daily movement and activity level.

The satellite platform transmitter terminals (PTT) (Telonics. Inc.. Generation ST-2 and ST-3) broadcast a brief (250 ms) digital signal once each minute. These signals are received by polar-orbiting satellites whenever the PTT is within view and relayed [o Semite Argos processing centres. To conserve battery power. our PTTs broadcast for 8 h each day.

Locations provided by Service Argos. although precise to 0.0010 for both latitude and longitude (roughly 100 and 65 m respectively). vary in accuracy. Three levels of "guaranteed" locations average within 1 km of the true location (Barrington *et al.*. 1987; Fancy *et al.*. 1988). In 1988. a fourth "non-guaranteed.' location index was added. These non-guaranteed locations are sometimes accurate but other times err by tens to hundreds of kilometres. To minimize locational errors. we used only the best daily location. chosen first on the basis of the quality index assigned by Service Argos and second on the number of messages received during the overpass (*more* messages = better signal). In 1988. if only a non-guaranteed location was available. this location was used only if it fell within the range of better quality locations obtained on previous and/or subsequent days.

The long-term (24 h) activity index. generated by a mercury switch within the PTT (Fancy *et al.*. 1988). discriminates well among running. walking and lying/feeding (S. Fancy. pers. comm. 1989). Although variation in [he installation angle of the switch may cause systematic differences in the index among individuals (S. Fancy. pers. comm. 1989: M. Ferguson. pers. comm. 1989: A. Gunn. pers. comm. 1989). the long-term activity index does provide a reliable index of relative activity for each individual caribou.

Satellite collars were deployed in April or May and were retrieved in December. at the beginning and end of the low-level flying season respectively. Adult female caribou were captured from helicopters using a CO. darting pistol. Either etorphine (1986) or carfentanil (1987-88) combined with xylazine or acepromazine were used as immobilants: these were reversed with diphrenorphine or naloxone. In May 1986, we attempted to recapture RWM caribou originally collared in 1982-83 (Brown. 1986). both to expedite locating animals already dispersed in the lowlands and to capitalize on their known histories. In April 1987 3nd 1988. we attempted to recapture RWM animals that had utilized suitable mess in past years. In 1988. we recaptured MM caribou that had been initially outfitted with VHF collars in 1985.

In 1986 3nd 1987. the 10 satellite collared caribou were divided into exposure and control groups. Each day. the most current location was obtained for the collared caribou 3nd relayed to each NATO air force as either "target" (exposure group) or "avoidance" (control group) coordinates. We requested as many overflights for each target coordinate as possible. Conversely. jets were requested to stay at least 9.2 km away from avoidance coordinates. Following a sortie. the pilot reported the time. speed and altitude of all target coordinates flown. Field-truthing exercises. in which observers were stationed at either target or avoidance sites. were conducted in 1986 and 1987 [o measure the reliability of directing overflights reward or away from [he study animals.

In 1988. the design was changed and flights were not regulated throughout LLT1. so that a "normal" distribution of exposure to low-level flying could be obtained. The number *of jets* passing Within 1 km of each caribou was estimated from the records of all flight tracks flown in the low-level training areas during 1988. The flight tracks were derived from the aircraft's turn coordinates, which were generated either by onboard computers or were recorded by hand from [orographic maps. All animals in LLT1 would be considered exposure animals but would differ in their level of exposure to low-level flying primarily due to geographical differences in low-level flying activity.

We chose the control caribou in 1988 from [he MM population because I) it ensured the military completely avoided the control animals, 2) all control animals in the RWM population had prior exposure to overflights and 3) under the 1988 study procedures, it was not possible to avoid specific caribou in the RWM population. The MM population was chosen for its proximity to Goose Bay, its similar characteristics in terms of both caribou and habitat and its position outside the present and historical range of low-level flying aircraft.

Data Analyses

Exposure to Overflights: The primary Independent variable was the measure of the caribou's daily exposure to low-level flying. In 1986 and 1987, this was simply the total number of reported overflights each day. In 1988, an overflight was defined as a jet within 1 km of the caribou's location. This radius was chosen to account for the inherent error in our estimate of the caribou's location, any movement that occurred since that location had been fixed, navigational error on the part of the pilot and because I km is similar [o the accuracy of reported overflights in 1986 and 1987.

Although military jets vary in their noise output, we did not control for this variation because 94% or' all sorties are flown by aircraft similar in noise output (Department of National Defence, 1989). In a study of low-level overflights conducted near CFB-Goose Bay, F-4s (41% of all sorties) and Tornadoes (30%) did not differ significantly in peak noise level (Canadian Public Health Association, 1987). Two other jets flown at CFB-Goose Bay are similar to either the F-4 (F-18: 3% of sorties) or the Tornado (F-16: 20% of sorties) in noise output (Department of National Defence, 1989). The smaller and quieter Alpha-jet accounted for only 6% of all sorties flown. Uncontrolled variation in altitude, attitude, air speed, engine power, masking noise and topographic features, as well as distance to the caribou, are expected to have a greeter influence on sound level than is aircraft type for the present study.

Response to Overflights: The two variables *used to* estimate the effects of exposure or' a study caribou to low-level flying activity were daily activity level 'and daily distance [ravened. The PTT 24 h activity index is suitable to compare daily variation in activity for an individual caribou. Daily distance travelled was the distance between the two highest quality locations on successive days. Daily distance was not normally distributed and was log-transformed for all statistical analyses. Seasonal variables modifying caribou activity and movements included Julian day, month and season. The variable season comprised the pre-calving, calving, insect and fall periods. The pre-calving period ran from [he date of capture in April or May to 22 May and included time on the [e-wintering areas in the Red Wine or Mealy mountains, as well as spring dispersal into the surrounding lowlands. The calving period was from the date of earliest suspected calving 23 May) [o the last day in June with sub-freezing temperatures. The earliest dire of calving was estimated by examining the patterns of daily activity and movements for 4-6 d periods of minimal activity and movement (S. Fancy, pers. comm. 1989). The insect period was from the last day with sub-freezing temperatures in the spring to the first day with sub-freezing temperatures in the late summer. The fall period followed the insect period and continued until low-level flying activity ceased. Temperature data were from Environment Canada in Goose Bay, Churchill Falls and Cartwright.

Other variables were the identity of the female and the presence of a calf. Calf survival was determined by periodic aerial surveys starting in mid-June in 1987 and 1988. Each female was located by helicopter every 3-4 weeks and briefly driven from cover (if necessary) so her calf could be detected. When a female lost her calf between successive surveys, it was assumed to have died in the middle of the interval.

Weather variables included minimum and maximum temperature, precipitation, atmospheric pressure, wind speed and hours of sunlight. The 12 weather variables for each caribou population are highly correlated and redundant. *Therefore,* a Principal Components Analysis using a varimax rotation was conducted for the RWM population using all April-October weather data collected in 1986-88 (N=642 days) and only the 198S data for the MM population. The analysis isolated three principal components for each set of data (Harrington and Veitch, 1990): factor 1 (temperature) was an indicator of temperature: factor 2 (precipitation) was a combination of precipitation, barometric pressure and hours of sun: and factor 3 (wind) largely comprised wind speed and atmospheric pressure. These three normalized weather factors were used to examine the relationship of weather to activity and movements.

Regression Analysis: The daily influence or' low-level flying activity was examined using regression analysis on [he set of variables. The analysis began with a step-wise regression, using one of the two dependent variables as the Y variate, to isolate a subset of predictors. From these predictors, a model was tested using multiple regression. Residuals from this analysis were plotted against variables to determine if other systematic variation might still reside in the data. All analyses were conducted using SYSTAT on a VAX 8350 mainframe computer.

Overflight Stimulus

To characterize the sound of a low-level overpass, audio recordings of overpasses were collected on two days in 1986 using a Nagra Model 4.2 reel-to-reel tape recorder at 38 $cm \cdot s^{-1}$ and an Electro-Voice D054 omni-directional microphone. The modulometer and potentiometer of the Nagra were set to act as a sound level meter, so that peak sound pressure level as well as change in amplitude could be recorded throughout the overpass. Peak sound pressure levels were measured by a Bach-Simpson Model 886 Sound Level Meter, using the fast setting on the C scale.

RESULTS

Overflight Observations

Red Wine Mountain Caribou: Observations of overflights were conducted in the Red Wine Mountains on 13 April 1987 nd 28 and 29 April and 5 May 1988. The terrain of heavily laciated hills with only low boulders and alpine tundra gave ttle protective cover. Most caribou were observed at distances of 500-750 m. and visibility was several kilometres.

A total of 40 overpasses were flown over eight groups of aribou (Table 1). High (300 m agl) or wide (>75 m) overpasses caused detectable responses only 38% of the time N=16 overflights). Direct overflights (30 m agl and within 50 n of the animals), on the other hand, resulted in overt esponses significantly more often (88% of the time [N=24]; G-test, P<0.001). The median time to react (0 s) was presumably in response to the most intense sound of the overpass. Eleven of 2 I direct overflights began with startle responses, in which caribou suddenly scrambled to their feet red/or bolted everal body lengths away, coincident with the jet's overpass. Eight of 10 responses that began prior to the jet's pass occurred when caribou sighted the jet at a distance.

Although caribou usually began to run after [heir initial response (22 of 27 overflights), they began slowing almost mmediately. The median time from beginning to end of novement was 9 s. with the last half of this period done at a slow walk. If animals had been feeding, standing or walking prior to the overpass. they resumed similar behaviour within the next minute (13 of 15 overflights). Animals that had been lying before the overpass usually continued to stand for at least a minute following the overpass (10 of 12 overflights). However. during the next several minutes. animals either began [o feed or lay down again. and by 5-10 min after the last overpass, behaviour had returned to pre-overflight level.

A multiple regression analysis. using data from direct overflights (N=24), indicated that only behaviour prior to the overpass was significantly correlated with the level of response (Table 2). When caribou were walking prior to the overflight, they reacted sooner (P<0.05) and ran longer (P< 0.05) and farther (P<0.01) than did caribou that were feeding/standing or lying prior to the overpass. Group identity (P>0.7), composition (P>0.6) and size (P>0.1) were not systematically related to any response variable.

One series of seven overpasses by a Bell 206L helicopter was flown at 30 m agl over a group of eight adult male caribou in 1987: the group had not been overflown by jets earlier that day. These animals were travelling at a walk prior to the overpasses, In 1988, three helicopter overpasses were flown 15 min after the last of eight jet overpasses over a group of eight bulls. Prior to the helicopter overflights. the animals were either bedded or feeding. In all cases. every caribou reacted prior to the helicopter's passing (Table 1). The animals sighted [he helicopter and trotted or galloped directly away from its path. They continued to gallop hard until [he helicopter passed overhead. when they turned to the side and slowed their pace. The animals continued to move for another 8-?.7 s after the helicopter passed and moved a total of 22-180 body lengths.

The group overflown on [he same day by both jet and helicopter aircraft responded significantly sooner to the helicopter and ran significantly longer and farther than it did in response to the jets (Mann-Whitney U: P<0.05).

George River Caribou: Observations of jet overflights of a group of approximately 500 GR caribou on upland tundra were videotaped on 13 May 1988. A steep ridge provided us with a panoramic view of the caribou in a relatively flat valley 30 m below. Hard. crusted snow covered 70-80% of the ground. Three independent surveys (total caribou = 276) indicated an average composition of 58% cows: 19% 11-month-old calves: 23% bulls.

Between 1250 and 1302 h. six series of a total of 13 overflights by F-16 aircraft were observed (Table 3). The jets arrived in the area in groups of two and three and were directed individually over the centre of [he caribou group at intervals of 6-22 s. During the first three series. when many caribou (30%) were still lying, only 15% (N=60) reacted before the initial overpass of each series. During the last three series. when all animals were standing, feeding or walking, an average of 50% (N=115) reacted prior to the overpass. However. the absolute level of this reaction was low; the maximum distance moved prior to a series of overflights was 10 BL (15-20 m) and the mean was 2 BL (3-4 m).

Most caribou (70%: N=260: 13 overflights) reacted suddenly. scrambling to their feet and bolting forward as the jet passed. Although 90-95% of the caribou began to run. most began slowing shortly after the overpass. Fifty-five percent stopped moving within 5 s, and 65% had stopped within 10 s of the overpass. unless another jet passed over in the meanwhile. Total median distance moved during a single overpass was 8 BL (12-16 m), ranging to a maximum of 34 BL (50-68 m) for the second overpass in a series or two.

Caribou within 50 m of the jet's flight track moved a greater distance in response to an overpass than those farther away (9.9±1.8 m vs. 4.2±2.3 m: 9 overflights/360 caribou: Two-way Anova: P< 0.001). All caribou within 50 m of the flight track ran, but 7% (N=150) of those animals 50-100 m from the flight track did not run.

Five overpasses were flown by an A-Star 300D helicopter one hour after the last set or' jet overpasses. Most (90%) caribou on snow-free ground were feeding. while [hose on snow were either standing or walking. The caribou began to run 10-20 s prior to an overpass and the median animal had moved a

TABLE 1. Summary of response parameters of Red Wine Mountain caribou to low-level jet and helicopter overflights in the Red Wine Mountains in 1987 and 1988 (raw data in Harrington and Veitch. 1990)

	Group data		Responses to direct overflights[1]				Responses to high or wide overpasses[2]			
Aircraft	Size	N	Latency[3]	Duration[4]	Distance[5]	R/TO[6]	Latency	Duration	Distance	R/TO
Jet	4-33	8	0	10	12	21/24	0	4	6	6/16
Helicopter	8	2	–8	19	85	8/8	–4	19	31	2/2

[1]Direct overflights: 30 m altitude and ≤ 50 m to side.
[2]High and wide overflights: > 50 m altitude and/or > 50 m to side.
[3]Median latency (s) is measured relative to the overpass (0 s = overhead).
[4]Median duration of movement in seconds.
[5]Median distance moved is expressed in caribou body lengths (1.5-2.0 m).
[6]R/TO = number of overflights with overt responses/total number of overflights

distance of 83 BL (125-150 m) before the helicopter passed overhead (Table 3). After the helicopter passed. the animals turned and ran back opposite their initial direction. Although they now ran at a slower pace. the median animal still moved another 36 BL (55-70 m) over the next 20 s.

GR caribou ran longer and farther in response to helicopter overpasses than to jet overpasses (N=18 overflights: Anova: P< 0.001). The greatest total median distance moved in response to a jet was 34 BL (50-68 m). This was exceeded by every helicopter overpass by a factor of two or more. Caribou also ran harder from the helicopter. The maximum rate of movement per 5 s period during an overpass was more than 45 BL (68-90 m) for the helicopter. but only 28 BL (42-56 m) for the jets. while the median maximal rates of movement were 39 and 6 BL respectively. Seventy percent of the response to the helicopter occurred prior to the overpass. whereas nearly all the response to jets occurred after the overpass.

Field-Truthing of Directed Overflights

Observers placed at five dummy target sites in 1986 recorded a total of 59 jets. Mean distance of jets from the target Coordinates was 225±262 m (N=33 jets). Forty-two percent passed within 50 m of the target. Only 54% of observed overflights were reported by pilots. indicating that exposure of target caribou to overflights in 1986 may be underestimated by half due to underreporting by pilots. However. an analysis of jet flight track data. caribou locations and overflight reports indicated that overflight report data and flight track data were highly correlated (r=0.89: P<0.01). Therefore. overflight reports do provide a reliable index of relative exposure to low-level aircraft activity.

In 1987.56 jets were observed at target sites. Mean distance from target was 170±263 m (N=52) and 60% of jets were within 50 m of the target. Significantly more overflights were reported in 1987 (82%) than in 1986 (G-test: P<0.01).

TABLE 2. Relationship between level of response to low-level jet overpasses and behaviour of caribou prior to the overflights

Behaviour prior to overflight	N[a]	Latency (s) Median	(range)	Duration (s) Median	(range)	Distance (BL) Median	(range)
Lying	10	0	(–4,–6)	5	(0-23)	4	(0-30)
Feeding/standing	8	0	(–2,0)	7	(0-25)	8	(0-62)
Walking	6	–4	(–7,–1)	18	(15-24)	51	(23-80)

[a]N = number of overflights.

following a more rigorous procedure for reporting instituted in 1987. Virtually all (40 of 42) reported overflights were observed by us in the field.

Observers stationed near four avoidance sites recorded a total of six jets (out of a possible 64) within the surrounding 9.2 km control zone. Their mean distance from the avoidance coordinates was 3.6±1.3 km. and no jet passed within 2 km of the avoidance site. indicating that control caribou locations were being avoided successfully.

Remote Monitoring of Overflights

A total of 1 S RWM and 4 MM caribou were captured. equipped with PTTs. and monitored between 1986 and 1588 (Table 4). Locations were obtained on 82% of available days (N=4906). improving from 76% in 1986 to 92% in 1988. allowing us to calculate daily distance travelled for 74% of days. Activity indices were obtained on 97% of possible days.

1986 and 1987 Low-Level Flying Seasons: In 1986 and 1987. both daily activity levels and distances moved vaned nearly twofold among the animals (Tables 5 and 6). The variation in exposure to overflights was similar in 1986 and 1987. ranging from none to 4.5 per day among the caribou. The two caribou exposed [o the greatest number of overflights had intermediate values for both daily activity and distance travelled in 1986. The two most overflown animals in 1987 had both the highest and the lowest mean activity indices and moderate to-nigh values for daily distance. The three animals never overflown had relatively low mean activity indices but low. medium and high values tor daily distance travelled.

1988 Low-Level Flying Season: Flight track data from 83% of the sorties flown during 1988 indicated that exposure levels varied more than tenfold among the RWM caribou (Table 7). Two animals had an average of one jet or more per day within 1 km of their location. whereas the other three were exposed only once every 2.5-10 days. Mean activity indices and daily distances travelled for RWM animals were similar to previous years (Anova: df=2.22: P>0.8 and 0.1 respectively). and neither variable was correlated with an animal's exposure to overflights (Anova: df=2.22: P>0.4 and O.? respectively). For MM caribou. mean activity indices and daily distance travelled were less than those obtained for the RWM animals in 1988 (Table 7) but were similar to RWM animals in previous years (activity in 1987: daily distance in 1986). Overall. MM caribou moved less on a daily basis in 1988 than did RWM caribou over the three years they were foilowed (Anova: df=1.27: P=0.049). but the two population samples did not differ significantly in mean daily activity level (Anova: df= 1.27: P>0.3).

TABLE 3. Median distance moved by George River caribou during overflights by jet and helicopter aircraft on 13 May 1988 (summarized from Harrington and Veitch. 1990)

Aircraft	N[b]	Interval in relation to overflight[a] –20 s	–15 s	–10 s	–5 s	+5 s	+10 s	+15 s
Jet[c]	13	—	—	—	0[d] (0-13)	6 (0-15)	0 (0-10)	0 (0-4)
Helicopter[c]	5	15 (0-23)	12 (1-27)	18 (15-30)	38 (14-45)	23 (2-38)	8 (0-39)	2 (0-17)

[a]Negative intervals immediately preceded the overpass: positive intervals followed the overpass.
[b]N = number of overflights.
[c]Altitude of jet overflights varied between 25 and 60 m (median = 30 m).
[d]… moved are measured in caribou body lengths (1.5-2.0 m). with the range in parentheses. Each individual overflight median is based on sample

Regression Analyses of Activity and Daily Distance Travelled: The 24 h activity index and daily distance travelled are correlated variables. as directional movement is one component contributing to the total activity index. Thus daily distance was one of the predictor variables used in the regression analysis for the 24 h activity index (but not *vice versa).*

Few variables were significantly related to the daily distance travelled by the animals (Table 8). In general, daily distance was lowest during the calving period. highest in the insect and fall periods. and also increased after a female had lost her calf. When the RWM and MM data sets for 1988 were considered together. the population variable accounted for the greatest amount of variance (1.8%): on average. MM caribou moved significantly shorter distances on a daily basis than did RWM caribou. The total amount of variance explained by these correlated variables. however. was under 5% in any year. The level of exposure to low-level flying, as measured by the number of overflights. was not related to the distance an animal travelled each day.

For the 24 h activity index. daily distance travelled accounted for about 15% of the variance (Table 8). Temperature, a weather component, accounted for another 5%. while season. individual and calf survival together accounted for an additional 5%. The activity index was positively correlated to temperature and was highest during the insect period. It also was higher for females not accompanied by calves. even when their greater daily travel rates were taken into account. The index was lowest during the calving period and was lower for females accompanied by calves. MM caribou had lower 24 h activity indices. even when their. shorter daily travel rates were taken into account. In all. these variables accounted for 20-32% of the variance in the 24 h index.

TABLE 4. Red Wine and Mealy Mountain caribou followed with satellite telemetry between 1986 and 1988

Caribou[a]	Age[b]	Initial capture[c]	# recaptures	PTT-years[d]	Comments[e]
RWF013	9	03/19/82	6	3	PTT-F (88/296)
RWF016	8	03/20/82	3	2	PTT-F (S7/114)
RWF035	7	03/27/83	2	1	
RWF037	7	03/26/83	5	2	PTT-F (88/250)
RWF039	12	05/09/86	2	2	
RWF040	12	05/09/86	1	1	
RWF041	9	05/09/86	0	1	Mort. (86/235)
RWF043	14	05/09/S6	1	1	
RWF044	14	05/12/86	3	2	PTT-F (87/273)
RWF045	12	05/15/86	1	1	PTT-F (86/177)
RWF046	10	04/04/87	1	1	
RWF047	3	04/05/87	1	1	
RWF048	5	04/05/87	1	1	
RWF050	6	04/10/s7	1	1	
RWF051	9	04/02/s7	1	1	
RWF052	3	04/05/s7	3	2	
RWF053	2	04/07/88	1	1	PTT-F (SS/279)
RWF055	1	07/04/88	1	1	
MMF001	8	04/10/85	1	1	Mort. (88/224)
MMF002	6	04/02/85	7	1	
MMF003	12	04/10/s5	2	1	
MMF004	3	(34/20/s5	3	1	PTT-F (SS/106)

[a]Caribou: RWF = Red Wine Mountain female: MMF = Mealy Mountain female.
[b]Age calculated as of resumed birthdate in 19S6.
[c]Caribou captured prior to 1986 were initially outfitted with VHF collars.
[d]PTT-years = number or' low-level flying seasons wearing PTT.
[e]PTT-F . PTT failure: Mort. = Mortality. Year and Julian day of death are given in parentheses.

TABLE 5. Summary of daily data collected for satellite-collared Red Wine caribou during the 1986 study semen

Caribou	Activity index		Distance travelled (km)		Overflights reported	
RWF013	141±56[1]	(171)	2.8±2.2	(101)	3.4±5.3	(165)
RWF016	208±68	(170)	3.4±2.5	(87)	0.1±0.6	(165)
RWF035	122±47	(153)	3.0±2.3	(74)	0.1±1.3	(153)
RWF037	143±66	(172)	3.1±2.4	(132)	0.0±0.0	(165)
RWF039	137±53	(176)	3.7±2.2	(98)	0.0±0.0	(165)
RWF040	192±57	(104)	3.1±2.4	(69)	0.0±0.0	(165)
RWF041	116±53	(106)	2.0±2.9	(75)	0.7±2.1	(95)
RWF043	119±60	(176)	2.6±3.0	(150)	0.4±1.6	(165)
RWF044	156±58	(173)	2.9±2.5	(135)	2.8±5.0	(165)
RWF045	97±73	(42)	2.8±2.7	(37)	0.1±0.5	(37)
Grand mean	146±66	(1443)	2.9±2.5	(958)	0.8±2.9	(1440)

[1]Mean ± sd (number of days).

TABLE 6. Summary of daily data collected for satellite-collared Red Wine caribou during the 1987 study season

Caribou	Activity index		Distance travelled (km)		Overflights reported	
RWF013	98±46[1]	(187)	3.0±2.2	(51)	3.2±5.1	(208)
RWF016	111±65	(17)	3.1±2.1	(11)	0.0±0.0	(17)
RWF039	113±48	(199)	3.5±2.3	(75)	0.0±0.0	(206)
RWF044	137±48	(166)	2.7±2.6	(90)	1.5±2.9	(177)
RWF046	122±54	(204)	4.0±2.6	(185)	0.2±1.2	(206)
RWF047	143±54	(206)	3.5±2.4	(177)	0.8±2.0	(208)
RWF048	128±56	(205)	3.5±2.3	(198)	0.1±0.6	(208)
RWF050	111±49	(207)	2.4±2.4	(184)	0.0±0.0	(210)
RWF051	110±57	(207)	2.6±2.5	(184)	0.1±0.4	(209)
RWF052	174±47	(206)	3.5±2.2	(184)	4.5±6.6	(208)
Grand mean	126±56	(1804)	3.2±2.4	(1339)	1.1±3.4	(1857)

[1]Mean ± sd (number of days)

TABLE 7. Summary of daily data for satellite-collared Red Wine and Mealy Mountain caribou during the 1988 study season

Caribou	Activity index		Distance travelled (km)		Overflights (# jets < 1 km)	
Red Wine Caribou						
RWF013	138±62[1]	(199)	2.5±2.8	(101)	1.0±2.5	(203)
RWF037	114±53	(157)	3.5±2.5	(140)	0.4±1.3	(157)
RWF052	162±55	(175)	3.9±2.2	(160)	1.7±3.6	(175)
RWF053	168±59	(180)	2.9±2.3	(170)	0.1±0.7	(181)
RWF055	143±51	(120)	3.8±2.4	(120)	0.3±1.8	(120)
Grand mean	146±60	(831)	3.3±2.4	(691)	0.8±2.3	(836)
Mealy Mountain caribou						
MMF001	135±78	(119)	2.6±3.8	(108)	—	
MMF002	111±62	(201)	2.7±2.9	(173)	—	
MMF003	135±74	(201)	2.3±2.5	(198)	—	
MMF004	108±30	(174)	2.7±2.1	(153)	—	
Grand mean	121±64	(695)	2.6±2.7	(632)	—	

[1]Mean ± sd (number of days)

TABLE 3. Contribution of predictor variables to the variance in the daily distance travelled and the 24 h activity index, as determined by multiple regression

Predictor variable	1986 season % explained	1986 season P[a]	1987 season % explained	1987 season P	1988 Red Wine % explained	1988 Red Wine P	1988 Mealy Mountain % explained	1988 Mealy Mountain P
Dependent variable = daily distance travelled								
Individual	—		0.9%	0.002	2.1%	<0.001	—	
Calf survival	.		0.4%	0.013	—		—	
Julian day	4.1%	<0.001	–					
Month	0.7%	0.01	—				—	
Wind	—		—		1.3%	0.002	–	
Dependent variable = 24 h activity index								
Daily distance	15.4%	<0.001	18.6%	<0.001	11.2%	<0.001	21.6%	<0.001
Temperature	2.0%	<0.001	7.7%	<0.001	8.6%	<0.001	7.1%	<0.001
Season	1.6%	<0.001	–		3.4%	<0.001	1.1%	<0.001
Individual	1.4%	<0.001	1.5%	<0.001	1.2%	<0.001	2.2%	<0.001
Calf survival	na[b]		0.3%	0.033	1.0%	<0.001	—	
Overflights	—		3.5%	<0.001	—		na	

[a]Only those values significant at $p < 0.05$ are shown.
[b]na = not applicable.

Overflight exposure was significantly correlated with activity level only in 1987.

Overflight Stimulus

Regression analysis of 52 low-level overpasses, using altitude, horizontal distance and aircraft type as independent variables, indicated that noise level decreased 6.9 dB every 100 m from the jet's flight path ($r=-0.817$; $P<0.001$) (Fig. 2). Sound level also decreased at the rate of 5.9 dB per 100 m altitude. Aircraft (F4 and Tornado jets only) did not differ significantly in noise level ($P>0.1$). The maximum noise level recorded was 131 dB for a direct overpass at 30 m agl, and mean noise level for close overpasses (within ±30 m of flight track) was 115±8 dB.

Noise level increased rapidly as a jet approached, rising from ambient levels to a maximum in about 1 s. Sound level dropped immediately after the jet passed over but did not return to ambient levels for another 10 s or more. The noise was broadband, with peak amplitudes between 1 and 4 kHz. The amount of warning we had of a direct overpass was dependent on background noise. On calm days we could hear the approach of a jet 10-20 s before it was overhead, but on windy days, especially when surrounded by trees, we had little warning of an overpass.

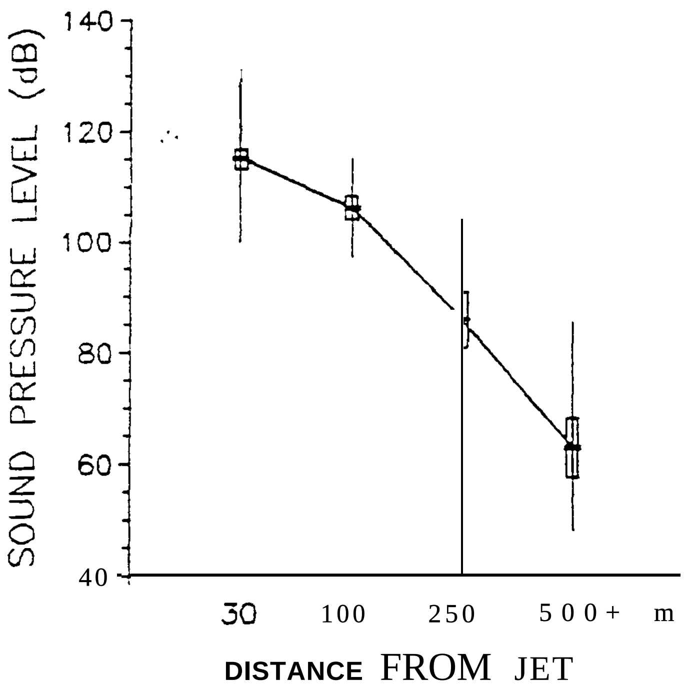

FIG. 2. Mean sound pressure level (dBc) of F4 and Tornado jet overpasses are shown as a function of mean distance from flight track. Vertical bars connect minima and maxima; boxes enclose standard errors of the mean; horizontal dashes indicate the mean.

DISCUSSION

Behavioural Response to Overflights

Our observations indicate that the initial response of caribou to a low-level jet aircraft is caused by the sound of the overpass, not the sight of the jet. The usual response to a sudden, intense noise is the "startle reflex," with its concurrent activation of the sympathetic nervous system (Moller, 1978). Direct overpasses will produce sounds with the most rapid rise times and highest peak levels and thus should cause the most intense startle reactions. In addition, due to the reflex nature of the response, habituation to such stimuli is not likely. Overpasses

Startle responses may be especially detrimental to caribou during calving, causing problems such as stillbirths, cow-calf separations or injuries to newborn calves (Banfield, 1974; Cowan, 1974; Miller and Broughton, 1974; Miller *et al.*, 1988). Panicked cows and calves during thaw could result in calves mired in wet snow. Startle responses may have more subtle effects, such as reduced milk production (Ely and Peterson, 1941) and calf thyroid function (Ames, 1971). Possibly, calves exposed to frequent overflights may grow slower and could consequently suffer higher mortality from increased predation, inability to cope with inclement weather or the energetic demands of summer movements and insect

Startle reactions may also be detrimental where sudden movements can result in injury because of rugged topography. especially when ice cover reduces traction. Injuries are also possible when animals are congregated in groups. especially when constrained by deep snow, river crossings or icy ridges.

Following the initial startle. the animals" responses followed a time course similar to that of the overpass itself. If animals began [o run. maximum rate was reached almost immediately and within 5-10 s they had stopped. Following an overpass. the caribou often oriented to the receding jet. apparently watching it. which suggests that the visual image of the jet becomes an important focus after the initial startle. Within the first minute following an overpass. most animals appeared [o relax [heir vigilance (e.g.. lie down or lower head and feed) and resumed former activities within several minutes of [he overpass. On those occasions when caribou could watch an approaching jet. the animals reacted before the pass. thereby running a longer period. These more prolonged responses are to be expected in open habitat. as caribou in forested habitats are unlikely to see jets. except briefly as they recede.

The slower air speed of [he helicopter gave advance warning of its approach and thus reduced [he startle impact. The caribou began [o run sooner and ran significantly longer than during jet overpasses. Following a single helicopter overpass. the animals were displaced farther than for jet overpasses. The longer overpass time and [he visual stimulus of a helicopter suggests that they may cause greater avoidance responses in caribou over time than would jet aircraft. as the latter are rarely observed by the animals prior to the overpass. In addition. helicopters are the only aircraft likely [o actively pursue caribou. either through [he pilot's curiosity or during wildlife management operations (e. g.. capturing/collaring. classification surveys). Caribou that are pursued by helicopters may learn to associate helicopters with the threat posed by predators. intensifying the response with the reinforcement of periodic exposure.

Impact of Low-Level Flying on Energy Expenditure

The 24 h activity index appears to be the most valid of our two daily measures of impact. First. this index was significantly and consistently correlated to a number of biologically relevant variables. Second. it is an absolute measure of head movement that is related in predictable ways to standard measures of activity (running, walking, feeding/resting). The other "dependent variable. daily distance travelled. has a significant amount of error (20-40%) on the scale of movements made daily by woodland caribou (24 km·day^{-1}). Also. when movements are not strongly directional. daily distance will underestimate actual distance [ravelled. The location data are better suited [o analyze home range use. which is a more valid indication of long-term disturbance (Barrington and Veitch. 1990).

Neither the 24 h activity index nor [he daily distance travelled was consistently related to [he degree of exposure to low-level flying aircraft. These findings are consistent with the directed overflight observations. which indicated that the animals' reactions to an overpass were short-lived.

Heart rate telemetry. however. shows that heart rate often stays elevated after any initial overt response has ended (Kanwisher *et al.*. 1978: Moen *et al.*. 1978: MacArthur *et al.*. 1979). The overt response of a bighorn sheep (*Ovis canadensis canadensis*) to a helicopter overpass (MacArthur *et al.*. 1979) paralleled that of caribou to jets in the present study [bus it is likely that heart rate similarly remains elevated fo several minutes following a jet overpass. However. the energy expenditure associated with an elevated heart rate. in the absence of an overt behavioral response, is equivalent tc moving only a few body lengths (Floyd *et al.*. 1988). The one significant correlation between exposure [o overflights and daily activity index in 1987 suggests [hat under higher levels of exposure. as occurred when particular animals were being deliberately overflown by jets on a daily basis, a slight increase or a few percentage points in overall activity level may occur. consistent with Geist's (1971) calculations on the costs of harassment in caribou.

Overall Impacts of Low-Level Jet Overflights

Our results indicate that the greatest impact of low-level flying jet aircraft will be due [o the startle reactions caused by the loud and sudden noise of low.. direct overflights. Peak sound pressure levels in excess of 120 dB occurred with direct overpasses at 30 m agl. but peak levels were typically less and fell off rapidly (7 dB/100 m) as distance from the flight track and jet altitude increased. Beyond 250 m from [he jet's flight path. the mean sound pressure level for jet overpasses was under 90 dB. which is less aversive in domestic and wild mammals (Manci *et al.*. 1988). Thus. the "disturbance footprint" of an overpass is probably confined to a width of less than 500 m. As most low-level [raining flights are at 30-150 m agl (Department of National Defence. 1989). however. every jet still has the potential [o disturb caribou within this 500 m corridor.

Data collected in 1988 on satellite-collared caribou and jet flight tracks indicate that overflights close enough [o elicit startle responses by caribou are infrequent under present levels of flying. The animal designated as RWF052. which spent most of the 1988 low-level flying season in the heavily used southeast corner. would have experienced one or more overpasses within this 500 m wide "disturbance corridor.. once every eight days. on average. For other caribou. the frequency of such overflights was much less. However. it is possible that under the higher levels of low-level flying activity expected by 1996. some caribou may be exposed to an unacceptedly high number of overflights during sensitive periods. Any potentially adverse impacts could be minimized by monitoring jet flight paths through the Red Wine population range. so that excessive exposure of specific areas can be avoided. particularly during the calving period.

ACKNOWLEDGEMENTS

We owe a special thanks to Stu Luttich (Regional Wildlife Biologist. Labrador) for all his support and assistance. We are also grateful to the other members of the project's steering committee: J. Hancock. J. Inder. E. Mercer (Newfoundland-Labrador Wildlife Division): A. Noseworthy (Intergovernmental Affairs Secretariat): B. Moores (Environment Canada): C. MacNeil and J. Rowell (Labrador Inuit Association): and their alternates.

We thank for their valuable contributions to field work: B. Baikie. D. Baikie. M. Berger. D. Blake. C. Butler. B. Chaulk. B. Dalton. B. Hearn. K. Hollett. N. Hughes. T. Kent. F. Phillips. H. Supper. R. Trask and Z. Tooze. We also thank the staffs at Sealand (Canadian) and Universal Helicopters. Goose Bay Air Services (Labrador

Airways) and Air Northland, and their pilots: H. Blake. P. Bradford. H. Day. C. House. B. Kendall. K. Loder. W. Massie. W. Mitchell. G. Nuttall. G. Penny. B. Raymond. B. Smith. H. Supper and R. Taylor. We thank T. Downs and his staff. Department of National Defence. Ottawa. for their continued assistance. At CFB Goose Bay, the staff of the Military Coordinating Centre deserve a special thanks. including Mst. Cpl. J. Getschell. Pvt. D. Ottway and Pvt. M. Tinkham, and especially Major D. Ghyselinks. We thank the officers, squadron leaders and operations personnel in the German Air Force, Royal Air Force and Royal Netherlands Air Force.

D. Decker. J. Russell and S. Tomkiewicz. of Telonics. Inc.. and Semite Argos staff in Toulouse. France. and Landover, Maryland. especially L. Morakis and H. Sparks. providea help and advice. S. Fancy, through the Alaska Fish and wildlife Research Center (U.S. Fish and Wildlife Service) and Alaska Department of Fish and Game. provided computer programs used in [he analyses of the satellite data. A. Kenney and the Nova Scotia College of Geographical Sciences provided additional programming and the analyses of jet flight tracks. R. Kafer provided consultation on statistical matters. M. Houlihan and the computer serf ices staff at Mount Saint Vincent University assisted in the mainframe analyses.

Funding and other support for this study were provided by the Newfoundland-Lobrador Wildlife Division. the Department of National Defence. the Natural Sciences and Engineering Research Council and Mount Saint Vincent University.

A. Gunn. S. Murphy and an anonymous reviewer greatly enhanced [he paper through their many helpful comments.

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ARCTIC
VOL. 45, NO. 3 (SEPTEMBER 1992) P. 213-218

Calving Success of Woodland Caribou Exposed to Low-Level Jet Fighter Overflights

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(Received 1 October 1990; accepted in revised form 12 October 1991)

ABSTRACT. Effects on woodland caribou (*Rangifer tarandus caribou*) of low-level military jet training at Canadian Forces Base – Goose Bay (Labrador) were studied during the 1986-88 training seasons. Calf survival was periodically monitored during 1987 and 1988 in a sample of 15 females wearing satellite-tracked radiocollars. During 1987, each female's exposure to low-level overflights was experimentally manipulated on a daily basis. In 1988, daily exposure was determined by analyzing jet flight tracks following the low-level flying season. Calf survival was monitored by survey flights every 3–4 weeks. A calf survival index, the number of survey periods (maximum = 4) that a cow was accompanied by a calf, was negatively correlated with the female's exposure to low-level jet overflights during the calving and immediate post-calving period and again during the period of insect harassment during summer. No significant relationship between calf survival and exposure to low-level flying was seen during the pre-calving period, during the late post-calving period prior to insect harassment, and during fall. In view of the continued depression of population growth in the woodland caribou population within the low-level training area, jets should avoid overflying woodland caribou calving range at least during the last week of May and the first three weeks of June.

Key words: caribou, *Rangifer tarandus caribou*, calf survival, low-level flying, jet aircraft, disturbance, Labrador

RESUME. Au tours des saisons d'entrainement de 1986 à 1988, à la base des Forces armées canadiennes de Goose Bay au Labrador, on a étudié les retombées sur le caribou des bois (*Rangifer tarandus caribou*) de l'entrainement à basse altitude sur des avions militaires à réaction. En 1987 et 1988, on a observé périodiquement la survie des veaux dans un échantillon de 15 femelles équipées de colliers émetteurs suivis par satellite. Err 1987, on a manipulé quotidiennement de façon expérimentale l'exposition de chaque femelle à des survols à basse altitude. En 19X8, on a déterminé l'exposition quotidienne en analysant le parcours des avions à réaction apres la saison de vol à basse altitude. On a observé la survie des veaux en effectuant des relevés en vol toutes les 3 ou 4 semaines. Un index de survie des veaux [e nombre de fois (maximum = 4) durant les relevés où une femelle était accompagnée d'un petit — a été corrélé négativement à l'exposition de la femelle au survol à basse altitude des avions à réaction au tours de la mise bas et de la période lui faisant immédiatement suite, ainsi que durant la saison estivale de harcèlement par les insectes. On n'a observé aucun lien significatif entre la survie des veaux et l'exposition aux vols à basse altitude au tours de la période precédant la mise bas, au tours de la période tardive suivant la mise bas et precédant celle du harcèlement par les insectes, ainsi que durant l'automne. Vu la baisse continue de la croissance de population du caribou des bois à l'intérieur de la zone d'entrainement à basse altitude, les avions à réaction devraient éviter de survoler le territoire de mise bas du caribou des bois au moins durant la dernière semaine de mai et les trois premières semaines de juin.

Mots clés: caribou, *Rangifer tarandus caribou*, survie des veaux, vol à basse altitude, avion à reaction, perturbation, Labrador

Traduit pour le journal par Nésida Loyer.

INTRODUCTION

Most studies of aircraft impacts on caribou (*Rangifer tarandus*) have focused on the short-term effects of overflights (Klein, 1974; Calef *et al.*, 1976; Surrendi and DeBock, 1976; Miller and Gunn, 1979; Gunn *et al.*, 1985). Although knowledge of the nature of these short-term effects and the variables influencing their severity is important, these studies fall short in terms of answering a more fundamental question: does aircraft disturbance have a negative impact on population dynamics in the long term (Bergerud *et al.*, 1984). The validity of extrapolating from short-term reactions of individuals to long-term impacts at the level of the population has not been proven. For example, 5 minutes of hard running in response to an overflight may appear to have a greater potential long-term impact than a brief startle followed by several minutes of alert behaviour. But if the energy expended in running can be recouped the same day by extending a foraging bout, whereas the physiological depression of lactation caused by the startle reduces the calf's milk intake by 25%, then the impact on population growth may be the reverse. Consequently, both short-term and long-term effects must be monitored to more fully assess the impacts of aircraft disturbance on caribou.

In our study of the short-term effects on woodland caribou (*R. t. caribou*) of low-level flying activity by fighter-type jet aircraft in Labrador (Harrington and Veitch, 1991), we also investigated the potential for long-term effects on population dynamics and behaviour. Previously, Davis *et al.* (1985) assessed the long-term impacts of jet aircraft activity through population-wide habitat use and demographics. We assessed long-term effects on an individual level by determining the relationship between an animal's exposure to low-level flying and its corresponding calf survival. An individual's exposure to low-level overflights was assessed on a daily basis, whereas calf survival was determined every 3–4 weeks. We hypothesized that frequent overflights during the calving and immediate post-calving periods would reduce calf survival as a consequence of the startle responses caused by low-level overpasses (Harrington and Veitch, 1991).

STUDY AREA

The study area encompasses the ranges of two woodland caribou populations (Fig. 1). The Red Wine Mountain population of about 700 animals (Veitch, 1990) inhabits a 23 000 km² area that includes a heavily overflown portion of the northern low-level training area. Several NATO-member air forces engage in low-level jet fighter training there between April and November each year. During winter, most Red Wine Mountain caribou can be found within the training area, whereas a portion of the population migrates out prior to calving and remains to the south or west of the training area until after the fall rut. The Mealy Mountain population of about 2000 animals (Hearn and Luttich, 1987) inhabits a 22 000 km²

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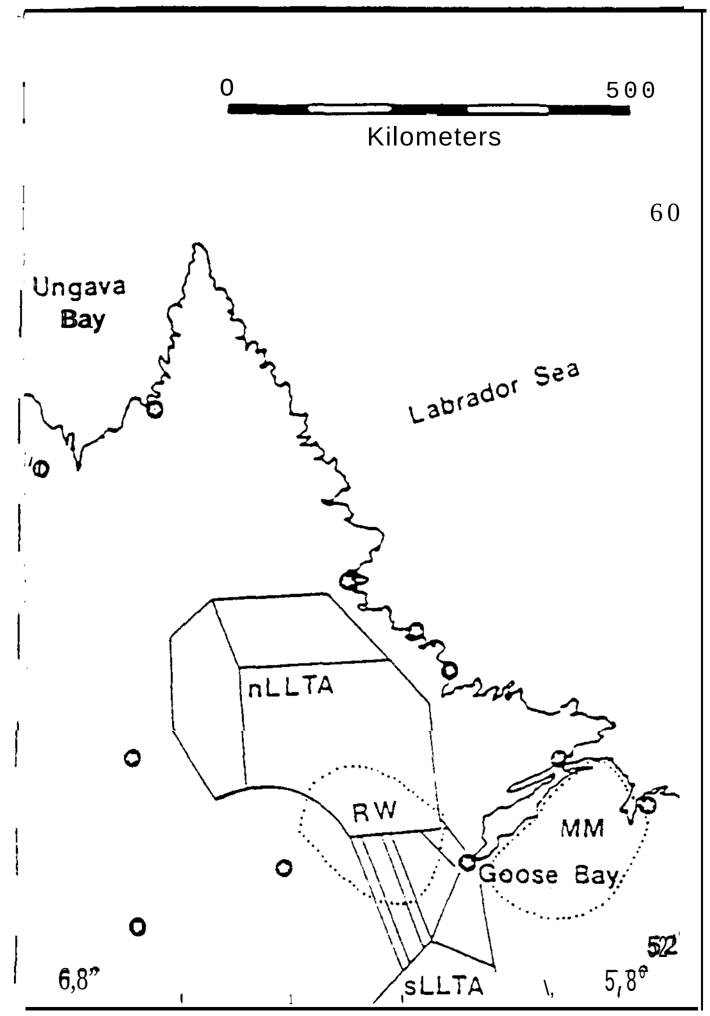

FIG. . The study area and approximate ranges of two woodland caribou populations in Labrador. The ranges of each population are denoted by dotted lines: RW = Red Wine Mountain population; MM = Mealy Mountain population. nLLTA = the northern low-level training area; sLLTA = the northernmost portion of the southern low-level training area. The three units of the nLLTA are indicated, as are the corridors between the LLTAs and CFB Goose Bay. Permanent communities are indicated by circled stars.

...ea cost of Goose Bay and is removed from both [raining ...eas. Topography, climate and vegetation are generally simi...ar for the ranges of both caribou populations. Each range includes an area of rounded, barren hills supporting alpine tun...ra, providing late-winter forage when deep snow in the sur...ounding lichen -conifer forest plateau limits foraging opportunities and impedes travel (Brown, 1986).

METHODS

We used satellite telemetry, Platform Transmitter Terminals (PTT), to manipulate and/or measure the daily frequency of ...posure to low-level flying of each study animal (Harrington and Veitch, 1991). Satellite telemetry allowed us to locate each animal as often as daily without disturbance. Using these ...cations, jet aircraft (Alpha-jet, F4, F16, F18, and Tornadoes) ...ere directed either toward or away from an animal's loca...ion. By manipulating exposure frequency among animals, we

Adult female caribou were captured prior to the beginning of the low-level flying season each spring by darting from helicopter (Bell 206B, 206L). Each animal was outfitted with a satellite collar containing a PTT (Generation ST-2 or ST-3; Telonics, Inc., Mesa, Arizona). These collars were retrieved in winter for refurbishment.

Locations obtained from Service Argos (Landover, Maryland) through satellite telemetry vary in accuracy. Three levels of "guaranteed" locations average within 1 km of the true location (Harrington *et al.*, 1987; Fancy *et al.*, 1988), which is similar to the accuracy of locations we obtain using VHF radiotelemetry. To minimize locational error, only the best location obtained each day was used. This was chosen first on the basis of the quality index assigned by Service Argos and second on the number of messages received during the overpass (more messages = better signal). Locations were not obtained on all days. The percentage of days with locations (Location-days) varied among PTTs and tended to decline several months after a PTT was deployed (Harrington *et al.*, 1987). During the calving and immediate post-calving periods, however, locations were obtained on 93% of days in 1987 and 98% of days in 1988.

In 1987, the 10 satellite-collared caribou were all obtained from the Red Wine Mountain population. These were divided into exposure and control groups. Each day, the most current location was obtained for each animal and relayed to each participating NATO air force prior to that day's flying as either Target (exposure group) or Avoidance (control group) coordinates. Each Target coordinate was accompanied by a request for as many overflights as possible. Avoidance coordinates, on the other hand, were to be avoided by jets by at least 9.2 km. We received a report back indicating the number of times each day that a Target animal's coordinates were overflown. Field-truthing exercises, in which we were stationed at dummy target or avoidance coordinates, indicated a high degree (90%+) of accuracy in these reports (Harrington and Veitch, 1991). The number of reported overflights each day was used as the measure of an animal's exposure to low-level jet activity.

In 1988, our study animals were taken from both the Red Wine Mountain and Mealy Mountain populations. Red Wine Mountain caribou were used as exposure animals, whereas Mealy Mountain caribou served as controls. We placed the control animals outside the Red Wine Mountain population because 1) it ensured the military completely avoided the control animals, 2) all control animals in the Red Wine Mountain population have had prior exposure to overflights and thus constitute a biased sample, and 3) under the 1988 study procedures, it was simply not possible to avoid specific caribou in the Red Wine Mountain population. The Mealy Mountain population was chosen for its proximity to Goose Bay, its similar characteristics, and its position outside the present and historical range of low-level flying aircraft.

Records of all flight tracks flown by jets during 1988 were collected. Each flight track consisted of a list of coordinates that represented turning points during the flight. For some aircraft (F16, F18, Tornado) these were generated by onboard computers, whereas for other aircraft (F4, RF4) these were recorded by hand from topographic maps. From these coordinates, flight lines were constructed from which indices of exposure were generated. An overflight was considered to be a jet within 1 km of the caribou's location. This radius was cho... ...r the inherent error in the caribou's location.

fixed. and navigational error on the part of the pilot and is similar to the accuracy of reported overflights in 1987.

Calf Survival

Calf survival was determined by periodic aerial surveys starting in mid-June (Fig. 2). Every 3-4 weeks each female was visually located by helicopter so that any accompanying calf could be detected. A calf's survival was measured as the number of survey periods (0-4) during which her calf was observed. These periods included survival to mid-June (1), to mid-July (2), to mid-August (3), and throughout the entire low-level flying season (4). No direct observations of calving were available, but declines in 24 h activity indices and daily movements (Harris *et al.*, 1991) were used to estimate the calving period. Females never seen with calves were treated in two ways. First, we assumed they lost their calves between birth and the first survey. Second, we assumed they were never pregnant and therefore deleted them from the sample.

Statistical Analyses

We divided the low-level flying season into seven biologically relevant seasons (Fig. 2). The pre-calving period began with the initiation of low-level flying during the third week of April and ended with the beginning of the calving period. The calving period (23 May - 5 June) included all but one of the suspected calving dates. The initial post-calving period (6-19 June) included the remaining calving date (8 June) as well as the first one or two weeks post-calving. The pre-insect post-calving period (20 June - 3 July) ended when both temperature indices and 24 h activity indices indicated that insect harassment had become extreme. Two equal-length summer insect periods ended with the first day of sub-freezing weather (as determined by Environment Canada at Goose Bay and Churchill Falls). Insect activity is expected to be high during the first of these periods and to continue periodically throughout the second. A fall period followed from 17 September to the end of the low-level flying season. For each period, the mean number of low-level overflights per day was determined for each animal. In addition, the overall mean number of overflights per day was calculated for the entire period a female's calf was presumed to be alive. For this latter analysis, we presumed a calf was lost at the mid-point of the interval during which it disappeared.

Once a calf was determined lost, its mother's data were deleted from the analyses of subsequent periods. Because females were dropped from the sample as the season progressed, we computed separate Spearman correlation coefficients for each period between a calf's survival index and the mean number of overflights it was exposed to during that period. Our hypothesis predicted a negative effect of exposure frequency on calf survival: therefore one-tailed probability values were used.

Two females were followed during both years. To avoid "pseudo-replication" (Hurlbert, 1984; Machlis *et al.*, 1985), we represented each female by her mean values over the two years. Both females held the same ranks among all females each year in terms of frequency of exposure to flying.

RESULTS

Of the ten Red Wine Mountain females outfitted with PTTs in early April 1987, eight provided calf survival and satellite data throughout the entire low-level flying season and a ninth provided satellite data through the end of September and calf survival data throughout. The tenth animal's PTT failed in late April, and thus was deleted from the study. In 1988, five female caribou were initially collared on the Red Wine Mountains in early April and one in early May. Two of these animals were deleted from the sample after they emigrated from the Red Wine Mountain population range in May and were assumed to have been George River caribou. Exposure to

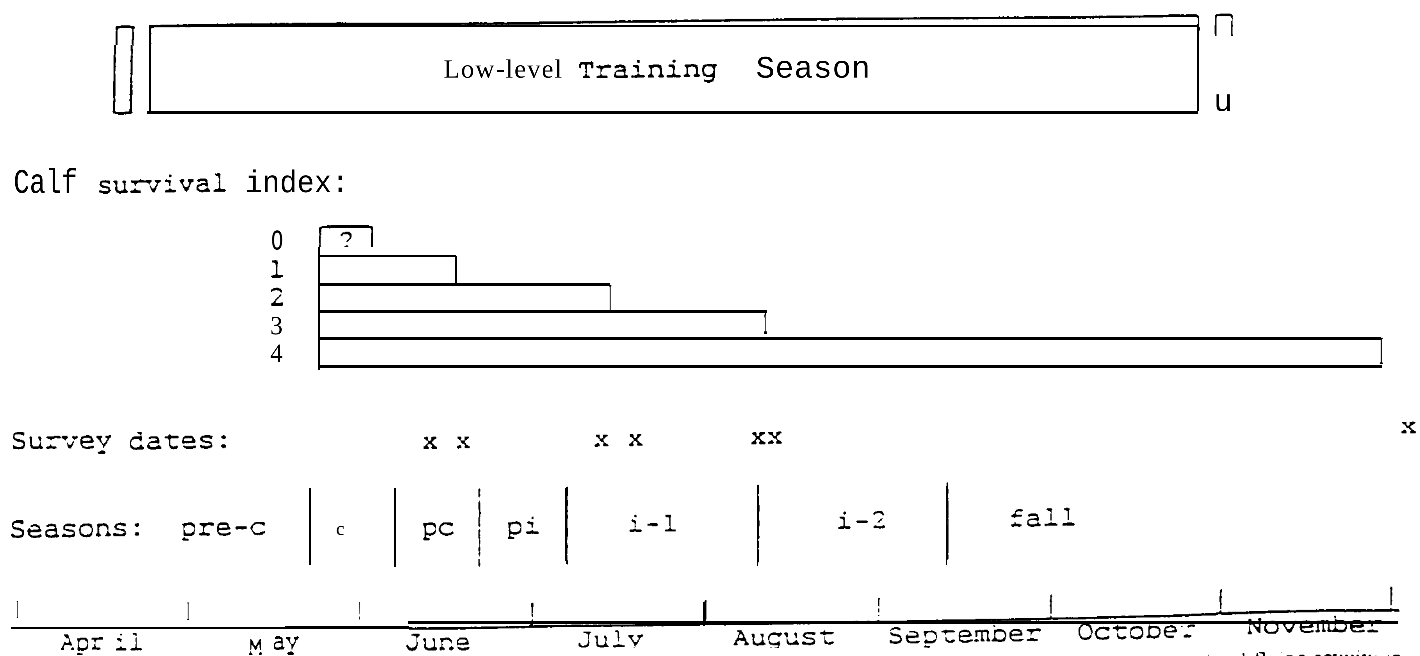

FIG. 2. The temporal relationships among the variables used in the data analyses. The upper box indicates the approximate period of low-level flying activity in 1987 and 1988. The closed bars of the calf survival index indicate the minimum period that a calf was known to survive, except for index = 0, when the presence of a calf was unknown. The timing of survey dates in 1987 and 1988 is indicated by an "x". The biological seasons are: pre-c = pre-calving period; c = calving period; pc = immediate post-calving period; pi = pre-insect post-calving period; i-1 = first summer insect period; i-2 = second summer insect period; and fall = fall period.

TABLE 1. Calf survival and frequency of exposure to low-level jet overflights of satellite-collared female woodland caribou in Labrador

Population	Year	n	Calves surviving to:[a]				Frequency of overflights[b]		
			June	July	August	October	Mean±SD	(range)	n
Red Wine	1987	9	7	7	4	4	1.0 ± 1.6	(0–4.5)	1857
Red Wine	1988	4	1	1	1	1	0.8 ± 0.7	(0.1–1.7)	716
Mealy Mtn.	1988	4	3	3	2	2	—	no overflights	—

[a]Number of calves (of maximum n) alive during surveys in the months noted.
[b]Frequency of overflights is the number of jet overflights reported <1 km from an animal's location within each 24 h period.

low-level flying aircraft varied greatly among Red Wine Mountain caribou (Table 1). In each year, some animals had virtually no exposure whereas others were exposed to several low-level passes each day, on average.

Four Mealy Mountain females were also followed by satellite telemetry during the 1988 season, after the early failure of a fifth PTT in April (Table 1). One of these animals died on 11 August but was never seen with a calf, and thus is included in the sample. None of the four Mealy Mountain caribou was exposed to low-level jet activity, as these animals did not inhabit the low-level training area and flight tracks indicated that no jets strayed over the area.

Calf Survival

Calf survival was negatively correlated with exposure to low-level flying activity for all periods analyzed (Table 2). This relationship was significant during the calving and immediate post-calving periods (23 May -19 June) for the subset of females known to have calved and was marginally significant (.05 < P < .10) during the calving period for the entire sample of females. The relationship was also significant during both of the summer insect periods. Deleting the Mealy Mountain caribou from the sample did not change the results: Red Wine Mountain caribou still showed significant negative correlations between mean exposure frequency and calf survival during the same four periods.

Five females successfully brought their calves through the entire low-level flying season. Two of these were Mealy Mountain caribou and thus were never exposed to low-level overflights. Of the three successful Red Wine Mountain females, one was never known to have been overflown, another experienced overflights only during the pre-calving period and again briefly during the fall period, while the last was exposed to overflights only during the calving period.

TABLE 2. Survival of caribou calves as a function of exposure to low-level jet training activity during 1987 and 1988

Period	Dates	Sample[a]	N	r_s[b]	r_s^2
Pre-calving	18/4-22/5	All	15	-.252	.05
Pre-calving	18/4-22/5	w/calf	11	-.212	.06
Calving	23/5-05/6	All	15	-.414	.17
Calving	23/5-05/6	w/calf	11	-.567*	.32
Post-calving	06/6-19/6	w/calf	11	-.727*	.53
Pre-insect	20/6-03/7	w/calf	11	-.441	.19
Insect I	04/7-09/8	w/calf	[illegible]	-.653*	.43
Insect II	10/8-15/9	w/calf	9	-.735*	.54
Fall	16/9-20/10	w/calf	8	-.221	.05

[a]All = entire sample of females, w/calf = only those females known to have produced a calf.
[b]Spearman correlation coefficient.
*P < .05

The frequency of exposure that individual caribou experienced throughout the low-level flying season remained relatively consistent for most caribou. For example, the mean correlation for exposure frequency from one period to the next was 0.910. However, changes in the frequency or distribution of jet activity over the season, as well as caribou movements into or away from areas of jet activity, did result in substantial changes for some animals, reducing the overall correlation among periods to 0.694. When the mean exposure frequency for the entire period the calf survived was used, the correlation between calf survival and exposure to low-level flying was not significant (all females: n = 15, r_s = -.312; females known to have calved: n = 11, r_s = -.553; Red Wine females: n = 11, r_s = -.418).

Discussion

We have shown a significant negative correlation between a female caribou's exposure to low-level jet training activity and her calf's subsequent survival. The magnitude of this effect was substantial: during the two calving periods considered, 42% of the variance in calf survival was explained by exposure level to low-level overflights, and for the summer insect periods this proportion increased to 48%. The robustness of our finding is strengthened by the fact that it was shown for each subsample of females analyzed. That this relationship was significant only during the calving and immediate post-calving periods, and again during the summer periods of insect activity, further indicates the biological reality of this relationship. In fact, the lack of a significant relationship during the pre-calving, pre-insect, and fall periods may be as important a finding as the significant relationship during the other periods.

The effects of disturbance on calf survival should vary in magnitude as a function of season. The greatest effects would be expected during critical stages in the animal's development or during periods when other stressors are also acting. The calving period is one such critical period, as disturbance during this period may result in stillbirths, injuries, or cow-calf separations (Banfield, 1974; Cowan, 1974; Miller and Broughton, 1974; Miller *et al.*, 1988). Within a week of birth a calf's lactation demands are greatest (Parker *et al.*, 1990), and any reduction in lactation caused by disturbance (i.e., Ely and Peterson, 1941) may have long-term consequences for growth and survival. In particular, failure to develop sufficiently prior to the onset of the insect harassment season may jeopardize later survival. Reduction in feeding rates, movement to insect relief habitat at the expense of forage quality, the energetic costs of insect avoidance behaviour, and simple loss of blood may increase the calf's susceptibility to other stressors during the summer insect period. For these reasons, significant negative effects of disturbance from low-level overflights would be expected during the above periods and were found.

On the other hand, the calf is well protected *in utero* during the pre-calving period, when most females migrate substantial distances over rugged terrain to calving areas. During the period just prior to the emergence of insects as major pests, the calf is being weaned to solid food, which it may find in sufficient quantity and can eat in relative peace. Finally, during fall the disappearance of insects frees the cow and calf to exploit better resource habitat and forage without disturbance. The short-term effects of low-level overflights may be relatively benign during these periods, as other stressors on the animals have been removed and critical stages have been passed.

The exposure of an individual to low-level flying often did not change greatly during the low-level flying season; correlations among the periods analyzed were relatively high. For this reason, it is unknown whether each of the significant correlations between exposure to low-level flying and calf survival represents an effect from that period or from another period in which exposure frequency was similar. For example, a strong effect during the calving period will also be reflected in every subsequent period in which the distribution of exposure among females remains the same. Thus, the relationship between calf survival and exposure to flying found for the summer insect period could represent a spurious correlation as a result of a real effect from the calving period, coupled with similar exposure frequency during the summer periods. If our data do record such spurious correlations, however, they are more likely to be seen for the latter periods. Correlations seen during the earlier periods are based on a larger sample of animals and thus are not likely to be the result of effects acting later in the season. By the beginning of the summer insect period, one-third of the calves had already been lost, and data from their mothers had been dropped from the analyses.

Born the boundaries of the low-level training area and the topography constrain the distribution of low-level training activity. In particular, areas near the transit corridors leading to CFB-Goose Bay and deep river valleys receive a disproportionate amount of flying activity (Harrington and Veitch, 1990). In our requests for target coordinate overflights in 1987, we found that targets in *some* areas were readily overflown whereas targets in other areas were seldom overflown. This same bias in the distribution of overflight activity was seen in 1988, when pilots were permitted to fly wherever they wished. If an unknown mortality factor, such as predation by wolves or black bears, was distributed in a similar manner (e.g., along valleys, nearer Goose Bay, etc.), the relationship seen between calf survival and overflight frequency may be spurious.

In an earlier, unpublished report of these tintings (Harrington and Veitch, 1990), we used a mean exposure index that was based on the animals' exposure to overflights throughout the entire flying season and found a non-significant negative correlation between overflight exposure and calf survival. Because relative exposure did change throughout the low-level flying season, using a season-long mean exposure index was a serious flaw in our earlier analysis, as the ability to detect important but short-lived effects during sensitive periods was lost.

Management Implications

Through 1987, the Red Wine Mountain population has shown no growth, despite a ban on hunting since 1972 (Veitch, 1990), whereas the Mealy Mountain population has more than doubled during the same period (Hearn and Luttich, 1987), may have been an important factor limiting the growth of the population during that time. The early loss of calves in this study is also consistent with predation mortality, as both black bears and wolves are relatively common in the study area and have been shown to be responsible for three-quarters of the adult mortalities of known cause (Veitch, 1990). In the present study, we have shown that calf survival is also negatively correlated with exposure to low-level flying, which indicates that current levels of training activity may have reached a level where negative impacts on calf survival will become noticeable. Together, the impacts of predators and disturbance from low-level training activity may be preventing the recovery of the Red Wine Mountain population, despite over 15 years of protection from human hunting.

The most conservative conclusion from the results presented here is that calf survival is affected by frequency of exposure to low-level overflights during and immediately after calving. Thus we recommend that calving areas of Red Wine Mountain caribou not be overflown at altitudes below 300 m above ground level during the last week of May and the first three weeks of June. If it is not possible to avoid all areas of the calving range, then corridors of permitted training activity should be designed to minimize the number of females being overflown. In addition, further study of the potential link between low-level flying and calf survival is necessary to firmly establish the relationship and, in particular, to determine its temporal properties.

ACKNOWLEDGEMENTS

We owe a special thanks to Stu Luttich (Regional Wildlife Biologist, Labrador) for all his support and assistance. We are also grateful to the other members of the project's steering committee: J. Hancock, J. Inder, E. Mercer (Newfoundland-Labrador Wildlife Division); A. Noseworthy (Intergovernmental Affairs Secretariat); B. Moores (Environment Canada); C. MacNeil and J. Rowell (Labrador Inuit Association); and their alternates.

We thank the following for their valuable contributions to field work: B. Baikie, D. Baikie, M. Berger, D. Blake, C. Butler, B. Chaulk, B. Dalron, B. Hearn, K. Hoilett, N. Hughes, T. Kent, F. Phillips, H. Supper, R. Trask, and Z. Tooze. We thank the staffs at Sealand (Canadian) and Universal Helicopters, Goose Bay Air Services (Labrador Airways) and Air Northland, and their pilots: H. Blake, P. Bradford, H. Day, C. House, B. Kendall, K. Loder, W. Massie, W. Mitchell, G. Nuttall, G. Penny, B. Raymond, B. Smith, H. Supper, and R. Taylor. We thank T. Downs and his staff (Department of National Defence, Ottawa) for their continued assistance. At CFB Goose Bay, the staff of the Military Coordinating Centre deserve a special thanks, especially Major D. Ghyselinks. We thank the officers, squadron leaders, and operations personnel in the German Air Force, Royal Air Force, and Royal Netherlands Air Force for their cooperation.

D. Decker, J. Russell, and S. Tomkiewicz, of Telonics, Inc., and Service Argos staff in Toulouse, France, and Landover, Maryland, especially L. Morakis and H. Sparks, provided help and advice. S. Fancy, through the Alaska Fish and Wildlife Research Center (U.S. Fish and Wildlife Service) and Alaska Department of Fish and Game, provided computer programs used in the analyses of the satellite data. T. Barrett, R. Kafer, F. Messier and J. Reid provided advice on statistical matters.

Funding and other support for this study were provided by the Newfoundland-Labrador Wildlife Division, the Department of National Defence, the Natural Sciences and Engineering Research Council, and Mount Saint Vincent University.

F. Miller, D. Russell, and an anonymous reviewer provided very

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APPENDIX 3

Russian Taimyr and Norwegian Wild Reindeer and Migration Disruption

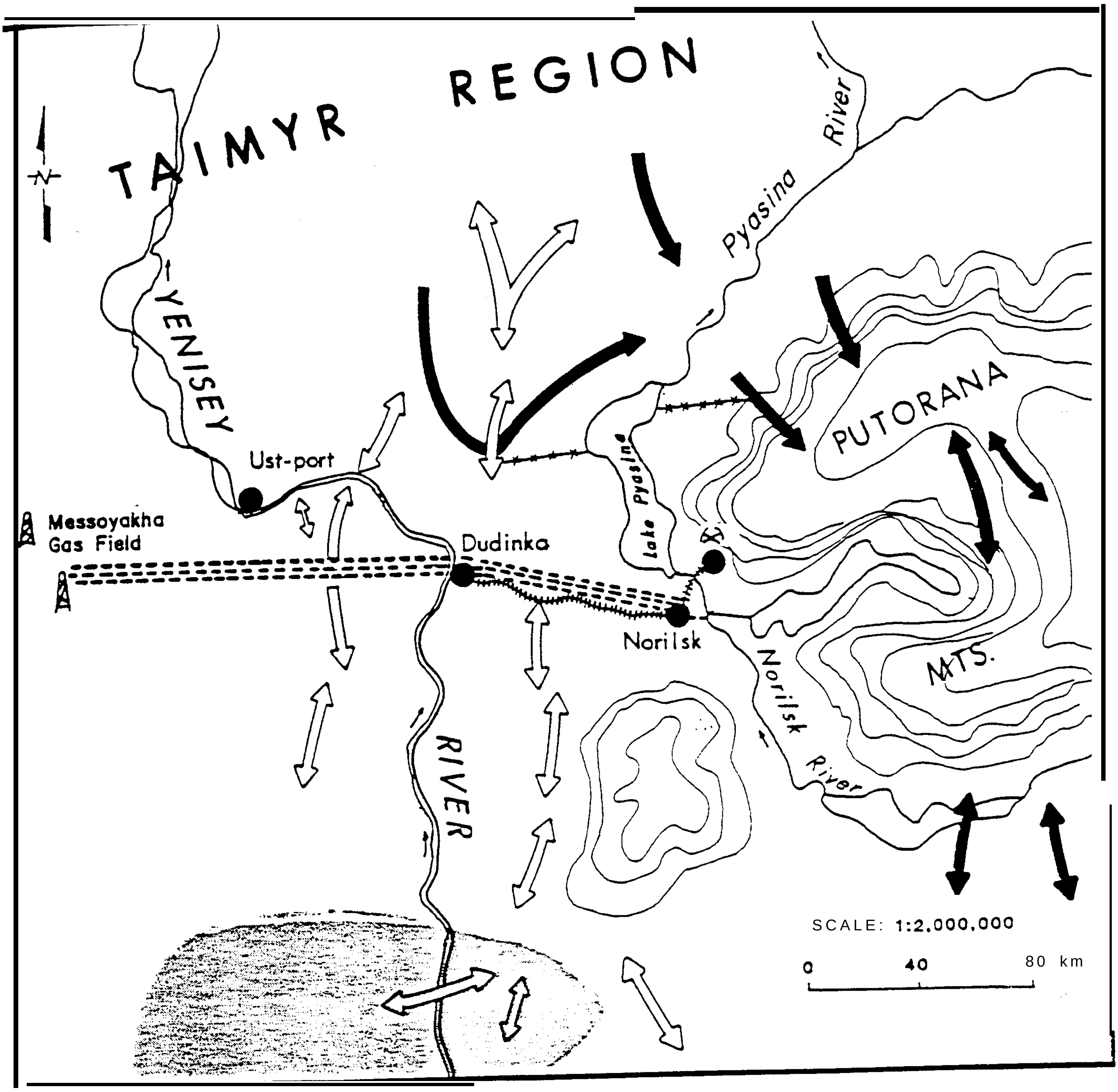


Fig. 5. Caribou Movements and the Norilsk, U. S. S. R., Transport Corridor. (After Jakimchuk 1979; Klein 1984, pers. comm.; V. Lazmakhanin 1985, pers. comm.; Skrobov 1972; Soviet base map courtesy of D.R. Klein)

PIPELINE

RAILROAD

MINES

NATURAL GAS FIELD

TOWN

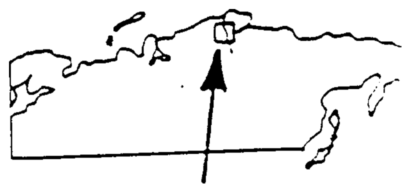
WINTER RANGE PRIOR TO 1969

DIVERSION FENCE (INSTALLED 1974)

MIGRATION ROUTE PRIOR TO 1969

MIGRATION ROUTE AFTER 1969

DIRECTION OF RIVER FLOW



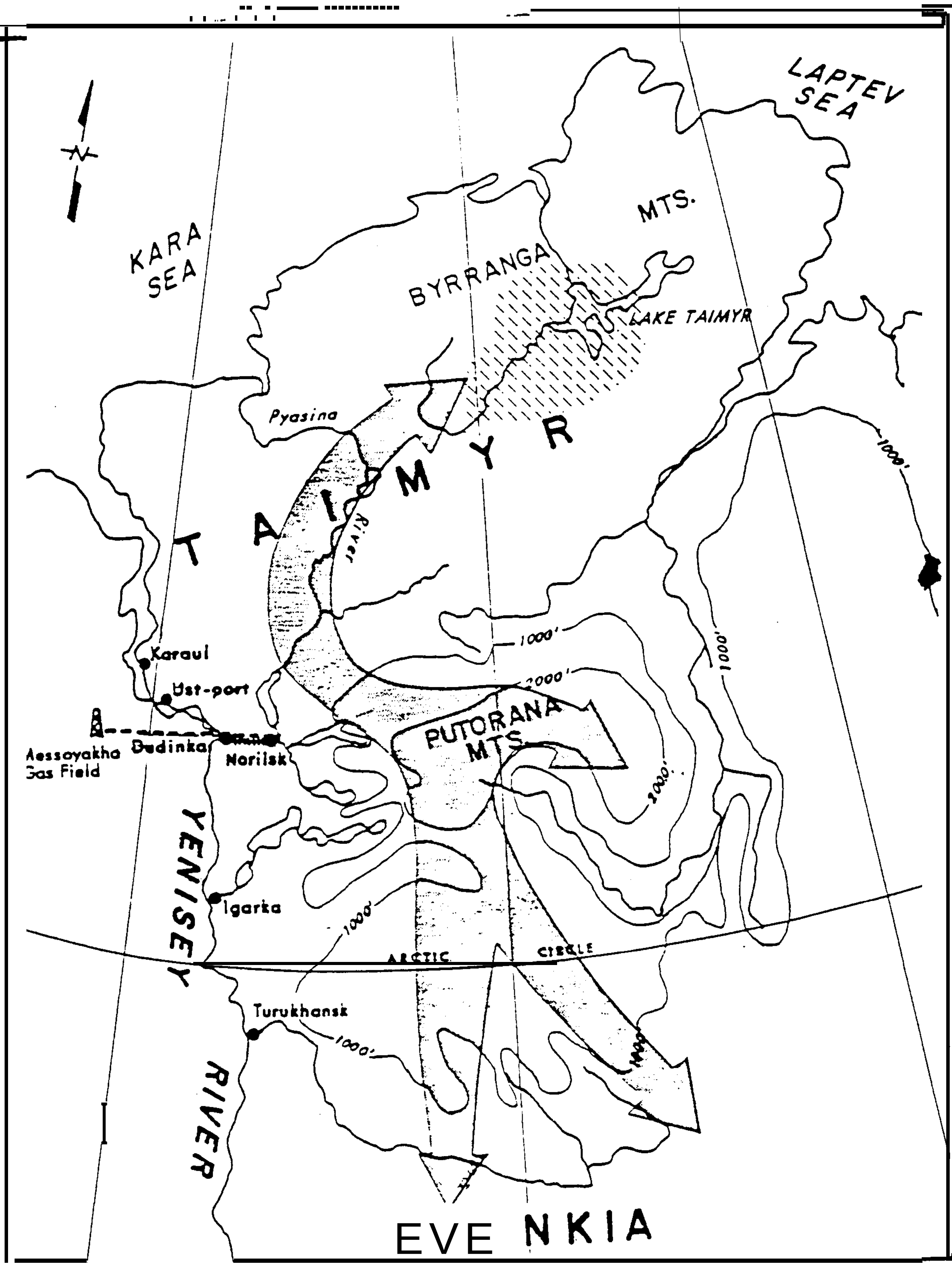
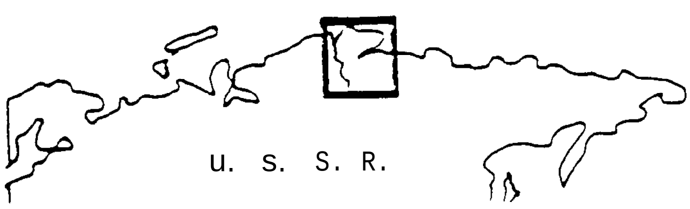


Fig. 4. Caribou **Movements** in the Taimyr Region, USSR.



SCALE: **1:8,000,000**

● TOWNS

----- **PIPELINES**

RAILROAD

GAS FIELD

— 1000' — *1000' MSL*

CALVING AREA

GENERAL MIGRATION

in the short term, it views these factors as less important over the long term. Proponents of this school of thought are likely to view the impacts of a pipeline in terms of access to forage or effects on grazing.

The second school of thought is most thoroughly articulated by Bergerud (1978) and by Bergerud et al. (1984). Proponents of this school of thought feel that habitat relationships in terms of forage availability and utilization are a relatively insignificant factor in North American caribou life history as compared with the effects of predation and human harvest. This school of thought views habitat relationships in terms of predator avoidance, therefore the foremost component of habitat is space—space in which to avoid predators. Proponents of this school of thought are likely to view the impacts of a pipeline in terms of its effects on physically restricting caribou movements so that caribou become less able to escape from predators, or by creating other conditions conducive to increased predation, and by the potential for creating increased access by hunters to caribou .

These schools of thought are not mutually exclusive, and most caribou biologists are philosophically distributed along a continuum between the two schools .

3.1.2 Case Histories

There are two case histories that demonstrate the effects of linear developments on Rangifer. The first case is that of the Norilsk gas pipeline corridor in the Taimyr region of the Soviet Union (figure 4). In this case a gasline corridor disrupted fall and winter migration of wild reindeer, and resulted in deflecting these migrations to adjacent areas. Soon thereafter the reindeer abandoned a portion of their winter range because they were unable to reach it. The second case is that of the Snohetta herd in the Dovrefjell region of southern Norway. In this case a highway and railroad corridor across a wild reindeer range resulted in a cessation of migration between summer and winter range, and eventually in a decline of the population when the animals spent both winter and summer on summer range and overgrazed their range.

In the 1940's an electric railroad was established between the industrial (primarily mining) center of Norilsk and the port of Dudinka, which linked the Kara Sea to the north with the railroad line (figure 5). The Yenisey River was kept open into late fall to Dudinka by icebreakers. This industrial complex is located within the range of the Taimyr wild reindeer herd. In the early 1960's the general pattern of fall migration in this area had been for reindeer to spend the summer in the north near Lake Taimyr, and for the major portion of the herd (several hundred thousand animals) to migrate southeastward to winter ranges in the Putorana Mountains and for a smaller portion of the herd (a few tens of thousands) to move southward across the Yenisey River near Ust'port (figure 5) and generally to the south and west onto winter range (Syroechovskii 1984). In fall of 1967, movements changed so that the majority of the herd moved southward and came into contact with the railroad and road corridor between Norilsk and Dudinka because they had been unable to get across the Yenisey River farther north due to the broken ice and open water caused by ice breakers (Geller and Borzhanov 1984). Many animals drowned in the attempted crossing of the

Yenisey River, or were injured or killed in collisions with trains between Norilsk and Dudinka. Most of the herd moved onto winter ranges into Evenkia (figure 5) or west across the Yenisey River. In spring 1968 the reverse movements occurred, and wild reindeer again came into contact with the railroad corridor where mortality from collisions with trains occurred, and animals wandered through the city of Norilsk in an attempt to circumvent the railroad corridor and the water pipeline between the city of Norilsk and the Norilsk River (ibid.). In fall 1968 a majority of the herd again moved through the Norilsk area—mortality of calves due to drowning while attempting to cross the ice-choked Yenisey River was again documented (Skrobov 1984), and animals were again diverted into the Norilsk area, eventually moving south to the same wintering areas they had used in 1967.

In 1968-69, construction was completed on a 60 cm (24 in) diameter gasline connecting Norilsk with the Messoyakha gas fields located 150 km (90 mi) to the west (figure 5). This pipeline was elevated 1 m (3 ft) above the ground, and paralleled the Norilsk-Dudinka railway corridor for part of its length. No reindeer crossing structures were provided although occasional topographic changes (e.g., ravines) resulted in sections of the line being elevated 2-3 m (6-10 ft) above the ground. The first encounter with the pipeline by reindeer occurred during their spring migration northward in 1969, when tens of thousands of cow groups, after crossing the railroad (which also deflected and halted movements somewhat) encountered the pipeline, and "ran back and forth" until they encountered a ravine or an area of drifted snow where they could cross (Skrobov 1984). Many of the groups would not cross the pipeline, and returned to the railroad track. Many groups deflected westward between the railroad and pipeline until they encountered the port of Dudinka, or until they reached a buried section of the gasline where it crossed the Yenisey River. Although train traffic was limited in order to allow animals to cross, some animals remain stranded into the summer—over 20,000 animals, mostly cows, were still south of the corridor in late May (Klein 1980; Skrobov 1984). Zabrodin (1984) reported that a higher than normal incidence of warbleflies was reported for a portion of the Taimyr herd in 1970, and he attributed this to the fact that reindeer had been delayed farther south than normal because they were unable to get across the Norilsk pipeline.

Harassment because of hunting may have contributed to the disruption of migration. According to Skrobov (1984) "...poaching increases near Norilsk at the time of reindeer migrations. In 1969 ... they had killed 300 reindeer, undoubtedly a very conservative estimate."

In fall 1969, reindeer diverted around the Norilsk-Dudinka area, and did not encounter the pipeline/railroad/highway corridor. Subsequent movements were not as large as those in 1967-68; however, in 1970 a second gasline was constructed parallel and 1 km (½ mi) away from the first. During the period between 1967-70 due to the widespread public reaction and outcry from the Soviet scientific community, the government retrofitted the pipeline with sections of pipe elevated 3-6 m (10-20 ft) above the ground, 75-100 m (225-300 ft) wide and at intervals of 3-4 km (2-2½ mi) in order to provide crossing locations for the reindeer (Klein 1980). Many of the reindeer were still unable to negotiate both pipelines so fences were constructed between the two pipelines to divert the animals from crossings on one pipeline to adjacent crossings on the other. By 1970 the total number of reindeer using the Norilsk-Dudinka area for migration had declined to only several tens of thousands. Only one-quarter of those encountering the corridor managed to cross it--the rest either remained in the area, or diverted through the Norilsk industrial complex. After several years in which many of the reindeer apparently failed to accommodate to the crossing structures, a large wing fence was constructed (presumably in 1974 or 1975) northwest of Norilsk to divert animals completely from the area and into previously lightly used winter range in nearby Putorana Mountains (Klein 1980) (figure 5). This fence, which also utilizes a large lake as part of the barrier, consists of two segments totalling 56 km (34 mi).

Since the wing fence was constructed, the Taimyr herd wintered primarily in the Putorana Mountains and did not migrate across the Yenisey River (Klein pers. comm., 1984). The Taimyr herd has increased to 800,000 animals as of 1985, but does not use the historic winter range along the Yenisey River (V. Lazmakhanin 1985, pers. comm.). Serveral years ago a portion of the herd again deflected into Norilsk during spring[?] migration (ibid.). The population total for the Taimyr herd may also include that of two adjacent herds; however, the Taimyr herd has increased considerably in the past 10 years.

There are several conclusions from the Norilsk case history: (1) the transportation corridor, by virtue of its geographic location, disrupted movements and caused local destruction of winter range (primarily lichen range) prior to the construction of the first pipeline; (2) the gas pipeline initially created a physical barrier to movements, however even after it was retrofitted with crossing structures, many reindeer did not cross the structures and either deflected around the complex entirely, or remained in the area later than the usual season of use; (3) although no widespread direct population effects were observed, mortality due to collision with trains and drowning due to deflections into the Yenisey River, did occur; and (4) physical barriers that were erected to deflect wild reindeer away from the Norilsk area also disrupted their movements to a portion of their historic winter range and this winter range has been abandoned by wild reindeer for the past ten years. In spite of these disruptions the Taimyr herd has had sufficient alternative range available to allow the herd to double in size over the past 10 years.

Bergerud et al. (1984), Jakimchuk (1980), Skogland (1985), and Skogland and Molmen (1980) have summarized the available information about the history of the Snohetta herd of mountain caribou in southern Norway (figure 6). Unless otherwise stated, the following summary is from Skogland and Molmen (1980). Archaeological and biological investigations have indicated that wild reindeer have inhabited the Snohetta region at least periodically since 1100 A.D. Due to the increased use and efficiency of firearms, hunters in the late 19th century reduced wild reindeer to the point that in 1920-25 it was believed that the Snohetta herd numbered only a few hundred individuals. Bergerud et al. (1984) mention that in 1900, the herd numbered 1,000, and that 250 of them were on the Knutsho range and the remainder on the Snohetta range (figure 6). Traditional migration patterns were to winter in the Rondane and Knutsho areas in the eastern portion of the Dovrefjell region, and to migrate westward to the Snohetta area to calving and summer ranges. However, these migrations ceased when the herd was at extremely low numbers

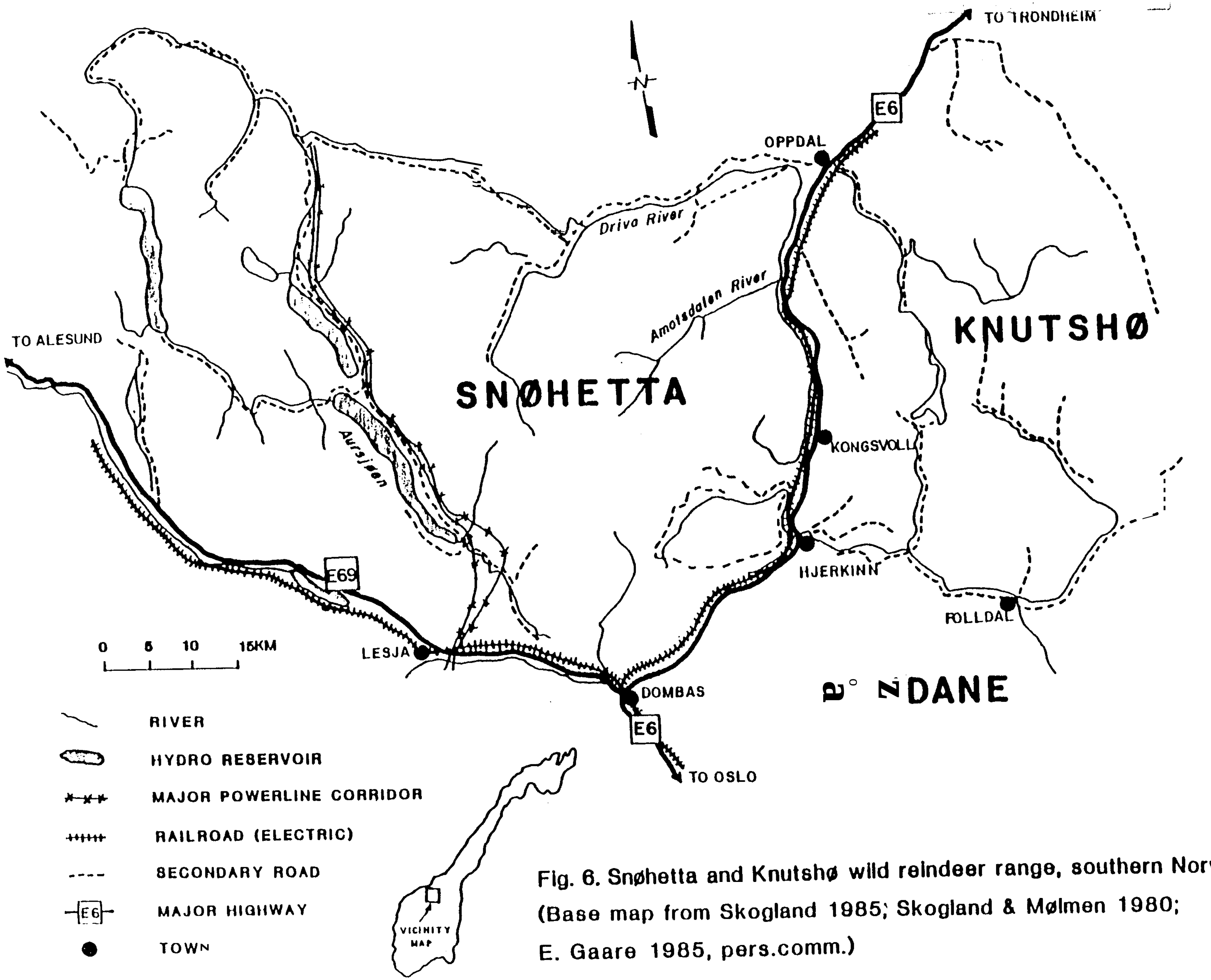


Fig. 6. Snøhetta and Knutshø wild reindeer range, southern Norway. (Base map from Skogland 1985; Skogland & Mølmen 1980; E. Gaare 1985, pers.comm.)

in the 1920's, and the herd remained year-round on the Snohetta range. The literature is unclear about whether or not there were two separate herds, or only one herd entirely on the Snohetta range. In 1921, construction of a railroad across the Dovrefjell began, and continued to the 1930's. During the railroad construction period, no animals crossed from the Snohetta to the Knutsho area. The herd gradually increased [in the 1930's, presumably] so that a controlled hunting program was in place. During World War II, Nazi occupation forces prohibited hunting and the herd increased to 10,000 animals by the 1950's (figure 6 in Skogland and Molmen 1980). Between 1946-53, several large hydroelectric projects flooded much of the calving areas in the Snohetta region, and a series of roads and transmission lines crossed several of the Snohetta calving areas which had been in use even during the early 1900's when the Snohetta herd was at low numbers (figure 6). Reindeer use of some of these calving areas ceased when the areas were inundated but other areas were abandoned because of the increased disturbance to the animals that was caused by activity along roads and by other developments such as powerlines (Skogland and Molmen 1980). During this period (1950's) a road, paralleling the railroad, was constructed across Dovrefjell. By the middle of the 1950's, the Snohetta group numbered 15,000 animals. Marked destruction of lichen range in the Snohetta area was documented. The destruction occurred because not only had animals remained year-round on what had previously been only summer range, but also because the herd had outgrown the available forage even if it had used the Snohetta area only during summer.

During the severe winter of 1956, approximately 200-600 animals moved across the highway and railroad to the eastern (Knutsho) side of Dovrefjell, probably as a result of starvation on the western (Snohetta) side (Jakimchuk 1980). A reduction hunt was initiated in 1960; however, in 1965 winter starvation on the Snohetta range was still high in spite of the fact that the Snohetta group had been reduced to 1,500 animals (figure 6 in Skogland and Molmen 1980), and that approximately one-third of the group had migrated to Knutsho in winter. During the 1960's the road was upgraded, and in the 1970's became a major travel route (E. Gaare 1985, pers. comm.). In 1972, high water in the Driva River along the road/railroad corridor prevented parturient cows on the Knutsho range from migrating to calving areas on the Snohetta range (Jakimuchuk 1980). Since then Knutsho animals have remained on their range to calve. Apparently, a portion of the Snohetta group also now migrates to Knutsho during the winter, crossing the highway at night when traffic is less (E. Gaare 1985, pers. comm.). The situation as of the early 1980's was that a portion of the Dovrefjell reindeer remained year-round in the Snohetta area, a portion summered in the Snohetta and wintered in the Knutsho region, and a portion remained year-round in the Knutsho (Skogland and Molmen 1980). However, for the past 3 winters the entire Snohetta herd has remained year-round on the Snohetta side of the transportation corridor (E. Gaare 1985, pers. comm.).

Skogland and Molmen (1980) conclude that: (1) hydroelectric development in the west and the transportation corridor on the east have acted as "semibarriers" to movements between seasonal habitats; (2) reindeer have been able to adjust to <u>structures</u> associated with the development (e.g., roads, snowfences, and a railroad), however the associated human activity has caused avoidance of many areas as well as disruption of traditional migration routes; and (3) overgrazing and destruction of lichen winter ranges has been caused by the restriction of migration. Bergerud et al. (1984: p. 15) however, argued that "the halt in migration was probably a result of a contraction of the range because the herd's numbers were low." Although Bergerud et al. (1984) may be correct that the construction of the Dovrefjell railroad may not have been directly responsible for the cessation of migration in the 1920's, they do not address the observation that migration to Knutsho did not begin again until the Snohetta group had experienced widespread starvation and a severe winter. Topographic barriers to movements are few along the historical migration routes, and it seems likely that reindeer would not remain in the same area until starvation forced them to move elsewhere unless some other feature of their environment, such as a transportation corridor, were restricting their movements. Furthermore, Bergerud et al. (1984) do not address the fact that use of the traditional calving areas in the western portion of Snohetta had virtually ceased by all but a few bulls after the road and powerline corridors and the hydro reservoirs had been constructed. The evidence points to human developments as being responsible for the herd's decline.

These two cases illustrate that linear transportation systems can disrupt movements between seasonal ranges to the point that utilization of portions of their habitat is eliminated. In the Norilsk case there have been no population effects documented, however this herd is similar to many North American Arctic herds in that wild reindeer densities were very low. The Snohetta case provides evidence of a demographic effect—the herd would have starved because of overgrazing its range if a reduction hunt had not been carried out in the 1960's. Since then animals of the Snohetta herd have been characterized by small body size and reduced reproduction in comparison with the adjacent Knutsho herd, due to the overgrazed condition of the Snohetta winter range (Skogland 1985).

3.2 DIRECT HABITAT LOSS

One immediately visible result of oil field development is the proliferation of roads, drill pads, and pipeline work pads that is necessary to provide access for vehicles and equipment and a stable, all-weather working surface that will support heavy equipment such as drill rigs. On much of the North Slope, pads and roads are constructed of gravel that is placed and compacted directly on the ground, thus destroying the underlying vegetation. Additional vegetation is destroyed when material sites are excavated in order to provide the gravel for roads and pads; however, the greatest amount of vegetation damage or destruction in addition to that covered with gravel is due to temporary or permanent ponding on the uphill side of roads and pipeline workpads when inadequate drainage structures (such as culverts) are placed in these roads or workpads. Walker et al. (1984) have determined that ponding accounts for vegetation loss equivalent to more than one-third that of gravel overlay (cf. table 11, ibid.). Additional losses or changes in vegetation occur when "fugitive" dust from the road systems covers nearby vegetation, or from minor oilspills or unauthorized off-road vehicle travel (bid.).

Although not all plant species or vegetation types are of equal value to caribou, or are even used by caribou, the current oil fields are located in the summer range of the CAH, and many forage species and plant communities are utilized by caribou during this period (White et al. 1975). Therefore,

IMPACTS OF HUMAN DEVELOPMENTS AND LAND USE ON CARIBOU: A LITERATURE REVIEW
Volume II: Impacts of Oil and Gas Development on the Central Arctic Herd

by

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Technical Report No. 86-3

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January 1986

APPENDIX 4

Red Dog Mine Monitoring Plan

CARIBOU MONITORING PROGRAM

Presented below are portions of the Red Dog Mine project caribou monitoring plan which provides methods for monitoring caribou movements, guidelines for restrictions of road traffic and options for minimizing adverse effects on caribou movements, This plan has been accepted by NANA, Cominco Alaska, Alaska Department of Fish and Game plus the National Park Service for monitoring caribou which migrate through the area,

Each year a major migration occurs after the calving period; calving occurs approximately 100 roles north of Red Dog along the head waters of the Colville, Ketik, Meade and Utukok Rivers from late May through mid-June. Some caribou may disburse across the North Slope, while others travel on a counter-clockwise movement west and south toward Cape Thompson and then eastward into the Brooks Range, where the animals move onto summer ranges in the mountains and onto the Arctic Coastal plain. In some years, the post-calving movements extends as far south as the Wulik River. This movement would normally not reach Red Dog.

Few caribou remain in the Red Dog area in summer. Most of the herd remains north of the Brooks Range until fall. Fail migration is a leisurely movement that may reach the Noatak River or Mulgrave Hills any time from August through October, A majority of the Western Arctic herds moves southward on migration routes far to the east of Red Cog, but in some years, large numbers of caribou winter north of the Brooks Range.

Potions of the Western Attic Caribou Herd spend the winter southeast of Kotzebue and some of the herd may occur as far east as the Alatna-Bettles area or as far south as the Yukon River delta. A small segment of the herd has, in recent decades, wintered in the Mulgrave Hills and the adjacent drainages of Wulik and Kivalina Rivers. Bands of several thousand caribou may occur along the DMTS read at anytime.

CONCLUSIONS

The Red Dog facilities and DMTS road are south of recorded post-calving migration areas.

- The DMTS road is in an area of irregular fall migration but may experience large numbers of caribou in years of use.
- The DMTS road traverses a caribou wintering area that may be used by several thousand caribou each winter.
- The port site should be without caribou during the ice-free period each year.
- The mine site will have occasional caribou, primarily bulls and yearlings, during summer months.
- The primary period of concern for monitoring caribou movements is from August through October, in years of major fall coastal migrations. This coastal migration has occurred only four times in the past 20 years, according to the ADF&G records.
- Traffic levels are not anticipated to cause serious impact to overwintering caribou along the road system. Road traffic from the mine will consist of, at a minimum, concentrate haul trucks, pick-up trucks and road maintenance vehicles. Operations traffic is also not anticipated to cause serious impact to overwintering caribou.

- Road traffic may need to be stopped or carefully controlled if a large number of migrating caribou approach the road.

In order to assure adequate advance notice of caribou migration approaching the project area, the following program will be initiated:

1. In years when caribou migrate southward near the coast in the fall, they may pass Point Hope and Kivalina prior to reaching the DMTS road. It is also possible that large numbers of caribou could approach the road from inland rather than the coast, in some years. The scheduled fall aerial survey conducted between August and October, by the Project Caribou Specialist and independent surveys by cooperating agencies should identify any evidence of unusual migrations. However, to assure major movements are not missed, the NANA Subsistence Committee has assigned one person from the villages of Kivalina and Noatak to monitor local caribou movements. These representatives will alert either the NANA Land Manager of Mine General Manager and/or the Project Caribou Specialist by telephone if there is any significant caribou activity in the project area from August through October. The General Manager will also alert truck drivers on the road to report any caribou activity near the road or other project facilities.

2. The winter aerial survey will confirm total numbers ant! composition of caribou in the project area. The Subsistence Committee representatives from Kivalina and Noatak, plus truck drivers will alert the General Manager and Project Caribou Specialist of any unexpectedly large concentration of caribou near the project area.

3. Post-calving migrations have not been known to extend south of the Wulik River and should not result in road traffic restrictions, An aerial survey will be conducted during post-calving migration each Year to determine if any unusual movements are anticipated. Personnel are instructed to notify the General Manager and the Project Caribou Specialist of any significant migration activity.

4. Special aerial surveys will be flown, as required, whenever there is a potential for road restrictions,

5. **Whenever a major** caribou migration has been identified and toad restrictions appear warranted, an acrid survey will be conducted to estimate when caribou would be within 15 miles of the haul road. Once the proximity of caribou to the road *occurs,* a final decision on read restrictions will be made.

6. An Annual Monitoring Report with caribou distribution maps will be provided to Cominco, NANA, Alaska Industrial Development and Export Authority and cooperating agencies by **the** Project Caribou Specialist. The report will include starting dates and duration of surveys as well as an explanation of the method employed to conduct the caribou survey,

PROCEDURE FOR IMPLEMENTING ROAD RESTRICTIONS

The purpose of the caribou monitoring program is to provide information on caribou movements that Is necessary to determine when road traffic restrictions may be needed **to minimize** or prevent **adverse effects on caribou** migration and distribution patterns during road construction and operation.

The NANA and the NANA Subsistence Committee are concerned about providing for uninterrupted movement of the lead bands of caribou during fall migration. For the many years in which village elders have observed and hunted caribou, they have observed that there are lead animals, and if these animals are allowed to pass then the remaining caribou will be more likely to follow.

The Alaska Department of Fish and Game (ADF&G) and NPS are concerned that all migrating caribou be allowed free passage through the developed corridor, The primary objective of a traffic restriction program is to minimize the obstruction and disturbance of migrating caribou so that natural migration and distribution patterns can be continued,

STEP 1 - SIGNIFICANCE

Caribou movements in or near the project area will be detected by the methods described above. However, in each case, it maybe necessary to judge whether or not the observed caribou movements are the result of local feeding activity (as observed in recent winters in the Mulgrave Hills) or is part of a major caribou migration.

A movement would be considered significant and require special action if it:

- involved more than 2,000 animals;
- was occurring within 15 miles of the road system;
- would intercept the road system; and,
- is clearly a migration and not just local feeding activity.

STEP 2- NOTIFICATION

If there is potential for inhibiting free passage of caribou based on the above criteria, it will be necessary to immediately notify the General Manager, or the NANA Land Manager. The NANA Land Manager will then inform the Project Caribou Specialist and other members of the Caribou Monitoring Team. However, it will be the prerogative of the General Manager to take immediate action to prevent unnecessary impacts to caribou movements and to notify the Caribou Monitoring Team as soon as possible of the corrective action.

STEP 3- NOTICE OF ALERT

If the General Manager and/or the Caribou Monitoring Team determines that a major caribou movement is likely to cross the road corridor, within 24 hours, a "Notice of Alert" will be issued. The "Notice of Alert" will be provided to truck drivers, equipment operators and other employees using the road and will inform them of the impending road crossing by caribou, the estimated time of caribou arrival, and a request they immediately notify the General Manager when caribou are observed approaching the road system.

STEP 4- OPTIONS FOR ROAD RESTRICTIONS

Based on the information at hand, the NANA Land Manager and the General Manager, with due consideration of the recommendation of the Caribou Monitoring Team, will determine the traffic restrictions to be applied to allow free passage of caribou across the road corridor.

Traffic or construction restrictions will depend on the number, speed ant! direction of caribou movements. Options will include but not be limited to:

- limit nonessential road traffic;
- limit road maintenance traffic;
- convoy road traffic;
- alternate closures and opening of road traffic; and,
- road closure.

Specific guidance for application of these options maybe provided by the Project Caribou Specialist.

STEP 5- INITIATE ROAD RESTRICTIONS

Traffic restrictions will commence prior to migrating caribou approaching within three miles of the road and will be in effect on that potion of the road within one mile on either side of where the caribou are crossing. Traffic restrictions will be in force until caribou have crossed the road. The initial restriction option can be changed if necessary, depending on the number, speed and direction of caribou remaining to cross the road. The Caribou Monitoring Team and AIDEA will be notified of changes in traffic restrictions.

STEP 6. DURATION OF RESTRICTIONS

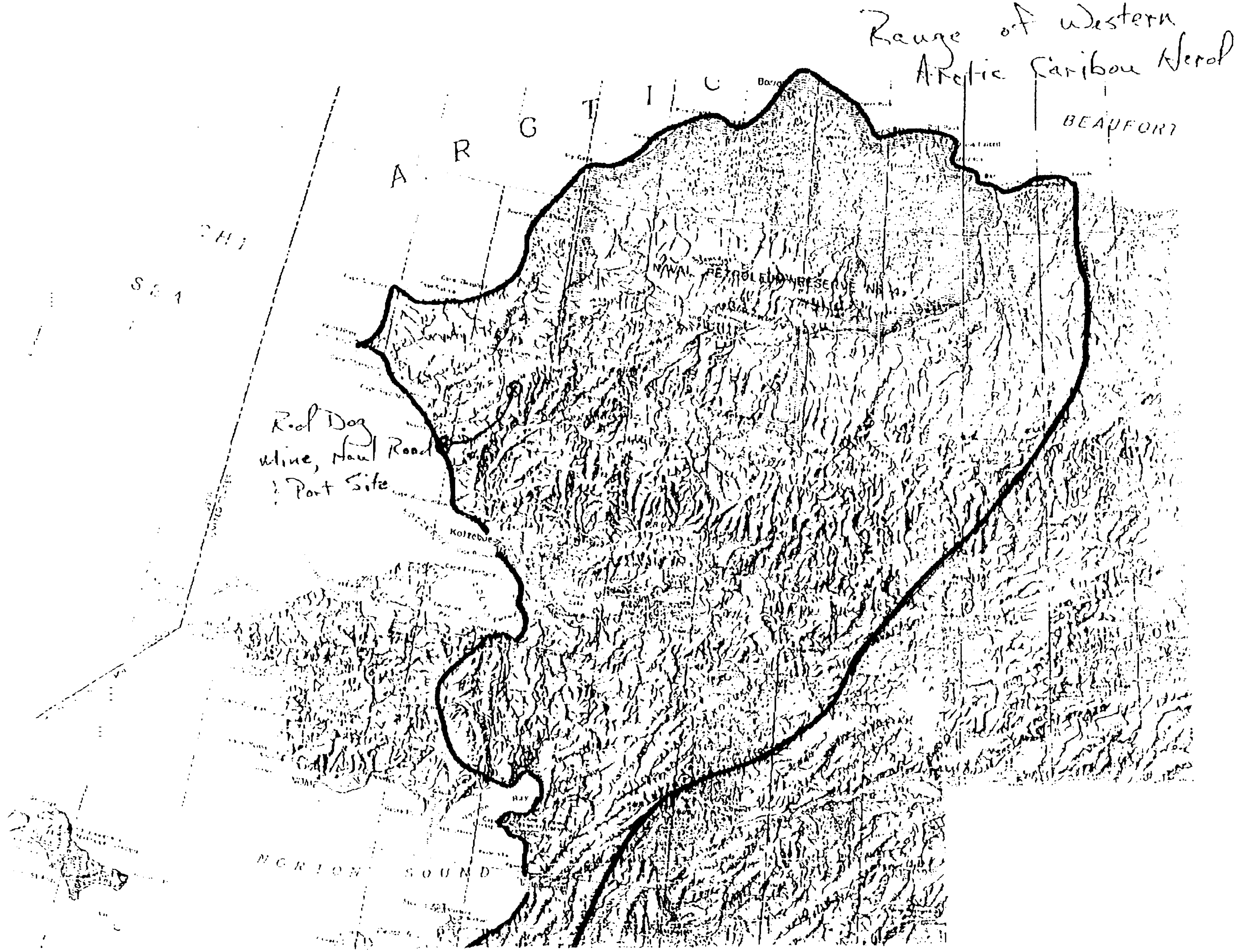
Once caribou have been allowed to cross the read, the General Manger with the concurrence of the NANA Land Manager, or the designated NANA representative, will lift the restrictions on road or construction traffic.

DISAGREEMENT

In the *event of* a disagreement about a road restriction, remedy can be sought by the affected agencies as outlined in Exhibit B, Section E of the Cape Krusenstern Land Exchange Agreement. In part, this subsection states that in the event of disagreement between NANA, ADF&G and the NPS concerning the imposition of such restrictions, the fins.f determination shall be made by NANA, except that ADF&G shall be able to go to court if NANA proceeds with the Caribou Monitoring Program as defined by this Section of the Agreement, without receiving ADF&G's approval of the specifications of the contract or the selection of the contractor, or if NANA proceeds with restrictions on construction or control of traffic on the system without having given due consideration to the view of ADF&G; provided further, however, that the NPS may file suit to compel NANA to adopt the restriction recommended by the NPS when significantly adversa impacts are deemed likely to result from construction or vehicular activities.

Any judicial proceeding initiated by the United States in accordance with the procedures herein to compel NANA to adopt the restrictions recommended by the NPS shall be de novo and the burden shall be on the United States to establish that significantly adversa impacts are likely to result from construction or vehicular activities if the restrictions are not adopted.

5-year re-evaluation


Range of Western
Arctic Caribou Herd
Red Dog
Mine, Haul Road
& Port Site
ARCTIC
BEAUFORT
CHUKCHI SEA
NAVAL PETROLEUM RESERVE NO. 4
Kotzebue
NORTON SOUND

APPENDIX 5

Resume for Anne Gunn

ANN GUNN

Education:	B.A. (Hens. Natural Science), 1970 University of Dublin, Ireland Ph.D. 1973 University of London, U.K.
Current employer:	Government of the Northwest Territories Department of Renewable Resources 600, 5102-50 Avenue Yellowknife, NWT Canada XIA 3S8
Positions held:	
Caribou Biologist	Jan. 1993- present Yellowknife
Kitikmeot Regional Biologist	Aug. 1984- Jan. 1993 Cambridge Bay and Coppermine
Environmental Assessment Biologist	Aug. 1983- Aug. 1984 Yellowknife
Caribou Biologist	Nov. 1979 - Aug. 1983 Yellowknife
Previous employer:	Canadian Wildlife Service (1973 - 1979) Research Scientist, Biologist and contracts (caribou and muskoxen, controlled burns and toxicology).

Work experience, skills and abilities:

Since 1979, most of my work experience has been the different facets of muskox and caribou management, population dynamics and ecology. Those studies have depended on a close working relationship with Inuit hunters and as well I have led cooperative programs with federal agencies to investigate caribou responses to oil and mining developments. Other cooperative inter-agency programs led to the national classification of Peary caribou as “Endangered” and the establishment of an inter-agency Recovery Team which I chair.

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