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Editors:

Doug Heard and *Mark Williams*

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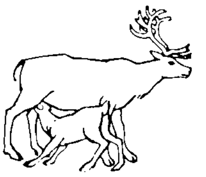

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Proceedings of the Fifth North American Caribou Workshop.

Content **Page**

Status of woodland caribou in western north America

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Abstract: A review of current population size and trends of woodland caribou *(Rangifer tarandus caribou)* in seven jurisdictions in western North America shows a wide range of situations. A total maximum population estimate of woodland caribou west of the Ontario/Manitoba border is 61,090. Of 44 herds or populations described in this review: 14 are stable; two are stable to slightly decreasing; four are decreasing; four are increasing; and 22 are of unknown status. Caribou are classified as a threatened species in Alberta and as an endangered species in Washington/Idaho. The decline of caribou in North America following settlement (Bergerud 1974) has continued along the southern edge of woodland caribou distribution. Direct loss of habitat to logging, mines and dams continued throughout the 1960's, 1970's and 1980's. The secondary effects of these habitat changes, (i.e. increased roads leading to increased hunting and poaching, and increased early succession habitat leading to increased alternate prey/predator densities) has led in some cases to the total loss or decreased size of local herds. Three ecotypes of woodland caribou are described and their relative distribution delineated. These ecotypes live under different environmental conditions and require different inventory and management approaches. Woodland caribou herds in northern B.C., Yukon and N.W.T. generally are of good numbers and viable (stable or increasing), and management primarily is directed at regulating human harvest and natural predation to prevent herd declines. Land use activities such as logging or energy development are not extensive. Managers in southern caribou ranges stress the need for a better understanding of caribou population stability within mixed prey/predator regimes; how habitat changes (eg. through logging) affect these regimes; and how to develop effective land use guidelines for resource extraction that can sustian caribou populations and maintain resource industries. Caribou managers have suggested that herds may be priorized for research and management efforts. Unstable, remnant populations may be left to their own fate. The limited research dollars available and difficult management decisions should be applied to caribou herds that are apparently sustainable and provide the greatest potential for long-term viability.

Keywords: woodland caribou, population site, trend, ecotype, populations, population dynamics.

Rangifer, Special Issue No. 7: 91—107

Introduction

Woodland caribou *(Rangifer tarandus caribou)* generally do not form very large aggregations but tend to be dispersed at low densities throughout their range. This does not imply that they never aggregate, as most studies of woodland caribou have shown seasonal changes in group size. However in comparison to barren ground caribou *(Rangifer tarandus groenlandicus)* or Alaskan caribou *(Rangifer tarandus granti),* woodland caribou are more dispersed, particularly at calving time, and their seasonal movements are not as extensive. As well, I believe that woodland caribou in western North America fall into three ecological variants or ecotypes (Figure 1):

1. mountain/terrestrial ecotype inhabits mountainous terrain where moderate snow depths allow for primary winter foraging on terrestrial lichens.
2. mountain/arboreal ecotype inhabits mountainous terrain where deep snow necessitates primary winter foraging on arboreal lichens, and
3. boreal ecotype inhabits fens, muskegs and jack pine or lodgepole pine habitats of the boreal forest (primarily terrestrial lichen for winter diet).

Table 1. Population estimates of woodland caribou for 7 jurisdictions in western North America for 1979, 1985 and 1991 (population estimates are maximums).

Year of estimate	Jurisdiction							Total
	Manitoba	Saskatchewan	Alberta	British Columbia	B.C./Wash./ Idaho (Selkirk Herd)	Yukon	NWT	
1971[1]	3,600	<··········5,000··········>		10,000	25	14,700	10,000	43,325
1985[2]	5,000	2,500	3,000	5,700[3]	30	26,500	5,000	47,730
1991	2,000[4]	2,500	3,300	17,000	60[5]	26,230[6]	10,000	61,090

[1] Bergerud, A.T. 1980. Status of *Rangifer* in Canada. 1. Woodland Caribou *(Rangifer tarandus caribou). In* Proceedings of the 2nd International Reindeer/Caribou Symposium, Røros, Norway, 1979. Direktoratet for vilt og ferskvannsfisk, Trondheim, Norway. pp 748-753.

[2] Williams, M.T. and D.C. Heard. 1986. World status of wild *Rangifer tarandus* populations. *In* Proceedings of the Fourth International Reindeer/Caribou Symposium, Whitehorse, Yukon, 1985. *Rangifer*, Special Issue No. 1, 1986. pp 19-28.

[3] This does not reflect a 50% decline but is more likely the result of incomplete data from the Prince George, Kamploops and Fort St. John/Fort Nelson Regions.

[4] Does not include large tundra associated herd (Pen Island herd).

[5] This herd has been augumented with 60 caribou transplanted from central B.C. since 1987.

[6] Three herds that range across the Yukon/Northwest Territories border are included in Northwest Territory estimate (would increase the Yukon estimate by 10,000).

Stevenson and Hatler (1985) describe two ecotypes for British Columbia; a northern ecotype and a mountain ecotype which are the mountain/terrestrial and mountain/arboreal ecotypes, respectively. This distinction does not imply subspecies differences but recognizes the different adaptations to habitat variation by woodland caribou in western North America. Inventory and management of these woodland caribou ecotypes may vary, as well as the impact of industrial development on their habitat and population parameters.

In this paper, I discuss the population status and distribution of woodland caribou in Manitoba, Saskatchewan, Alberta, British Columbia, Idaho, Ykon and N.W.T. A brief description of woodland caribou status is pesented by jurisdiction and summary of the concerns expressed by caribou biologists for the future viability of woodland caribou in western North America. Information was provided by caribou biologists and managers from each jurisdiction and their assistance was greatly appreciated. More information was provided than can be covered in the main text of the paper. Therefore, a more detailed synthesis of this information is presented in Appendix 1 to 6 and the person providing the information acknowledged.

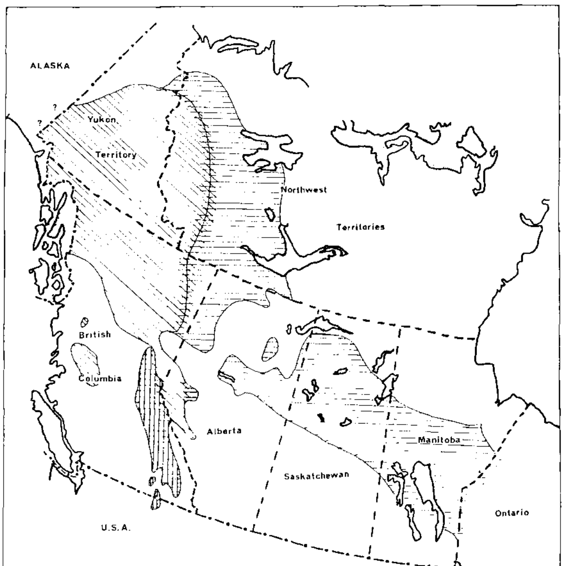

Fig. 1. Mountain/Terrestrial Ecotype
Mountain/Arboreal Ecotype
Boreal Ecotype

Past

It is generally accepted that woodland caribou numbers have declined throughout North America following settlement. Bergerud (1974) attributes much of this decline to overhunting and increases in predation. Habitat changes in the southern portions of caribou range due to logging, clearing and fires resulted in an increased abundance of deer and moose with corresponding increases of wolves and greater predation related mortality of caribou.

In the last half of this century the decline in numbers and distribution of woodland caribou along their southern range has continued though perhaps slowed somewhat. Again, overhunting associated with the increased access has been strongly implicated in these declines. As well, expansion of moose and deer in response to changes in caribou habitat has resulted in increased predator numbers and a corresponding decline in caribou numbers. Bergerud's (1980) assessment of woodland caribou status in Canada noted these factors for some of the herds in British Columbia. He estimated the population of woodland caribou west of the Ontario/Manitoba border to be 43,300. Williams and Herd (1986) in their assessment of the world status of wild *Rangifer*, estimated 47,700 woodland caribou west of the Ontario/Manitoba border. Table 1 shows changes in population estimates that have occurred between 1979 and 1990 by jurisdiction.

Current

Table 2 provides a summary of caribou population estimates and status by jurisdiction and some information for judging the estimate's reliability. Detailed information for each jurisdiction is provided in Appendices 1 - 6. A brief summary by jurisdiction follows.

Manitoba

Woodland caribou number about 2000 and occur in the central portion of Manitoba. Population estimates are based on aerial surveys and occasional observations of herds by departmental staff during winter. This population estimate is lower than previous estimates (Bergerud 1980; Williams and Heard 1986) and may reflect that the 1991 estimate does not include two large northern herds that behave like barren-ground caribou. Presently funding is low relative to other species for inventory programs but co-operative work with industry may improve this situation.

Sport harvest (20-25 animals annually) and subsistence harvest (50 animals annually) are low. Increased access related to resource extraction is a concern with respect to hunting. Predation by wolves is not considered to be a major problem in winter ranges, but wolves and black bears may be a factor on summer ranges or while travelling to summer ranges. Crichton (pers. comm.) expressed a concern that white-tailed deer infected with meningeal worm *(Parelaphostrongylus tenuis)* may invade caribou range, in response to habitat alteration from logging or fire. Recent mild winters appear to be associated with increased sightings of deer further into caribou range.

Presently, habitat is not a limiting factor. Where timber harvest is planned in caribou habitat there is a recognized lack of information about individual herds that can allow wildlife managers to provide meaningful input to forest management planning. Co-operation between the forest industry and wildlife interests is apparently good and a concerned, informed public supports the goal of maintaining woodland caribou in Manitoba.

Saskatchewan

Kelsall's (1984) population estimate of 2500 woodland caribou in Saskatchewan still holds. The herds are believed to be stable though localized, remnant herds along the southern boundary of distribution may not be recoverable. This population estimate is primarily based on incidental observations during aerial surveys, interviews, hunter and trapper reports. Caribou numbers and distribution have declined in the past 25 years along the southern portion of woodland caribou range. This decline was coincident with a northern expansion of agriculture and logging and overhunting of local bands (Trottier 1988a, 1988b).

Sport hunting was closed in 1987 with a commitement to the sportsmen of Saskatchewan to derive a provincial population estimate and a management plan for the species. To date the assessment work only has been done, i.e. literature reviews, habitat loss to fire and logging and a few aerial surveys (Rock 1988). Operating funds for inventory or research are minimal.

Caribou have traditional been a low priority species for management dollars and manpower. T. Rock (pers. comm.) believes that woodland caribou populations in Saskatchewan are still viable but that management of portions of the boreal forest for caribou only (i.e. not for moose or deer) is required to ensure their future viability. Changes in the pulp industry and a depressed mining industry has resulted in a recent moderation in road building and habitat loss.

Alberta

Current population estimate for woodland caribou in Alberta is 3300. Caribou sport hunting was closed in 1981. In 1985 a review of past and current knowledge of caribou numbers and distribution, and an assessment of future vulnerability of their habitat to logging, oil and gas activity and coal mining resulted in woodland caribou in Alberta being designated a threatened species.

Table 2. Woodland caribou population estimates by jurisdiction in western North America, based on most current surveys or assessment.

Jurisdiction	Population estimate	Status	Time period of Data collection	Notes
1. Manitoba	2000	stable	1970-1990	Population estimate is based on aerial surveys and incidental observations.
2. Saskatchewan	2500	unknown	1985-1990	Population estimate is based on incidental sighting information and a few localized surveys.
3. Alberta	3300	west central Alberta herds appear stable; rest of Alberta, status unknown	1980-1990	Caribou are classified as a threatened species. Population estimate is based on old (1975 to 1983) and sporadic transect surveys, except in west central Alberta where a population estimate of 300-400 is based on annual total count surveys conducted since 1981 (mount/terrestrial ecotype).
4. Selkirk herd	50-60	stable to slightly decreasing	1983-1990	Caribou are classified as an endangered species within U.S. jurisdictions. Transplants to this herd from central B.C. have occurred since 1987.
5. Yukon Territory	20,400-26,230*	of 18 recognized herds, five are stable, two are increasing, three are declining and eight have unknown status	1977-1990	Ten of 18 herds have been inventoried in the past 5 years or are currently being inventoried using total count or extrapolation survey methods.
6. Northwest Territories	7,000-10,000	stable or unknown	1990	No research studies or inventory of woodland caribou have been conducted in N.W.T. The population estimate is a guess and is an estimate for the Mackenzie Mountains area only.
7. British Columbia	13,800-17,000	Mountain/terrestrial ecotype - stable Mountain/arboreal ecotype - stable to decreasing	1980-1990	Population estimate is improving but is still based on a variety of methods from repeated aerial surveys to a guess. Some overlap of B.C. and Yukon herds in the northwest.

Total 49,050 - 61,090

*Three herds that range across the Yukon/Northwest Territories border are included in the Northwest Territories estimate.

Caribou inventory and management studies were minimal to non-existent in Alberta until 1980, when intensive long-term studies of caribou (mountain/terrestrial ecotype) in west-central Alberta began. In 1990, with large areas of forest land allocated for new or expanded pulp mills and renewed intensity in petroleum and natural gas exploration and development, the Alberta Fish and Wildlife Division began baseline studies and inventory of caribou in northern Alberta. This data collection comes late as meaningful input to develop timber harvest guidelines, and access and seasonal activity plans for petroleum and natural gas activity is needed now. «Adaptive» management programs will be implemented and their success or failure is dependent upon adequate monitoring of caribou response to management guidelines.

As inventory begins throughout caribou range in Alberta, we may find more caribou and our present population estimate may rise. However, the threat to caribou habitat remains serious and maintaining population levels will be difficult.

Yukon

Yukon presently estimates a woodland caribou population of 27,400 to 36,200 (this includes herds that overlap with the Northwest Territories). Ten of 18 recognized herds have been surveyed (either total count or extrapolation method) in the past six years. Remaining herd estimates are based on surveys or guesses. Of the 18 herds, five are stable, two are increasing, three are declining and eight have unknown status.

Prior to 1980, little was known and little done to learn about woodland caribou herds in the Yukon. Since 1980, studying and managing woodland caribou has become a substantial component of Yukon's big game management program. As woodland caribou are considered to be a very important resource to the Yukon public, this situation is likely to continue if not improve.

Long-term study and intensive management of one herd, the Finlayson Herd, is a key part of caribou management, providing additional knowledge to better assess to continual baseline inventory studies of other herds (Farnell and McDonald 1987).

The Selkirk population - Washington, Idaho and British Columbia

The international boundary Selkirk population was estimated to number 100 to 200 animals from 1900 to 1950. By the 1970's and early 1980's the population had declined and apparently levelled of at about 25-30 animals. This herd, designated and endangered species in 1984 has received considerable managment attention in the past 20 years. This has included a 20 year moratorium on logging remaining old-growth cedar/hemlock forest in caribou range. From 1987 through 1990 the herd was augmented with 60 caribou from central British Columbia. This agumentation effort is currently being evaluated with no final determination of success or failure. Preliminary information suggests that predation may be having a significant impact. Information on the status of this herd was provided by B. Compton, Idaho Fish and Game, Bonner's Ferry, Idaho.

British Columbia

Presently, B.C. has 13,800 to 17,000 caribou, of which 88% (12,000 to 15,000) are described as the mountain/terrestrial ecotype distributed primarily in the northern third of the province. There is some overlap of population estimates for caribou herds along the Yukon border in northwestern B.C. The mountain/arboreal ecotype number about 1900 to 2000 and are distributed within southeastern British Columbia. This is an increase over the estimate of 1450 reported by Stevenson and Hatler (1985). This increase is largely due to improved inventory rather than a substantial biological increase (Stevenson pers. comm).

The mountain/terrestrial herds appear to be stable with predation being the primary limiting factor. Hunting consists of bull or trophy bull seasons only. Caribou in the northwest areas are presently little affected by logging or mining but caribou range in northcentral and northeastern areas are presently being logged or will be logged in the near future. Oil and gas development and mining also impact caribou range in northeast British Columbia. It is expected that caribou numbers will decline where extensive logging occurs on their winter range.

The caribou herds of the mountain/arboreal ecotype vary considerably with respect to status. The southern herds have declined in both numbers and distribution since historic times but in recent decades this decline has slowed and most herds are described as stable. Hunting is closed in many areas or is on a limited entry/bull only basis. Fire suppression has helped to maintain old-growth habitat but logging of critical winter habitat continues to be the primary concern.

Mountain/arboreal caribou in central B.C. appear to have increased since the 1970's. The Quesnel caribou herd is a well documented exception and has declined dramatically due to wolf predation. Predation levels have increased due to a recent increase in wolf numbers (Seip in press). Mountain/arboreal herds in the Prince George area have increased since the 1970's but long term viability of these herds is of concern as timber harvest encroaches on the old-growth arboreal-lichen forests of their winter range. Hunting seasons are closed, except for the Quesnel herd, where an open bull season has an average harvest of two.

Northwest Territories

Any population estimate of woodland caribou in N.W.T., past or present, is a guess based on local knowledge. The maximum population estimate of 10,000 is for the Mackenzie Mountains herds (mountain/terrestrial ecotype?) which also range into Yukon Territory. Numbers of woodland caribou within the boreal forest is unknown. No research or inventory programs are planned for the future.

Woodland caribou populations receive low hunting pressure (sport and subsistence combined). Industrial activity and its associated access within woodland caribou range is minimal and is not expected to increase dramatically in the future so harvest levels should remain low. If increased access does occur, opportunistic hunting could increase. However, this situation may be tempered with falling fur prices and rising fuel costs, leaving local people with less reason to be on the land. The future of woodland caribou populations in N.W.T. looks healthy.

Comments

Since the reviews of woodland caribou population size by Bergerud (1980) and Williams and Heard (1986), it appears that numbers in western Canada have increased, primarily in northern British Columbia and Yukon. Some of this increase is based on incomplete data from northern British Columbia in 1985, however improved inventory in both of these areas appears to be the main reason for increased estimates. Total numbers in Alberta, Saskatchewan and Manitoba have remained about the same. Should inventories begin in the Northwest Territories it may prove that the estimate of 10,000 is indeed a conservative one. Yukon, Northwest Territories and northern British Columbia appear to hold the most numerous and possibly most viable populations of woodland caribou in western North America.

The boreal regions of northern Alberta, Saskatchewan and Manitoba presently have low numbers of caribou thinly scattered (boreal ecotype). Along the southern edge of distribution, herds are vulnerable to increasing resource exploration and development.

Managers in northeastern British Columbia, most of Alberta, Saskatchewan and Manitoba need baseline inventory data on herd size, status and range delineation to provide meaningful input to land use planning in caribou range. The affects on caribou populations of increased access, changing predator/prey relationships and loss and recovery of lichen producing habitat will be or should be assessed as resource exploitation activities progress into caribou range.

The mountain/arboreal ecotype of southern British Columbia has decreased in distribution and numbers since historic times but that decline has slowed in recent decades. However, as low elevation timber supplies diminish, the need to keep mills operating will require greater exploitation of remaining caribou habitat. All the problems associated with logging, increased access, direct loss of habitat and changing predator/prey relationships are expected to precipitate renewed declines.

Yukon, Northwest Territories and northwestern British Columbia primarily need to manage caribou populations (mountain/terrestrial ecotype) to ensure that human harvest, when added to natural mortality, does not drive a herd into decline. The intensive study and management of the Finlayson herd in the Yukon will provide the kind of information needed to manage a herd that experiences both human harvest and natural mortality. As well, as multi-prey/predator study that has been initiated in Spatsizi Provincial Park, British Columbia may shed further light on the role of moose and wolves in depressing caribou populations.

Research and inventory of caribou in British Columbia (primarily on the mountain/arboreal ecotype) increased dramatically in the 1980's. Three workshops on caribou research and management have been held since 1985 (Page 1988; Hebert 1990), and a thorough review and assessment of woodland caribou and their habitat in southern and central B.C. was completed (Stevenson and Hatler 1985). These forums of information exchange and problem-solving resulted in recommendations for further research needs. Some of the recommendations that arose repeatedly were: improved inventory methods, a need to better understand how caribou fare within multi-predator/prey systems, predation and its relationship to man-caused changes in caribou habitat, and lichen regeneration after logging.

Overall, there are still good numbers and viable populations of woodland caribou in western North America. However, along their southern range they continue to decline in numbers and shrink in distribution. We have not been very successful in maintaining caribou populations where their habitat has been altered or lost through resource exploitation. Management tools, like predator management or access control are difficult, if not impossible to implement and few battles have been won to save caribou habitat from timber harvesting or mining.

Several caribou managers have stated that if you can't adequately manage a herd or population then let them go, and most would agree that priorities must be set. Not all remnant herds can be maintained. The limited dollars available and the energy required to see difficult management decisions through to completion should be applied to herds that have the most potential for long-term viability. Priorities and the basis for establishing them will differ among jurisdictions.

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Appendix 1.

Manitoba Report - V. Crichton, Manitoba Departement of Natural Resources, Winnipeg, Manitoba.

Historically, woodland caribou ranged south to 58° latitude along the eastern edge of the province into Minnesota. Development activities over the years have resulted in the demise of caribou in the southeastern portion of the province. As well, this disappearance was probably associated with the nematode *Parelaphostrongylus tenius*, a parasite which invaded the province with white-tailed deer *(Odocoileus virginianus)* about the turn of the 20th century and is extremely pathogenic to woodland caribou.

Management activities until the mid 1970's were restricted to aerial surveys in the more accessible hunting areas, manipulation of hunting seasons and restrictions on the number of licenses available. In the past 15 years, radio telemetry studies have been initiated on discrete herds to obtain data for management purposes, primarily with respect to timber harvest.

The current population estimate is about 2000 and the distribution delineated on Figure 2. Insufficient funding to adequately survey the herds makes reliable population estimates difficult to obtain and the profile of woodland caribou, relative to other game species is low. Mortality factors affecting woodland caribou in Manitoba are licensed and subsistence hunting, predation and other natural causes. Improved access into caribou range resulting from industrial development, is a concern with respect to increased hunting.

It is certain that more development activities will occur and with this more effort must be expended to determine population numbers as well as annual ranges of those herds affected. An examination of woodland caribou range in Manitoba does not lead to the conclusion that habitat is a limiting factor. Caribou ranges need to be identified, delineated and assessed for their vulnerability relative to long term development plans of hydroelectric and logging companies, and government proposals for new access roads.

Development activities in areas frequented by caribou such as tourist establishments, logging, winter roads and all weather roads have to date caused little disturbance to caribou directly. The indirect effects such as increased hunting activity are of major concerns and «no hunting» corridors along new roads may have to be applied.

The identification of significant wood fibre within caribou range is required in order to assess destruction of habitat, increased harvest vulnerability due to increased access and increased predation resulting from easier access. Hristienko (1985) summarized the literature relevant to the impact of logging on caribou. In 1986, a study to determine the impact of logging on woodland caribou in eastern Manitoba was initiated and is near completion. Loss of merchantable timber outside of caribou range to wild fire could result in greater pressure to harvest timber in caribou range.

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Appendix 2.

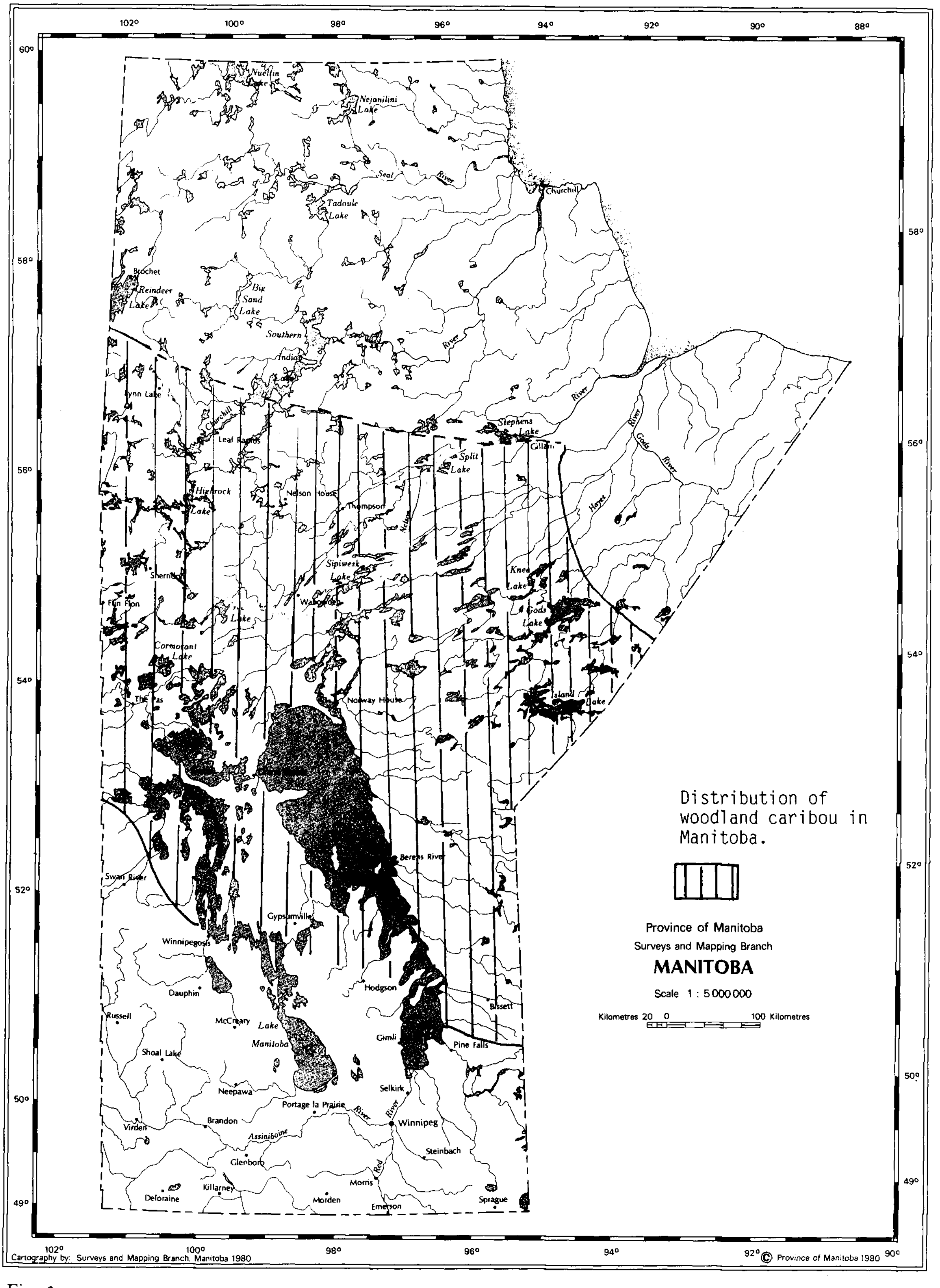
Saskatchewan Report - T. Rock, Departement of Parks, Recreation and Culture, Wildlife Branch, LaRonge, Saskatchewan.

There is no population estimate of woodland caribou in Saskatchewan prior to the 1980's. However, by the 1950's it was believed that caribou numbers were increasing in this assessment was associated with a hunting closure and low wolf numbers. A study completed in 1959 in the Sled Lake area estimated a density of 0.14 caribou/km^2). Figure 3 shows historic and current caribou distribution.

The current population estimate is 2500 and herd size has been reduced to individuals in som areas of the commercial forest, east of Prince Albert National Park, particularly along the forest/agriculture boundary and east of 104° longitude and north of 53° latitude. Group size declines with increasing latitude.

Historically the following factors have influenced woodland caribou population size and distribution:

1. The first pulp mill in Saskatchewan began operation in 1966. Road development associated with forestry and increased mining activities has contributed to increased mortality due to hunting. Rate of road building has decreased since the mid 1970's.



Distribution of woodland caribou in Manitoba.
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Gods Lake
Knee Lake
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Nejanilini Lake
Southern Indian Lake
Big Sand Lake
Reindeer Lake
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Fig. 2.

2. Cessation of wolf control programs in the 1970's. The last organized wolf control effort was in 1969.
3. Advent of snowmobiles in accessing caribou range which in turn can result in increased unregulated hunting and frozen, packed trails for easier wolf movement.
4. Mild winters in the 1980's resulted in an increase of deer populations in the boreal forest, in turn providing a higher prey base to support greater numbers of wolves.
5. Severe winters (combined deep snow and short growing seasons) in 1971/72 and 1973/74 with associated poor calf survival as reflected in low calf harvests in 1972 and 1974.
6. Non-resident woodland caribou hunting took place between 1970, 1971 and 1972. Success rates were very high.
7. Desiccation of bogs resulting in increased shrub and tree growth and corresponding increase in deer numbers.
8. From 1972 to 1976 moose licences were limited by a draw system and moose hunters began to hunt in groups with one licence per group. Because each hunter required a big game licence, others in the group purchased a caribou tag. The highest ever caribou kill occurred in 1971 and reamined high through to 1976.
9. Habitat loss due to logging and fire (bad fire years were 1970, 72, 73, 80 and 81). Viable herds of woodland caribou still exist in Saskatchewan but remnant populations along the southern range may receive little management effort in order to concentrate on maintaining the existence of healthy, stable or undisturbed populations. Both moose and caribou cannot be managed for high numbers on the same land base. Forest management for caribou only, must be considered.

Appendix 3.

Alberta Report - Janet Edmonds, Fish and Wildlife Division, Edson.

Prior to the 1960's knowledge of caribou distribution and abundance was provided through incidental observations of forest officers, guides, hunters, trappers, etc. Dwyer (1969) in an historical review of the caribou population in Alberta, stated that caribou numbers and distribution have declined substantially since early 1900's

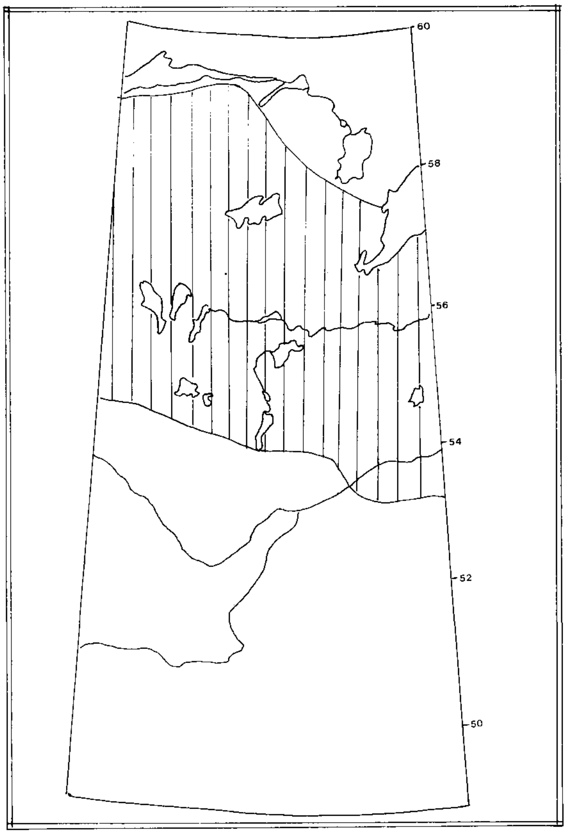

Fig. 3. Distribution of woodland caribou in Saskatchewan.

and that careful management of this species and its habitat is of paramount importance to their survival. Stelfox (1966) estimated a provincial caribou population of 6,860 to 9.060. Lynch and Pall (1973) revised this estimate to 4,800 to 5,200. The current provincial population estimate of 3,300 is primarily based on guess work as only four herds have been surveyed in the past 5 years. Figure 4 shows current and historic caribou distribution and Table 3 provides a population estimate break down.

Primary factors associated with the decline of woodland caribou in Alberta were overhunting, predation and habitat loss to logging, agriculture and coal mining. Extensive roads and seismic lines associated with petroleum and natural gas exploration and development greatly increased hunting and poaching levels through the 1960's. Concern for caribou in Alberta has increased steadily throughout the 1980's, in particular with respect to the recent allocation of large areas of forest lands in northern Alberta to new or expanded pulp and paper mills. Since 1980 caribou inventory and research primarily

Table 3. Alberta caribou herd population estimates as of January 1991.

Caribou management area	Number of caribou
1. West-Central	400
2. Chinchaga/Dixonville	250
3. Bistcho Lake	300
4. Caribou Mountains	500
5. Birch Hills	400
6. Fort McMurray	300
7. Wabasca/Red Earth	600
8. Slave Lake	100
9. Primrose Lake	250
10. Jasper	250
Total in Alberta	3350

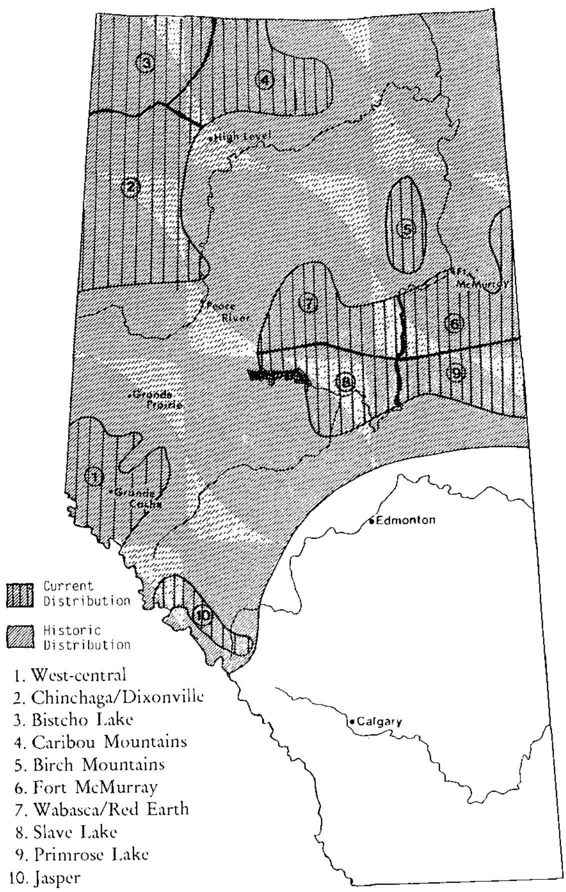

Fig. 4. Caribou Management Areas

was focused on a migratory mountain caribou herd residing in the Grande Cache area of west central Alberta. However, beginning in 1991

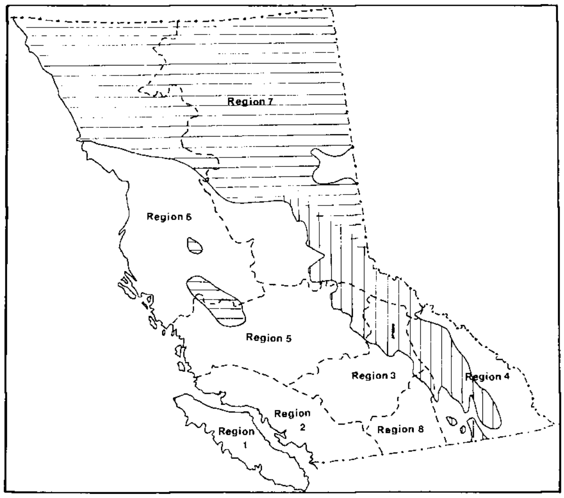

Fig. 5. ▤ Mountain/terrestrial ecotype
▥ Mountain/arboreal ecotype

collection of baseline data on herd numbers and distribution and seasonal ranges began in northern Alberta. The imminence of industrial activity determines which herds will be assessed first. Development of guidelines to protect and maintain caribou habitat while extracting timber, oil and gas and mineral resources is ongoing, experimental and will require a commitment to long-term monitoring to assess their success. After many years of benign neglect caribou populations in Alberta are receiving the management time and dollars they need.

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Appendix 4.

British Columbia Report

Region 3 Thompson-Nicola (Southern Interior) - D. Low, Ministry of Environment, Fish and Wildlife, Kamloops, British Columbia.

Prior to 1970, woodland caribou (mountain/arboreal ecotype) numbers in this region (Fig. 5) were estimated to be 250 to 500. Declines were associated with logging and fires but severe winters also affected herd growth. Mature timber canopy and its influence on snow conditions are and were an important factor affecting caribou mobility and food supplies.

Based on 1990 surveys, the caribou population is 500 of which 250 are associated with Wells Grey Provincial Park (Low 1990). Fire suppression appears to have improved range quality, particularly maturing forests important for late winter range. However, because logging removes old growth systems which are critical to caribou in wet forest zones, the rate of harvest and replacement of the stands will determine the changes in caribou population over the long term. The hunting season for caribou was closed in 1983. Presently no management dollars are allocated to caribou. Protection of habitat is handled through the «forestry referral» systems on a cutblock and road access basis as well as five year cut plans. An area has been set aside adjacent to Wells Grey Park to protect high elevation late winter ranges from logging. Fire suppression continues. Snow mobile activity is causing some concern.

Region 4 Kootenay - G. Woods, Ministry of Environment, Fish and Wildlife, Nelson, B.C.

Population trend for the mountain/arboreal ecotype since the distance past has been downward. Indications are that there may have been two or three times more caribou in this region (Fig. 5) around 1900. The Mica Reservoir is believed to have had a serious impact on caribou on the Rockies east of the Mica Dam. By the 1960's caribou in the southern Monashee Mountains seem to have disappeard. Distribution in the Selkirk and Purcell Mountains has not changed significantly but numbers have declined. Logging may have been a factor in this decline but it is difficult to confirm. Hunting is believed to have been excessive with increased access increasing hunting success. Seasons were reduced considerably in the 1960's.

Current population estimate of caribou in the Kootenay Region is about 600. Logging and loss of early winter habitat is believed to be a local problem now and a major problem for the future. Hunting is no longer a significant factor and predation by cougar may be an increasing factor. Deer numbers are higher and deer, elk and moose have expanded their distribution throughout much of the Region.

Future management efforts will be directed at maintaining habitat until caribou habitat requirements are well understood. Recent concerns about cougar predation need to be addressed. Land use decisions need to be made, based on whether the public want to maintain caribou throughout their historic range, and then the costs accepted for which ever course is chosen.

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Region 5 Cariboo (Northern Interior) - T. Smith, Ministry of Environment, Fish and Wildlife Division, Williams Lake, B.C.

This region (Fig. 5) has 2 main herds; the Quesnel Herd (mountain/arboreal ecotype) and the Itcha-llgachuz Mountain Herd (mountain/terrestrial ecotype). Prior to 1975 the Itcha-llgachuz herd was estimated to be around 350 caribou with a stable or slightly increasing status. Presently it is estimated to be about 1,400 in number and stable to slightly decreasing. This herd has expanded its winter range further in the lowland pine forests. Portions of this herd's winter range is scheduled for logging, wolf numbers appear to have increased within its range and it is expected that declining numbers in caribou will follow. The Itcha-llgachuz herd has a trophy bull season (25-30 annual harvest) and 40 cow permits (<5 harvested annually) for residents are issued. Thirty caribou from this herd were transplanted to Idaho in 1987 to

1989. Chichowski (1989) presents data on the status of this herd and its seasonal range use. The Quesnel herd was estimated to have 300 to 400 caribou prior to the 1970's. A spatial overlap of moose into caribou range and increases in wolf numbers has resulted in a sharp decline in this herd to about 100 (Seip in press). Predator management is required to prevent the loss of this herd. Conflict with snowmobile activity in spring range is also a potential concern.

Region 6 Skeena - R. Marshall, Ministry of Environment, Fish an Wildlife Division, Smithers, B.C.

Prior to the 1960's there was an estimated 10,000 to 12,000 woodland caribou (mountain-/terrestrial ecotype) in this region (Fig. 5). A major decline was suspected in the mid to late 1970's based on low calf percentages (4-12%) in several surveyed herds, and predation (grizzly and wolf) was perceived to be the main factor involved with this decline. Currently, there are estimated to be about 4,000 to 6,000 caribou in the Skeena Region, although no inventories have been carried out. Predation is assumed to be the primary limiting factor on herds. About 175 bulls are harvested annually (5 point restriction), and this is believed to have little affect on the herds (based on limited data, pregnancy rates are 85% or more).

Most of the northern Skeena Region herds are not, and for the foreseeable future, will not be adversely affected by man's activities. Logging and mining activities are not extensive. The two remaining southern herds (Telkwa and Tweedsmuir) are more likely to be affected by future logging activities. Timber harvesting is occurring along the primary migration route and will occur in 2-4 years in the primary winter range of the Tweedsmuir herd. Mid-elevation logging in the Telkwa Mountains may impact winter habitat of this small herd (75 animals).

Predation appears to be the main limiting factor of all herds. Additional research is required on multi-predator/prey systems. The Spatsizi Association for Biological Research is undertaking studies at present and results can be applied to our northern herds. In addition to research on predators of southern caribou, research is required on the impacts of forest harvesting on terrestrial lichen communities.

Given the lack of resource development and current harvest levels in the north, priorities will remain directed to the Tweedsmuir Herd. The development of an inventory technique is essential although funds may not be available within the next five years. Stable or decreasing numbers of caribou are anticipated over the long term.

During the late 1970's and early 1980's significantly more effort was spent on developing caribou inventory methods and was in response to perceived very low calf crops. Since 1983 (other than the Tweedsmuir Caribou Herd Study) virtually no data (other than harvest) have been collected regarding northern populations. The only non-hunted population is the Telkwa Herd. Presently, management effort on caribou is directed primarily to monitoring the yearly harvest and that effort is considerably less than the current time and effort directed towards moose, grizzly bear and mountain goat.

The most significant project is that being undertaken by the Spatsizi Association for Biological Research (D. Hatler, Smithers, B.C.) whose focus was on caribou (Hatler 1986) and is now on wolf, moose and grizzly bear. It is hoped that this project will shed some light on Bergerud's hypothesis that inceased numbers of moose have caused an increase in the number of wolves which then affect caribou.

Region 7 Omineca-Peace, Sub-region 7.1 Peace/Liard - R. Thomson, Ministry of the Environment, Fish and Wildlife Division, Fort St. John, B.C.

Currently woodland caribou in this sub-region (Fig 5, primarily the mountain terrestrial ecotype and an unknown number of boreal ecotype in the northeast corner) are estimated to be about 5,000. The current population is relatively stable but is about 25% of that estimated for the 1960's and early 1970's. This decline is believed to be due to deep snow winters in the late 1960's and early 1970's and predation. Woodland caribou are found throughout this sub-region except in the area around Fort St. John and Dawson Creek which is primarily agricultural land.

Presently snowfall and predation (wolves and grizzlies) are considered to be the primary factors influencing population size and distribution

(Bergerud and Elliot 1986; Bergerud and Page 1987). Hunting is restricted to trophy bulls only. In the north Liard zone caribou appear to be stable now but may start to decline to early 1980 levels because of predation. Inventory is poor for the south Peace zone. It is probable that populations are stable but may decline in the area south of Dawson Creek as logging moves into poor pine stands with terrestrial lichens.

Region 7 Omineca-Peace, Sub-region 7.2 Prince George - Dave King, Ministry of Environment, Fish and Wildlife, Prince George, B.C.

This sub-region (Fig. 5) presently has about 600 to 700 mountain/arboreal ecotype and 1200 to 1600 mountain/terrestrial ecotype. This is decrease of more than 50% since the past (prior to 1960) but an apparent increase from the low estimates of the 1970's. Some of this increase may be a reflection of better inventory rather than a biological increase (S. Stevenson, pers. comm.).

Reasons for decline in mountain/arboreal populations are many and complex but over-hunting and habitat loss are considered to be of primary importance. Less is known about the more northern mountain/terrestrial ecotype. Hunting is closed or restricted throughout caribou range in this sub-region. Logging and increased road access is affecting all of the range of the mountain/arboreal ecotype and at least half of the mountain/terrestrial range.

Since 1985 a substantial increase in dollars and manpower has been applied to caribou management in this sub-region primarily to adress forest harvesting conflicts within caribou range. Due to habitat change and loss (primarily due to logging), it is not excpected that caribou numbers will reach historic levels. The goal is to attain population levels that can sustain a harvestable surplus. There is concern for maintaining adequate amounts of old growth forest for the mountain/arboreal ecotype, and in some areas logging and access are encroaching on lower elevation winter habitat of the mountain/terrestrial ecotype. An industry/government co-operative program is underway to develop ways of managing and harvesting timber without destroying caribou habitat (Mountain Caribou in Managed Forests Program).

Appendix 5.

Northwest Territories Report - R. Graf, Department of Renewable Resources, Fort Smith, N.W.T. and P. Latour, Department of Renewable Resources, Norman Wells, N.W.T.

No assessment of woodland caribou numbers and distribution prior to 1970 is available. Current knowledge is still scant. No extensive surveys have been done over the Mackenzie Mountains or Mackenzie Valley, but woodland caribou numbers in the Mackenzie Mountains may be 7,000 to 10,000. Densities are believed to be much lower in the Valley, where woodland caribou are scattered broadly and thinly.

Whitin the Mackenzie Mountains, numbers appear to be highest in the central one third

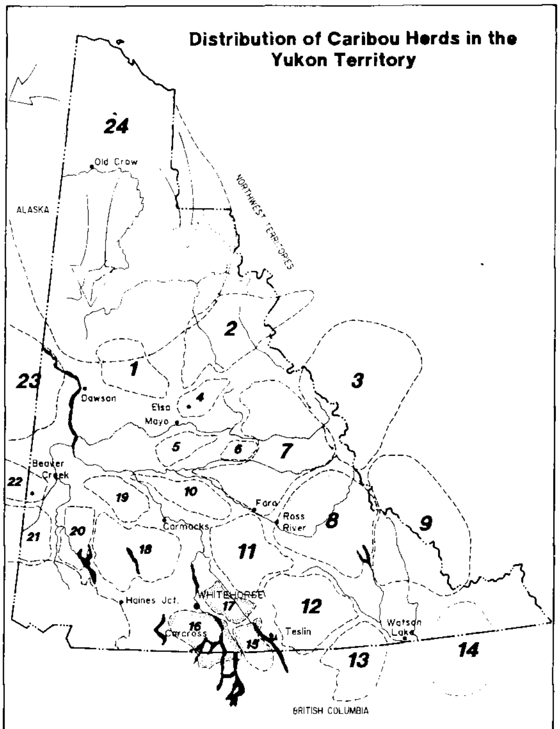

Fig. 6. Caribou herds: 1. Hart River. 2. Bonnet Plume. 3. Redstone. 4. Mayo. 5. Ethel Lake. 6. Moose Lake. 7. Tay River. 8. Finlayson. 9. Nahanni. 10. Glenlyon/Tatchun. 11. Pewlly Herds. 12. Wolf Lake. 13. Little Rancheria. 14. Smith River. 15. Teslin/Atlin. 16. Carcross Herds. 17. Squanga. 18. Aishihik. 19. Klaza. 20. Burwash. 21. Chisana. 22. Nelchina/Mentasta (Alaskan caribou). 23. Fortymile Herd (Alaskan caribou). 24. Porcupine Herd (Alaskan caribou).

and major wintering areas occur along the Keele River and at Wrigley Lake. Work carried out by the N.W.T. and Yukon Wildlife Departments in the early 1970's indicate that these caribou disperse west as far as the Yukon border in summer. Caribou in the northern third of the Mackenzie Mountains are thought to move between these mountains and the Wernecke Mountains in the Yukon; even less is known of caribou in the southern one third of the Mackenzie Mountains.

Approximately 200 woodland caribou are shot in the Mackenzie Mountains, annually: 100 as trophy bulls by outfitted hunters and 100 as native subsistence kill. The demography of these caribou is poorly known but based on limited data, Colling (1983) concluded that this was a high quality population exhibiting high pregnancy, birth, and calf survival rates and relatively short life spans. There is negligible harvest of woodland caribou in the Mackenzie Valley and east.

In the near future, there is no plan to conduct research on woodland caribou (barren-ground caribou receive all research and management dollars). Currently caribou status is good and hunting levels are low and relatively controllable. Industrial activity in the Mackenzie Mountains remains negligible and in the Valley seismic and drilling activity is localized. This situation results in little access into the majority of caribou range, thus harvest levels and loss of habitat remains low.

Appendix 6.

Yukon Report - R. Farnell, Department of Renewable Resources, Wildlife Branch, Whitehorse, Yukon Territory.

Prior to the 1970's the size and distribution of Yukon's woodland caribou herds was understood at a minimal level, based on local knowledge. No inventory or management activities were carried out and reasons for suspected declines or increase are speculative. The decline of the Forty Mile herd coupled with increased road expansion may have resulted in the overharvest of some herds.

Current population estimates for herds in the Yukon Territory is presented in Table 4. Figure 6 shows approximate distribution of the herds. Wolf predation has been identified as the single most influential factor in naturally limited populations. Winter ranges are traditional as a result of obligatory response to snow cover and are critical seasonal habitats. However, in the Yukon, there has been as yet no evidence of winter forage or range condition limiting caribou populations. Hunting is an additive factor and if greater than 2-3% will cause population decline where wolves are not manipulated.

For the future, woodland caribou in the Yukon will be managed to maintain viable populations. Caribou herds will not be allowed to decline in numbers to the point they become threatened with extinction or reach unbalanced sex composition ratio due to any man-caused factors. Some herds will be intensively managed to provide hunting, while other herds will be allowed to follow their own natural course of growth or decline without substantial human interference.

Although it is well understood that predation and hunting exceed the influence of range condition on population dynamics, some population mechanisms still need investigation, e.g. low male ratio and its affect on population dynamics, and natural adult mortality rates.

Yukon's caribou management program entails a broad initial inventory of all herds on their winter range. Snow cover and food habits on the winter range are measured to provide a crude assessment of a herd's potential based on its most critical habitat. A second program is the intensive management of one representative herd, the Finlayson herd, to evaluate factors limiting population growth, to assess practical management methods, to test monitoring procedures, etc. The combintation of an intensive management model of one herd with ongoing inventory of other herds, guides management decisions.

This approach has been in place for 10 years and represents a substantial portion of Yukon's big game management scheme. Woodland caribou are viewed as an important resource to the Yukon public, so the program is likely to continue or gain greater support in the future.

Table 4. overleaf →

Printed from manuscript after editorial review.

Table 4. Summary of woodland caribou population status

Herd	Population estimate	Year	M[1]	T[2]	Yukon harvest No.[3]	Yukon harvest %	Current status and notes
Hart River	1200	1978	B	S	13	1.1	Healthy. Inventoried in 1981-82. Porcupine herd overlaps with herd in late fall to spring.
Bonnet Plume	5000	1982	C	I	37	0.7	Healthy. Range partially in N.W.T. Inventoried in 1981-82. Porcupine herd overlaps with herd in late fall to spring. Almost all harvest is by non-residents.
Redstone	5000-10000	1982	C	U	38	0.4-0.8	Healthy. Harvested in MacPass area. Range largely in N.W.T.
Mayo	?	—	—	U	0	0	Anecdotal information only. Occasional caribou harvest.
Ethel Lake	200	1977	C	U	2	1.0	Vulnerable. Presently being inventoried. Population census slated for March 1992.
Moose Lake	87	1991	A	U	10	11.5	Vulnerable. Inventoried 1989-91. Population census in 1991. Large portion of winter range burned in 1989. Entire harvest is by non-residents.
Tay River	5752±594	1991	B	I	21	0.6	Inventoried 1989-91. Population census in 1991. Favourable bull/cow ratios and calf recruitment.
Finalyson	5950±1053	1990	B	I	55	0.9	Increasing. Intensive management. Wolf reduction program 1982-89. High bull/cow and calf/-cow ratios.
Nahanni	2000	1981	C	U	29	1.5	Range partially in N.W.T. Moderate level of harvest from Tungsten Road.
Glenlyon/Tatchum	350	1977	C	U	10	2.9	285 caribon observed during Tatehnm 1976 sheep snrvey.
Pelly	1000	1977	C	U	14	1.4	670 caribou observed during 1978 sheep survey.
Wolf Lake	664±133	1987	B	S	4	0.6	Inventoried 1984-87. Population census in 1987. Skewcd sex ratio: 29 bulls/100 adults cows.
Little Rancheria	681±136	1988	B	S	0	0	Vulnerable. Inventoried 1985-88. Skewed sex ratio: 30 bulls/100 adult cows. Summer range in

							herd).
Smith River	200	—	C	U	0	—	Anecdotal information only. Estimate from B.C. Wildlife Branch. Partially range in B.C.
Teslin/Atlin	400	1978	C	U	0	—	Possibly 2 discrete herds or may be part of Gladys Lake herd from BC. No licensed season in Yukon.
Carcross	400	1980	B	S	6	1.5	Vulnerable. Range partially in B.C. Permit hunt closed after 1989 season. Only Ibex herd inventoried 1982-85. Ongoing annual rut counts on Ibex herd since 1983. Substantial native harvest on Ibex and Nares herds.
Sqnange	300	1980	C	U	9	3.0	Partially inventoried 1978-90 (Foothills Pipeline)
Aishihik	785	1991	A	D	43	5.5	Inventory commenced 1991. Population census April 1991. Extremely low bull/cow ratios and poor calf recruitment. Caribou hunting closed in 1991. Postcalving and rut counts conducted in 1981, in which 1,225 caribou were observed and population estimated at 1,500.
Klaza	441	1989	A	U	4	0.9	Vulnerable. Mining road developments in area. Resident and non-residents hunting closed for moose and caribou after 1988 season. Permit hnnt for caribou scheduled for 1991 season.
Burwash	200	1990	B	D	11	5.5	Susceptible to overharvest. Paritally range in Kluane Game Sanctuary. Population estimated at 400 in 1982. Caribou hunting closed in 1991.
Chisana	1660	1989	A	D	12	0.7	Range largely in Alaska and Kluane Game Sanctuary. Counted by Alaska Department of Fish and Game. Mainly non-resident harvest. Alaska harvest average 2,5% of herd each year. Extremely poor calf recruitment for 1989 and 1990.
Total	27,397 - 36,229				318		

[1]Method A = Total count, B = Extrapolation, C = Guess
[2]Trend I = increasing, S = stable, D = declining, U = unknown
[3]Some herds are hunted by NWT residents.

Can woodland caribou and the forest industry coexist: The Ontario scene

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Abstract: Ontario is in the process of developing a strategy to improve the likelihood of woodland caribou *(Rangifer tarandus caribou)* and the forest industry coexisting in the province. This strategy is described within a set of proposed *Timber Management Guidelines for the Provision of Woodland Caribou Habitat.* The proposed guidelines advocate managing for large blocks of suitable winter habitat across caribou range, large cutovers to regenerate caribou winter habitat and the protection of traditional calving areas and travel routes. Summer habitat will be provided by the resulting mosaic. The forest industry can provide a sustainable supply of woodland caribou habitat that was traditionally maintained by wildfire.

Keywords: caribou, forestry, Ontario, habitat, conflicting interests, Canada

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Introduction

Woodland caribou *(Rangifer tarandus caribou)* range in Ontario has receded northward since the late 1800's, probably as a result of a combination of factors including hunting, fire, land clearing, logging, increased predation by wolves *(Canis lupus)* due to increased densities of moose *(Alces alces)* and deer *(Odocoileus virginianus)*, disease caused by brain worm *(Parelaphostrongylus tenuis)* and human disturbance (Darby *et al.* 1989). At present, the southern boundary of the zone of continuous distribution of woodland caribou in Ontario is approximated by the northern limit of large-scale timber management.

Ontario has made a commitment not to let any species decline provincially as a result of timber management activities. At the same time it recognizes the economic and social importance of the timber industry to well-being of the citizens of the province. As a result, Ontario has embarked on developing a set of guidelines that will enable the forest industry to coexist with woodland caribou.

This report describes, in general terms, the principles behind the proposed *Timber Management Guidelines for the Provision of Woodland Caribou Habitat.* It describes aspects of summer and winter biology which are considered significant for woodland caribou living in areas subject to timber management. In addition, it describes general concepts for timber management within woodland caribou range and explains the rationale for why we believe caribou and the forest industry can coexist.

Habitat requirements

Forest-dwelling caribou are found over most of Ontario's woodland caribou range. They are essentially solitary from just prior to calving in May until just prior to the rut in late September. They form small groups during and after the rut until late April. Maximum group size seldom exceeds 50 animals, and usually averages less than 10 throughout the September to April period. Average group size from May to September is less than two animals.

Table 1. Size of individual wintering areas[a] for radio-collared woodland caribou that occupy boreal forest year-round.

Citation	Study area	No. of caribou	Size of wintering area Mean	Range (km²)	No. of winters[b]
Shoesmith and Storey 1977	Reed L., N. Manitoba	2	253.4	124–383	1
Fuller and Keith 1981	N. E. Alberta	21	254.3	32–549	2
Darby and Pruitt 1984	Aikens L., S. E. Manitoba	1	34.0		1
Edmonds and Bloomfield 1984	W. Central Alberta	5	274.4	152–784	2
Mean value per caribou			250.0		

[a] As determined by minimum convex polygon (Mohr 1947; Jones and Sherman 1983). This does not account for overlapping individual ranges.

[b] Note additional studies are necessary over time to determine factors affecting range size utilization.

Winter habitat

In autum and winter, woodland caribou feed on arboreal and terrestrial lichens, sedges (*Carex* spp.), and bog shrubs: woody browse is not a dietary staple (Simkin, 1965; Bergerud, 1972; Darby and Pruitt, 1984; Edmonds and Bloomfield, 1984). In late winter, caribou in northern Ontario feed primarily on terrestrial lichens (Simkin, 1965; Cumming and Beange, 1987; Bergerud, 1989a).

Early winter (October to January) habitat of woodland caribou is generally lowland black spruce-muskeg or open bogs (Fuller and Keith, 1981; Darby and Pruitt, 1984; Bergerud, 1989a). When snow depths in lowlands exceed about 50 cm, caribou move to upland coniferous forest (Stardom, 1975; Fuller and Keith, 1981; Darby and Pruitt, 1984; Bergerud, 1989a) where snow is usually less deep from January to March (Stardom, 1975; Darby and Pruitt, 1984). Caribou seek open jack pine (*Pinus banksiana* Lamb.) and black spruce (*Picea mariana* (Mill.) B.S.P.) uplands (less than 70% canopy closure) where they dig feeding craters for terrestrial lichens.

Generally, conifer stands are not useful as winter habitat until 40 years of age when stand density decreases and terrestrial lichens become abundant. Stands between 40 and 100 years of age may provide satisfactory lichen supplies when canopy closure is 70% or less. By about 100 years, their usefulness begins to diminish due to declining lichen productivity and the increasing prevalence of bryophytes like feather-mosses (Ahti and Hepburn, 1967; Miller, 1976; Bergerud, 1989a). At this stage, fire and logging can serve to regenerate lichen supplies (Ahti and Hepburn, 1967; Miller, 1976). However, the standing crop and species composition of the lichens appear to be more related to differences in humidity, soil texture and depth, tree canopy, slope, drainage, aspect and past use by caribou than to stand age (Miller, 1976).

The amount of area occupied by woodland caribou in winter depends on the number of animals in a herd, forage availability and quality, snow conditions and predators. Studies of woodland caribou occupying boreal forest year-round show that individual caribou may occupy 32 to 784 km² in winter, 250 km² on average (Table 1). However, mean monthly group size in winter varies from 2.8 to 11.4 (Shoesmith and Storey, 1977; Fuller and Keith, 1981; Darby and Pruitt, 1984; Brown *et al.* 1986; Cumming and Beange, 1987; Bergerud 1989a). The wintering areas occupied by individual caribou in these groups are largely overlapping. Consequently, the wintering area of a population or *"herd"* of caribou needs to be considered for the purpose of managing habitat.

Table 2 shows the size of wintering areas reported for various herds of woodland caribou occupying boreal forest year-round in or adjacent to Ontario. The mean wintering area required per caribou on a "herd" basis is 16.1 km². Behaviour may vary but the main factors affecting area occupied in winter are forage availability and quality, snow conditions and predators. For example, some caribou make long distance movements in mid-winter (Fuller and Keith, 1981; Edmonds and Bloomfield, 1984), sometimes in response to deep snow (Brown *et al.*, 1986) or to predators (Bergerud, 1989b).

Calving/summer habitat

Information from marked cows (Shoesmith and Story, 1977; Fuller and Keith, 1981; Brown *et al.*, 1986) indicates that individual forest-dwelling, cow caribou exhibit inter-year fidelity to certain geographic locations, including both calving sites and summer ranges.

Calving generally occurs at sites where security from predation is maximized (Bergerud and Page, 1989). For forest-dwelling caribou, these areas include islands in lakes, lake shorelines (especially those with rutted topography and/or peninsulas), and isolated or secluded islands in bogs and fens (Bergerud, 1974; Shoesmith and Storey, 1977; Darby and Pruitt, 1984; Brown *et al.*, 1986).

Caribou that occupy islands or shorelines often represent those forest-dwelling caribou with the greatest degree of cohesive behaviour and visibility during calving. This permits some "*herd*" identification and has led to a preponderance of data on island and shoreline calving locations resulting in an emphasis on their management. Although justification for this is linked to visibility and the amount of data available, in most documented cases it is clear these locations are used annually by significant local or regional groups of caribou.

In contrast, mainland calving sites may represent the calving habitat of more dispersed cows. Identification of a "herd" or even association with a specific wintering area is difficult. Widely dispersed calving sites in isolated or secluded bogs, fens or in mainland forest stands are more difficult to identify, and less likely to attract human attention. This has resulted in the collection of little information, and a lack of emphasis on their management. However, a much higher proportion of Ontario's caribou may give birth to calves in this type of site and collectively they may be more important than islands or lake shorelines.

Summer home range is generally the smallest seasonal home range for both sexes, compared to fall and winter. Females with calves often move back and forth to the mainland in July and August (V. Crichton, Manitoba Dept. Nat. Resources, pers. comm. 1990). Much of their activity occurs within 100 m of shore, possibly

Table 2. Estimated size of herd wintering areas for herds of woodland caribou that occupy boreal forest year-round, in or adjacent to Ontario.

Study area	No. of caribou	Size of wintering area Mean	Range (km²)	No. of winters[a]	Mean area per caribou (km²)	Citation
Aikens L. S. E. Manitoba	35–37	235		2	6.5	b
Aikens L. S. E. Manitoba	35–40	117.5	95–140	2	3.4	c
Royd L.	22	332		1	15.1	d
Haggart L. N.W. Ont.	14–26	486		1	24.3	
Sesaganaga L., NW Ont.	31	969		1	31.3	c
Mean per Area	29.3	427.9			16.1	

[a] Note additional studies are necessary over time to determine factors affecting range size utilization.

[b] Stardom 1975

[c] Darby and Pruitt 1984

[d] Webruk 1986 and unpublished data

[e] Harris 1990

because of the potential for escape to water when predators threaten. There is a significant risk of predation of calves and adult females at this time of year (Shoesmith and Storey, 1977). Island and shoreline habitats may also provide some relief from insects.

Caribou seek rapidly growing green plants in spring and summer, and their diet is probably most varied during this period.

Forest management practices compatible with woodland caribou

Timber Management Guidelines for the Provision of Woodland Caribou Habitat are currently under development in Ontario. Details have not yet been finalized. However, the general principles which may be supported biologically, are described in the following text.

One of the primary, non-economic objectives of timber management activities in woodland caribou range is to ensure a sustainable mosaic of year-round caribou habitat. To achieve this, caribou habitat must be managed on a very large temporal and spatial scale, often spanning more han 1.000 km², and more than 60 years. Timber management may be planned to partially replace the renewal role that wild fire has played in the past. This strategy would see large blocks of land, usually exceeding 100 km², and containing winter habitat, set aside until other winter habitat blocks become available nearby in the mosaic. This in turn would require large blocks of timber to be allocated for harvest so they could regenerate to provide suitable winter habitat approximately 40 years in the future. Although the clearcut harvest system would be expected to be employed, it would not necessarily mean the harvest blocks would be cut clear.

Regeneration objectives on dry to very dry, sandy or shallow soils should be to reestablish jack pine or black spruce stands with 50–70 percent crown closure at maturity, and with relatively few deciduous trees or tall shrubs. These soils include Northwestern Ontario Forest Ecosystem Classification (NWO FEC) soil types S1, S2, and SS1 to SS5 (Sims *et al.*, 1989). Treatment options that encourage lichen regeneration should be used where possible.

Access should be restricted in areas of existing or potential high quality winter habitat by making roads of a temporary nature. This means that the primary road network should be developed around and not through existing or potential high quality winter habitat. Winter roads may provide suitable access to winter habitat blocks during harvest.

Potential calving areas such as lakes with long irregular shorelines or islands, or open bogs and muskegs with dry hummocks or islands should be protected with a no-cut reserve. Where the sites are known to support caribou calving, the size and shape of the reserve may vary to suit the site. Small scale manipulation of the reserve may be desirable to provide a continuous supply of summer food for the cow calf group.

Timber management operations should be planned to avoid creating a barrier between calving areas and associated winter habitat. This could be done by either scheduling harvest to provide continuity of habitat between the two areas, or by leaving a 2 km wide travel corridor to traverse otherwise large cutovers or young reforested areas. Known migration routes should be protected in a similar way. Mineral licks should be protected by a no-cut buffer.

Rationale for forest management practices compatible with woodland caribou

Caribou and moose have different winter habitat requirements. Caribou prefer large expanses of mature lichen-rich coniferous forest and do not use woody browse as a dietary staple. Moose prefer an interspersion of mature and early successional mixedwood stands that provide woody browse close to cover. Where caribou and moose overlap, high wolf densities supported by moose populations are likely to cause a reduction in caribou numbers. Thus, management for caribou and moose habitat on the same land base is counter-productive for caribou.

Sustaining the supply of caribou habitat is essential to maintaining caribou numbers. Management of access is equally important. Access development is a major contributor to increased mortality of caribou due to increased predator access, human harvest, road kills, and altered habitat use and suitability.

Habitat mosaic

The boreal forest has primarily been shaped by wildfire. The present abundance of old forest stands in the northern extremity of the commercial forest in Ontario is primarily due to the suppression of fire.

Fire size in the boreal forest is variable, with fires ranging in size from 0.1 ha to 1,000,000 ha. In northwestern Ontario, large wildfires are common (Table 3), with Ministry of Natural Resources (MNR) administrative districts of Red Lake, Sioux Lookout and Geraldton averaging at least one fire greater than 100 km² per year since 1976. If the present intensity of fire suppression persists, renewal of forest stands by timber management provides the best opportunity to sustain a supply of stands suitable for caribou winter habitat.

The purpose of creating a habitat mosaic is to ensure a sustainable supply of habitat. As younger stands with the attributes of desirable winter habitat become available, older winter habitat blocks may be allocated for harvest. Establishment of a sustainable mosaic of caribou winter and summer habitat will require long term, and large scale planning.

Caribou have behavioural adaptations for predator avoidance which manifest themselves in calving and winter habitat selection. Large areas of mature coniferous forest, particularly lichen-rich open jack pine or black spruce stands, are desirable winter habitat because they have an abundant winter food supply, a relatively low suitability for moose, and thus relatively low populations of wolves.

Any alterations to the habitat that encourage an increase in prey species for wolves within range quality is enhanced by patterns of timber harvest that produce abundant browse and edge. This is inappropriate in areas being managed for caribou.

There is an abundance of mature and overmature forest within existing caribou range. A sustainable mosaic of caribou habitat will require at least som large areas of land containing stands of each major age class. This condition cannot be realized within the first rotation of timber management in northern Ontario when the forest has a very high proportion of stands greater than 80 years of age. Within the first timber management rotation, caribou habitat management may require that winter habitat blocks consisting of stands greater than 80 years of age be left unharvested for up to 40 years. The ideal target for forest age classes within caribou range would be a relatively even distribution of each of the following age categories: 0–20; 20–40; 40–60; 60–80; and 80–100. Habitat and access planning on a temporal scale of 60–100 years may be required to achieve this habitat mosaic.

Table 3. Number of large fires in Red Lake, Sioux Lookout, and Geraldton MNR Districts from 1976 to 1989. Fire frequency decreases from west to east. All districts averaged at least one fire greater than 100 km² per year.

District	Fires > 100 km²	Fires > 10 km²
Red Lake	25	103
Sioux Lookout	18	102
Geraldton	13	49

In addition to access planning, fire planning may also be necessary. Timber management may reduce the inventory of mature stands suitable for caribou habitat to the level where losses to fire are less acceptable. Winter habitat blocks consisting of mature or overmature timber will have to be made a priority for fire suppression because both timber supply and caribou habitat are at risk.

Much of the rationale for managing habitat in caribou range is based on the premise that management for caribou and moose on the same land base will not benefit woodland caribou. At this time, almost all the productive forest lands in north western Ontario are managed for moose by applying the *Timber Management Guidelines for the Provision of Moose Habitat* (OMNR, 1988). Guidelines for moose habitat limit the size of cutovers to increase edge and provide cover and food in close proximity.

Woodland caribou take longer to reach sexual maturity than either deer or moose and do not have multiple births (Darby *et al.*, 1989). This low reproductive potential may be a life history adaptation which allows them to occupy the tundra and mature boreal forest niche. Predation and loss of mature coniferous forest are serious threats to Ontario caribou, especially where moose, deer, and wolf numbers increase to relatively high levels in caribou range after logging. Access provided by forestry operations can increase losses to predators, poachers, native hunters and vehicle collisions. A recent Alberta study, for example, showed 70% of mortality in winter range was human related along access routes (Edmonds, 1986).

The curious and often unwary nature of caribou, coupled with seasonal gregarious behaviour make caribou especially vulnerable to hunters and poachers where roads have accessed their range. Careful road planning to minimize access-related disturbance is an essential component of caribou habitat management.

Caribou are probably most sensitive to disturbance, including human activity, during the calving period (Bergerud, 1974; Klein, 1979; Valkenburg and Davis, 1986). Reaction to and avoidance of human-made obstructions such as roads differs between open habitats and forest habitats, and caribou appear more sensitive in the latter. Actual vehicular traffic may be a greater deterrent than the road alone.

Distribution of calving cows was altered by construction and use of a road system in Alaska (Dau and Cameron, 1986). Roads and human activity should be discouraged within about 1.5 km of calving areas.

Predator relationships

Forest dwelling caribou disperse or space themselves to avoid predators. The success of this predator avoidance strategy depends on the distance that they can space themselves from predators and alternate prey. When logging takes place it reduces the available space for caribou, thereby increasing caribou densities elsewhere and forfeiting the advantage of space (Bergerud and Page, 1989; Bergerud, 1989a) Forest fires also reduce space in the short term, but renew caribou habitat in the long term. Caribou have evolved to shift their range in response to fire and can likely shift it in response to logging. However, a given amount of cutting in different patterns can affect caribou differently. A pattern of small dispersed cuts likely increases edge, moose and deer density and over time, wolf and bear density. It also intersperses predators with caribou, increases number and length of roads and likely increases mortality of caribou. When logging and road access are concentrated in a single large cut, these negative effects on caribou are minimized.

Protection of calving habitat is particularly important for woodland caribou. The close association of calving and summer range, the risk of predation on productive components of the population, and the satsifaction of other habitat requirements (e.g. insect relief and food) are other strong arguments in favour of protection of identified areas of calving. Design of such habitat protection should minimize the likelihood of increased predation. For example, protecting a strip of forest that is too narrow would "trap" vulnerable animals in areas easily searched by predators.

Protection of these habitats has two important implications: 1) high value habitat of individuals which have been recruited into the reproductive segment of the population receives special treatment, and 2) the nature and location of secure calving habitat may be passed by association from mother to daughter so habitat of more than one generation is affected.

Travel corridors

Woodland caribou sometimes use traditional routes to move or migrate between summer (calving) and winter range. Distances between seasonal ranges may be large. In one study conducted over a year period, movement from summer calving habitat to winter range averaged 46 km (range 26–80 km) (Cumming and Beange, 1987). Migration distances between summer and winter ranges reflects the juxtaposition of shoreline, summer habitat (anti-predator strategy) and winter lichen supply (Bergerud, 1989a).

Spring movements of females from wintering to calving areas generally occur in April prior to mid-May peak calving. Travelling at this time of year often requires little effort since lakes, streams and bog areas remain frozen with minimal snow cover. Cumming and Beange (1987) described such a movement in the Whitesands River Valley adjacent to Lake Nipigon. Fall shifts to wintering areas occur at any time between late October and early January (Shoesmith and Story, 1977; Cumming and Beange, 1987).

Maintaining travel corridors is important to ensure continuity of caribou range. A 2 km wide corridor, consisting of stands greater than 3.0 m in height, between summer calving and winter range is recommended. This corridor should contain primarily coniferous trees and follow natural features such as streams, valleys, eskers and lichen-rich rock ridges. Its width will assist predator avoidance by increasing predation search time and reducing mortality compared to narrower corridors (Porter, 1983).

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Status of the Galena Mountain caribou herd.

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Abstract: A resident herd of caribou *(Rangifer tarandus granti)* inhabits the Koyukuk River valley and Kokrines Hills, which are located on the north side of the Yukon River near the Alaskan villages of Galena and Ruby. Personnel from the Alaska Departement of Fish and Game, U.S. Bureau of land Management, and U.S. Fish and Wildlife Service studied this herd from October 1983 to January 1990. The highest caribou count was 258 in June 1987. The proportion of newborn calves observed during the May calving period ranged from 0 to 28% (mean=10%) whereas it ranged from 4 to 17% (mean=13%) in October. Caribou inhabited mostly coniferous forest from October through April and open habitat from May through September. Male caribou occupied fewer habitat types, travelled less distance, and remained at lower elevations than female caribou. Management concerns for this herd are discussed.

Keywords: Alaska, caribou, Galena Mountain, land uses, *Rangifer*, subsistence.

Rangifer, Special Issue No. 7: 116—122

Introduction

The Galena Mountain Caribou *(Rangifer tarandus granti)* herd (GMH) inhabits the Koyukuk River valley and Kokrines Hills, which are located on the north side of the Yukon River near the Alaskan villages of Galena and Ruby. Galena Mountain is a local name for the Vertical Azimuth Bench Mark named Bald. Although the origin of these caribou is unknown, they may be survivors of a commercial reindeer *(R. t. tarandus)* operation in the Kokrines Hills that ended about 1935 (Osborne 1989). Feral reindeer may have also mixed with migrant members of the Western Arctic Caribou herd (WAH). Between 1950 and 1975, some WAH caribou migrated across the central Brooks Range into the Koyukuk River valley. Caribou migration into the Koyukuk drainage ceased as WAH numbers declined from 242,000 to 75,000 animals during the early 1970s (Davis and Valkenburg 1978). Data collected from 1983 to 1989 by personnel of the Alaska Department of Fish and Game (ADFG), U.S. Bureau of Land Management (BLM), and U.S. Fish and Wildlife Serivice (FWS) located animals on summer range, winter range, and calving areas, thus confirming existence of a resident herd. Because the observed calving dates coincided with those of caribou rather than reindeer, we concluded that these animals were caribou.

According to a BLM subsistence inventory, caribou are important to Galena residents (BLM 1986a). These people have hunted caribou on BLM lands in the headwaters of Holtnakatna Creek, which is related to the customary migration route of caribou through this area. Therefore, the Environmental Impact Statement for the Central Yukon Resource Management Plan examined conflicts between caribou and potential development of mineral resources (BLM 1986a). The preferred alternative in the Environmental Impact Statement was to open 78% of the caribou habitat within the Dulbi-Kaiyuh Mountain Subunit (1 of 5 subunits in the Central Yukon planning aea) to mineral entry and location and 83% to noncompetitive leasing for oil and gas. Known crucial habitats on BLM land were included in these openings, but designated as Areas of Critical Environmental Concern (ACEC) (BLM 1986b). A suspected but unsubstantiated movement route was deferred from mineral openings pending additional studies. Robinson (1988) prepared an ACEC management plan, which identified stipulations for protecting traditional calving areas. Final decisions regarding the movement route have not been made.

Objectives of this project were to (1) determine population status and trend of the Galena Mountain Caribou herd and (2) delineate herd boundaries, sesonal use areas, and movement routes on BLM land. This information was necessary to determine impacts from potential conflicting land uses. In addition, caribou survey data could be used to set hunting seasons and bag limits. This paper constitutes a final report for this prosject.

Study area

Caribou wintered in the Koyukuk Flats and summered in the Kokrines Hills (Fig. 1). Elevations ranged from 60 to 1,517 m. The Koyukuk Flats was a broad valley characterized by extensive wetlands, lichen crusted taiga, and black spruce *(Picea mariana)* forests. The Kokrines Hills were covered by mixed forest and scrub vegetation at lower elevations, while higher elevations were covered by alpine and subalpine vegetation. Key wildlife species for this area were waterfowl, raptors, furbearers, wolves *(Canis lupus)*, black bear *(Ursus americana)*, grizzly bears *(Ursus arctos)*, moose *(Alces alces)*, and caribou. More detailed information can befound in the Proposed Resource Management Plan, Final Environmental Impact Statement for the Central Yukon Planning Area and the Koyukuk National Wildlife Refuge Final Comprehensive Conservation Plan, Environmental Impact Statement, and Wilderness Review (BLM 1986a, FWS 1987).

Methods

We counted caribou to establish population size during October from 1983 to 1986 and 1988. Calving areas were examined during late May from 1985 to 1989. We looked for post-calving aggregations during June from 1987 to 1989. In April 1986, we captured and fitted four with ra-

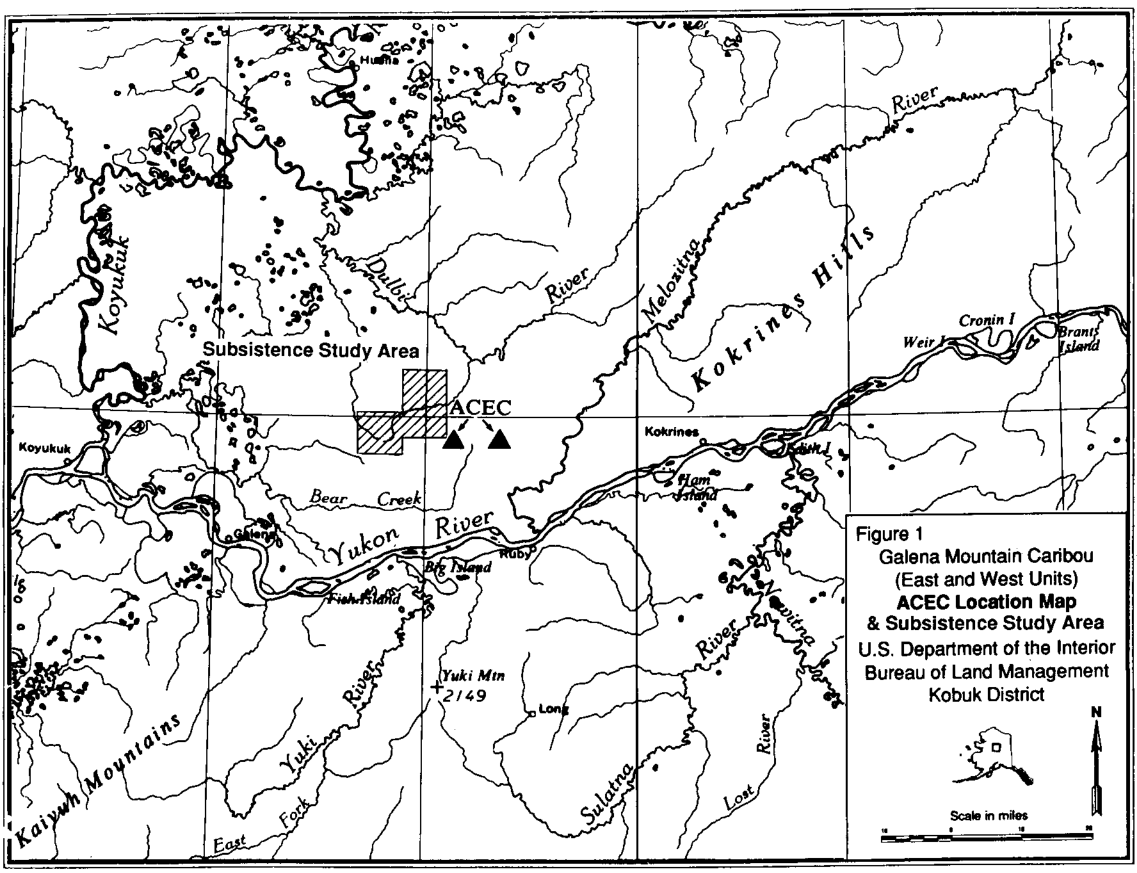

Figure 1
Galena Mountain Caribou
(East and West Units)
ACEC Location Map
& Subsistence Study Area
U.S. Department of the Interior
Bureau of Land Management
Kobuk District

Table 1. Radio frequencies, sex, dates collared, last date of location, and number of relocations of radio-collared caribou in the Galena Mountain Herd, 1986-90.

Radio frequency	Sex	Date collared	Date last location	Number of relocations	Notes
151.831	M	04/09/86	03/30/88	11	Mortality
151.820	M	04/09/86	11/25/88	17	Mortality
151.870	M	04/09/86	09/07/89	24	
151.841	F	04/09/86	01/24/90	26	
151.900	F	03/23/87	03/30/88	8	Mortality
151.850	F	03/24/87	06/27/88	11	Mortality
151.861	F	03/23/87	09/07/89	18	
151.881	F	03/23/87	09/07/89	20	

dio-transmitting collars (Telonics Inc., Mesa, Arizona) and four more caribou in March 1987 for at total of eight caribou (Table 1). Using either a Piper Super Cub or single-engine Cessna, we flew 34 monitoring flights from April 1986 to January 1990. Animal locations were plotted by latitude, longitude, and legal location on 1:63,360 and 1:250,000 scale quadrangles. Habitat data was described by broad vegetative type, landform, and elevation. We also recorded the animal's activity and group size. ADFG and FWS assisted with data collection.

Results

Poulation status and trend

Our total observed caribou numbers ranged from 17 in May 1989 to 258 in June 1987 (Fig. 2). The highest caribou counts during October were 184 and 185 in 1984 and 1985, respectively. The proportion of newborn calves observed during the May calving period ranged from 0 to 28% (mean=10%) whereas it ranged from 4 to 17% (mean=13%) in October. We estimated the total population to be 500 caribou: the product of 250 for mostly cows and calves observed in June 1987 times 2 for unseen bulls. This is equivalent to a density of 0.11 caribou per sq.km. These numbers do not include 100-200 caribou (probable members of the Wolf Mountain Caribou herd) seen with a GMH cow on the calving area near Wolf Mountain.

We collected trend data during the first three Octobers of this study, but caribou were difficult to track and locate during October 1986 and 1988 and no surveys were attempted during October 1987 and 1989. Therefore, we were hesitant to describe population trend for this herd.

Distribution and movements

We determined the home range, covering 4,648 sq.km, of GMH caribou from 135 observations of 3 male and 5 female radio-collared caribou (Fig. 3). Cows occupied winter range in the Koyukuk Valley from October through February, while bulls remained through April or May. In November 1988, one collared GMH caribou mixed with approximately 3,000 caribou of the Western Arctic Caribou Herd. Ninety-two percent of our cow observations and 88% of the bull observations were in the coniferous forest. Eight percent of our cow and bull observations were in mixed forest. The 4% balance of bull observations were in scrub habitat (Table 2). Elevations of the valley floor were 60 to 90 m.

Pregnant cows began moving to higher summer range during March and April, while barren cows stayed behind through May. Bulls also

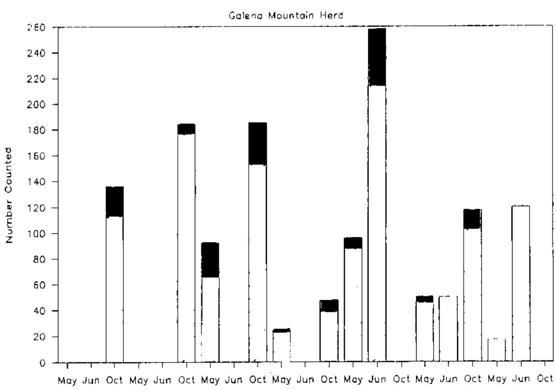

Fig. 2. Aerial counts of 1983–89.
☐ Adults ■ Calves
(Caribou were difficult to track and locate during October 1986 and 1988. Animals were neither sexed nor aged during surveys conducted June 1988 and 1989).

Table 2. Number of radio-collared GMH caribou observed by habitat during different seasons of the year, 1986-90.

	Females			Males		
Habitat	Oct-Feb	Mar-Apr	May-Sep	Oct-Apr	May	Jun-Sep
Conifer	11	13	6	21	5	5
Hardwood	0	0	3	0	0	0
Mixed forest	1	0	3	2	0	3
Scrub	0	0	2	1	0	1
Tundra	0	8	22	0	4	5
Snow field	0	0	3	0	0	0
No data	0	6	4	0	3	3
Total	12	27	43	24	12	17

waited until May before moving to higher country. During March and April, 48% of our cow observations were in the coniferous forest and 30% were on open tundra. Elevation of these cows ranged from 60 to 980 m (mean=315 m). During May, bulls demonstrated a similar pattern with 42% of our observations in the coniferous forest and 33% on open tundra (Table 2). Elevation of these bulls ranged from 60 to 670 m (mean=302 m).

We identified 2 separate calving aeas in the Kokrines Hills. Pregnant cows were on their respective calving areas during the latter half of May. The calving area west of the Melozitna River, covering 83 sq. km, was consistently used by 2 of the 5 collared cows. Elevation of our observations ranged between 430 and 850 m (mean=640 m). The other calving area east of the Melozitna River, covering 91 sq. km, was consistently used by 1 of the 5 collared cows. In 1987, this cow travelled 121 km, point to point, from her previously known location in the Koyukuk Valley. In 1988, she travelled 127 km, point to point, from a known location in the Koyukuk Valley. Elevation of our observations ranged between 760 and 1,160 m (mean=945 m). Cows of the adjacent Wolf Mountain Caribou Herd also used this same calving area. The other 2 cows either remained on their winter range or moved into the hills, but outside of the calving areas. These 2 cows did not calve during our period of observations.

Observations of post-calving aggregations during June were within or adjacent to the respective calving areas. During the balance of summer, cows roamed throughout the high country. From May through September, our cow observations switched from mostly forest (28%) to open (63%) habitat (Table 2). Elevation of these observations ranged between 180 and 1,160 m (mean=622 m). from June to September, bulls were more restricted than cows in their movements. For example, collared bulls did not follow the cows across the Melozitna River. They also occupied 4 habitat types whereas cows utilized 6 different types. During this time period, 47% of our bull observations were in coniferous and mixed forests whereas 35% were in open tundra and scrub habitats (Table 2). Elevation of these observations ranged between 240 and 850 m (mean=471 m).

We discovered a small portion of summer range, covering 149 sq. km, that bulls and cows consistently used from March through September. This special area, which lies within and adjacent to the calving area west of the Melozitna River, had the greatest number (20%) of all collared caribou observations. This special area is larger than the designated east unit ACEC. Also, we never observed any calving activity in the designated west unit ACEC on Galena Mountain.

Management concerns

Present activity

There are neither historic nor current mining claims in or near the calving areas. Therefore, geologists have reasons to believe that this area has low potential for occurrence of metalliferous minerals. The BLM lands within the home range of GMH caribou are currently closed to mineral leasing because of Public Land Order 5251, but the Central Yukon Resource

Management Plan will open these lands to leasing when fully implemented (BLM 1986b).

Analysis of the fire records from 1955 through 1986 revealed that 34 fires occured on winter range, 16 fires on summer range, and none on calving areas. The size of these fires ranged from less than 0.1 to more than 2,023 hectares; 80% were less than 4 hectares. The size of these fires was influenced by fuel type, weather, and suppression action taken at the time of the fire. Caribou reserchers have had differing opinions on impacts to caribou from wildfire (Bergerud 1980, Shideler *et al.* 1986). While some researchers base their conclusions upon destruction of lichens and a long regeneration time period of this valuable forage, other reasearchers base their conclusions upon maintenance of habitat heterogeneity, recycling of nutrients, and revitalization of sedges, forbs, and shrubs. Because of the study area' s fire history, caribou' s ability to move to unburnt lichen range, and the positive benefits to habitat in general, wildfire can do more good than harm to all wildlife inhabiting this study area.

Sport and subsistence hunters have harvested GMH caribou from August 10 to September 30; the bag limit was 1 caribou (ADFG 1990, FWS 1990). From 1981 to 1988, 0 to 6 (mean = 1) caribou per year were taken (Osborne 1990). Because of the mixing of GMH with WAH caribou on winter range, the Alaska Board of Game allowed emergency hunting seasons in December since 1988. The Federal Subsistence Board decided in 1991 to allow additional winter hunting. These actions are mostly intended for WAH caribou, but some albeit an unknown amount of GMH caribou could be harvested. Excessive harvest of GMH caribou wold be detrimental to its population size.

Subsistence use within the home range of GMH caribou is primarily winter trapping with some caribou and moose hunting by people from the villages of Galena and Huslia. BLM (1986b) identified 233 sq. km located north and west of the Galena Mountain (west unit) ACEC as a subsistence use study area because of suspected but unsubstantiated caribou movement routes (Fig. 1). Although the present

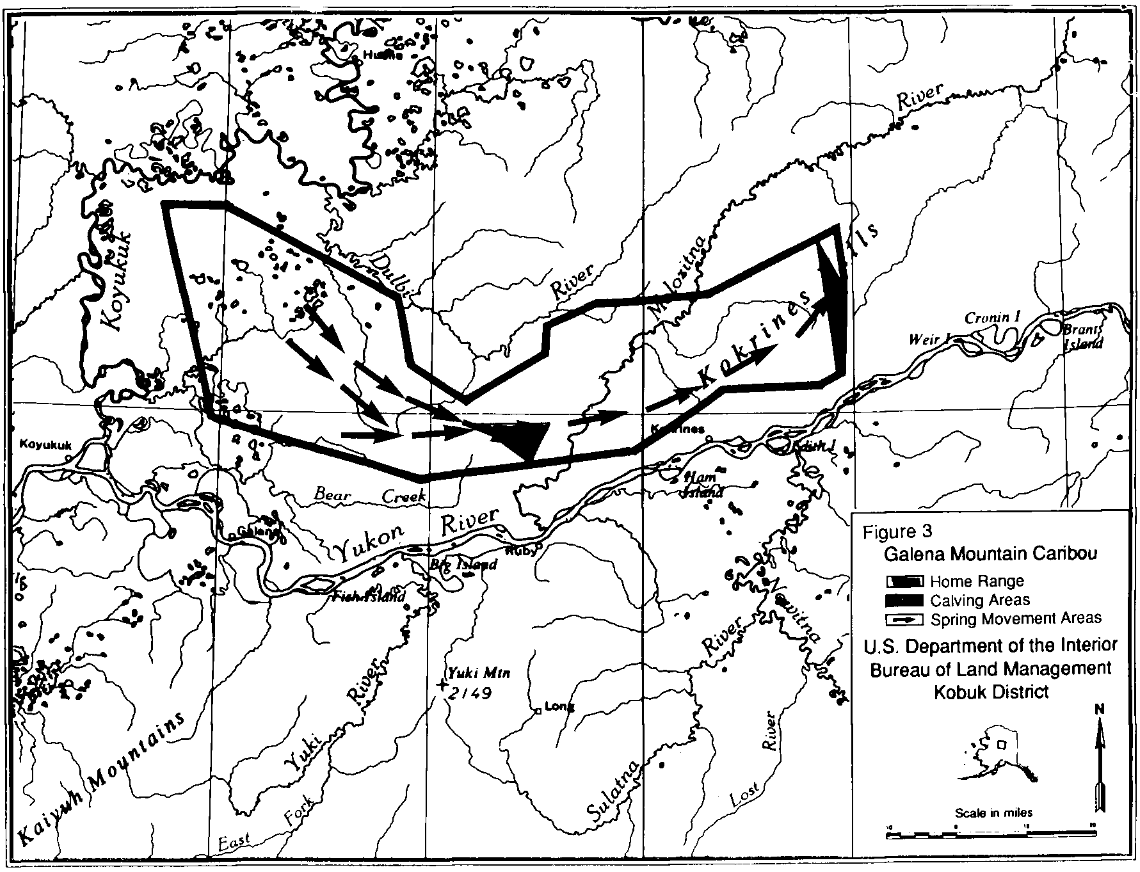

Figure 3
Galena Mountain Caribou

study identified caribou moving through this subsistence use study area during spring, Douthit (1991) recommended these townships be open to mineral entry and location, leasing for oil and gas, and other land use activities. However, each proposed action would have a Section 810 (a) evalution and finding conducted before being permitted, and appropriate stipulations protecting subsistence uses and resources would be applied as necessary (BLM 1986b). Such activity would not likely affect caribou calving areas, nor would such activity likely restrict any subsistence use or resource.

Future activity

BLM (1986a) described exploration and development scenarios for different mining operations. Because of the ACEC designation, an individual environmental analysis would be conducted for any proposed action. If mineral development occurs, then habitat loss would result from construction of new roads, airstrips, drilling pads, and camp facilities. Forage production that is immediately adjacent to these facilities would be reduced due to changes in snow accumulation, surface water distribution, roadside dust, and gravel spray. In comparison to the total available area, these surface disturbances would be minimal in size and impacts to caribou would be insignificant. However, if these disturbances occured within the calving and special areas identified during this study, then the impacts could be significant.

A human activity increases within the home range of GMH caribou, so does the possibility for disturbance to caribou. Behavioral avoidance of presently occupied habitat by caribou would cause an effective loss of habitat. This indirect loss of habitat would be greater than the direct loss described above. Maternal groups of caribou appear to be the most sensitive during the calving and post-calving period, May 5 through June 30 (Gilliam and Lent 1982, Bishop 1988). Therefore, human activity in the calving areas should be avoided during this period (Bergerud 1980).

Visual and auditory stimuli from aircraft, especially helicopters, associated with increased mineral exploration and development can be a major cause of disturbance. Possible impacts are decreased energy intake because of interruptions to grazing, accelerated energy expended while trying to escape, injury or mortality to young animals due to stampeding, and separation of the cow-calf bond (Shideler *et al.* 1986). Although harassment by aircraft is not legal, individual caribou exposed to aircraft can habituate if it is not perceived as threatening (e.g. associated with hunting) (Valkenburg and Davis 1985).

The BLM prepared an ACEC management plan for directing actions in this study area (Robinson 1988). The management actions for protecting crucial calving areas from undue and unnecessary habitat alterations and disturbances should include the special area identified during this study. Because we never observed any calving activity in the designated west unit ACEC on Galena Mountain, management restrictions could be lifted unless future observations identify calving activity.

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Foraging dynamics and woodland caribou: A winter management conundrum

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Abstract: Research, primarily on the endangered Selkirk woodland caribou population has enabled biologists to answer many of the basic ecology questions pertaining to caribou in high snowpack ecosystems. Data have been collected on habitat selection (Freddy 1974; Scott and Servheen 1985; Simpson *et al.* 1985; Rominger and Oldemeyer 1989; Warren 1990), food habits (Freddy 1974; Scott and Servheen 1985; Simpson *et al.* 1985; Rominger and Oldemeyer 1990), arboreal lichen biomass (Stevenson 1979; Detrick 1984; Rominger *et al.* submitted), tree density in subalpine forests (Rominger and Oldemeyer submitted), and arboreal lichen nutritional quality (Antifeau 1987; Robbins 1987). Specific knowledge that is lacking for caribou winter nutritional ecology includes: forage intake rates during winter and the constraints upon this process. The interrelationships of snow depth, aspect, lichen biomass within vertical strata of trees, daily intake, constraints upon this intake, and tree density in relation to both forage dynamics and potential predator detection combine to make this process very complex. The nearly monophagous late-winter diet reported for woodland caribou in these high snowpack ecosystems affords a unique opportunity in wild ungulate ecology to recreate an accurate facsimile of diet choices in a laboratory setting. We preopose a dissertation research project to test specific hypotheses related to late-winter foraging ecology using pen-raised woodland caribou at Washington State University.

Rangifer, Special Issue No. 7: 123

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Forestry and caribou in British Columbia

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Abstract: Forest harvesting in mountain caribou range has been an issue for many years. Radiotelemetry studies on mountain caribou in the last decade have helped identify the geographic areas of conflict, improved understanding of the mechanisms by which forestry activities affect caribou, and suggested new approaches to management. Forest harvesting has begun to impact population of northern caribou, and researchers have begun to examine those impacts. Interest in integrating forest management and caribou habitat management has increased and has manifested itself in two ways: experimentation with special stand management practices intended to maintain or create caribou habitat, and the creation of tools to help managers make decisions in a landscape context.

Keywords: *Rangifer,* caribou, British Columbia, habitat management, forestry, forest management, conflicting interests.

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Introduction

In the last decade researchers and managers concerned with caribou/forestry issues in British Columbia have seen major changes in the information base available to them and in the problems they confront. Mountain caribou in southeastern British Columbia have been the subject of a number of telemetry-based studies (Antifeau 1987; Simpson and Woods 1987; Rominger and Oldmeyer 1989; Servheen and Lyon 1989; Watts 1989; Seip 1990; Seip 1991). In west-central and northern British Columbia caribou/forestry issues have developed recently. There have been only two major caribou studies in that part of British Columbia (Hatler 1986; Cichowski 1989), and only the latter is directly related to forestry concerns.

The last decade has also seen a shift in how British Columbia biologists think about the natural regulation of caribou populations. Ten years ago, biologists were polarized into two camps - one that stressed the importance of predation in limiting caribou populations, and one that stressed the importance of habitat. Today, biologists are more likely to think of caribou as part of complex predator/prey/habitat systems. There is a general recognition that the major habitat variable affecting caribou numbers is space. The use of large home ranges allows caribou to select habitats offering acceptable combinations of snow conditions and food availability, select habitats that have given them an advantage over predators, and reduce their vulnerability to predators by dispersing themselves widely. There is also a reluctant, but increasing recognition on the part of managers that it may be counterproductive to try to maintain caribou and manage for high moose populations in the same area.

The objective of this paper is to discuss current efforts to maintain large areas of suitable habitat for caribou in British Columbia, in the face of an increasing demand for timber. I describe habitat use by caribou in British Columbia and identify some of the key habitat attributes that are important to maintain. Then I discuss experimental management practices that may help maintain or recreate those habitat attributes, and describe efforts to manage within a landscape context. This paper is based in part on results of recent research and new management ideas that were discussed at the British Columbia Caribou Conference held in Prince George in November 1990.

Habitat use by caribou in British Columbia

The distribution of the three ecotypes of woodland caribou that occur in British Columbia has been described by Edmonds (this publication). The «mountain/arboreal» animals of the southeastern and east-central portion of the province are generally known in British Columbia as «mountain caribou». The «mountain/terrestrial» type of west-central and northern British Columbia is often described as «northern». The «boreal» ecotype, which is not discussed here, is sparsely distributed in the northeastern corner of British Columbia, and is known largely from studies undertaken outside the province.

Mountain (mountain/arboreal) caribou

Most of the mountain caribou of high-snowpack ecosystems in the southeastern quadrant of British Columbia make altitudinal migrations, and some make horizontal seasonal movements as well. Their summer/fall ranges are located at high elevations, either above or below timberline. Many caribou migrate to summer ranges that are higher and more rugged than their winter ranges, while others use areas that are similar to winter ranges. Conflicts with forestry over summer/fall ranges are minimal.

Early winter ranges are mature timber stands that are lower in elevation than summer ranges and often located in areas of more subdued topography. During early winter, caribou feed on low evergreen shrubs and other vascular plants, and on arboreal lichens available on blowdown and as litterfall. The habitat attributes thought to be most important to caribou on early winter ranges are arboreal lichens, litterfall and blowdown, and, to a lesser extent, snow interception and vascular forage (Stevenson *et al.*, this publication). The absence of habitat attributes attractive to moose might also be considered a key habitat attribute for caribou, as range overlap with moose during early winter as likely to increase the vulnerability of caribou to predation. Nearly all early winter ranges are commersial forest stands.

As the snowpack becomes more supportive later in winter, caribou increasingly use opencanopied mature stands on high subalpine plateaus, where the snow is typically 2-3 meters deep. During this period, arboreal lichens, available on the lower branches of standing trees, are the major forage item and a key habitat attribute. Freedom form access development is also important, not only because heavy recreational use may cause caribou to abandon winter ranges (Simpson 1988), but also because of the risk that ploughed roads or packed trails may be used by wolves to gain access to high-elevation winter ranges. Some winter ranges are above the elevation of merchantable timber, but many are subject to forest harvesting.

In April and May, some caribou remain at high elevations, but many move to lower elevations, where green forage is available. There is more use of disturbed sites, such as avalanche tracks, road cuts, and clearcuts, during spring than during other seasons. Many spring ranges are in merchantable timber types. The impact of forest harvesting on spring range use is poorly understood. The presence of clearcuts in spring range does not seem to affect caribou adversely, but once the clearcuts have developed into closed-canopy seral stands, they are likely to be non-habitat, and may even constitute barriers to movement.

Calving generally takes place near snowline. No impacts of forestry activities on calving habitat have been identified.

Thus, the major conflicts between forestry and mountain caribou habitat are in winter ranges. Concerns that apply to all seasonal ranges are the potential effects of access and habitat fragmentation, especially where ranges are separated by immature stands.

Northern (mountain/terrestrial) caribou

Northern caribou inhabit the mountains and high plateaus of west-central and northern British Columbia. Snowfall is lower than in southeastern British Columbia, allowing the animals to crater for terrestrial forage under most winter conditions. The following comments on seasonal habitat use are based largely on the work of Cichowski (1989).

Summer ranges for northern caribou are typically alpine or subalpine, although some animals in some populations use low elevations. Forestry conflicts with summer ranges have not been identified.

Northern caribou exhibit two major patterns of winter habitat use. For most northern caribou, the primary winter habitats are mature lodgepole pine or pine/spruce forests with abundant terrestrial lichens. Caribou select feeding sites with high terrestrial lichen abundance. The lichens are most abundant on sites with well-drained soils, either in dry meadows or in open-canopied forests older than about 80 years. Younger forests are avoided. Dry meadows are used when snow depths are low or moderate, but not when snow is deep.

Arboreal lichens are also used by northern caribou, but the degree of use is unclear. The fecal fragment data of Cichowski (1989) suggest about equal use of arboreal and terrestrial lichens during winter, whereas the feeding site data suggest more use of terrestrial lichens. It seems likely that the importance of arboreal lichens varies among populations and among years. Arboreal lichens are used more in stands where spruce is present than in pure pine stands. The major conflicts with forestry are centred on low-elevation winter ranges.

Northern caribou also use alpine slopes with low snow accumulation during winter. One population regularly winters in alpine habitats. More commonly, the alpine is used by a small proportion of caribou throughout the winter, or by many caribou for short time. Sometimes caribou move to the alpine when snow conditions below treeline restrict their ability to move around or to forage (Hatler 1986).

During spring migration, northern caribou tend to use low-elevation movement routes and to feed on green vegetation in openings. Some use of clearcuts in spring has been reported. In some populations, nearly all the calving is at high elevations, but in other populations some cows calve at high elevations while others disperse throughout forested habitats.

Thus, for northern caribou the major overlaps with forestry activities occur on low elevation winter range, and on spring range. Habitat fragmentation and access are concerns for managers of northern caribou, as they are for managers of mountain caribou.

Management responses to accelerated logging in caribou range

Mountain caribou

Forest harvesting has been under way in mountain caribou habitat for many years, and has been perceived as a problem for many years. Until recently, many managers expected that large areas of low-value timber would remain unlogged for some time, providing a stable core of caribou habitat. Today, managers have observed changes in the rate of cut, the elevation of the cut, and merchantability standards that have caused them to alter their expectations. More than fifty percent of the timber volume that has been harvested in interior British Columbia since 1911 has been harvested in the last thirteen years (data compiled by R. Traves from Ministry of Forests Annual Reports, 1911-1990). In some drainages, first-pass logging has been completed at lower elevations and much of the planned logging is in high-elevation caribou ranges. Harvesting is now in progress in stands that were considered unmerhantable a few years ago, such as decadent cedar *(Thuja plicata)*-hemlock *(Tsuga heterophylla)* types and high-elevation subalpine fir *(Abies lasiocarpa)* types. Most managers concerned with habitat protection for mountain caribou no longer feel confident that there will be enough marginal or remote timber to support caribou.

Where logging has been proposed in important winter ranges, some managers have tried to institute reserves. Until recently, reserves have generally been either small or short-lived. In 1990, a landmark event occurred when a Ministry of Environment team succeeded in getting a consensus agreement for the Ministry of Forests at the regional level to the removal of a sizable area from the commercial forest land base for a 20-year period. The terms of the agreement are being observed locally, pending approval by the Chief Forester.

Another response to accelerated logging has been to try the develop management practices and strategies that allow timber harvesting and also maintain habitat values for caribou. A variety of partial cutting techniques are being used experimentally in mountain caribou habitat. The residual stand of lichen-bearing trees continues to provide forage for caribou, though at a reduced level, and also provides lichen fragments to colonize the regenerating trees. Other special management techniques are being used to recreate caribou habitat in second growth.

These efforts to integrate forestry and caribou habitat management are described by Stevenson *et al.* (this volume).

Northern caribou

Forestry is a relatively new concern for managers responsible for northern caribou in British Columbia. Until a few years ago, nearly all the logging activity was remote from the core ranges of northern caribou. In 1990, government biologists identified five northern caribou ranges in which major logging developments were in progress or imminent, and several others in which moderate impacts were anticipated.

Studies of the impact of forestry on northern caribou also have a short history in the province. Cichowski's (1989) investigation of habitat selection and winter feeding ecology of caribou in west central British Columbia helped identify potential impacts. In 1989, biologists began to examine the effects of forestry practices on terrestrial forage lichens, and to investigate whether special management practices can maintain winter habitat. Permanent plots have been established in scarified and non-scarified clearcuts to determine how clearcutting and site preparation affect terrestrial forage lichens. Manual and aerial techniques for transplanting terrestrial lichens are being investigated. Small patches have been logged in lodgepole pine stands where vascular plants were overgrowing lichens to determine whether lichen production could be enhanced. Finally, the potential of leave patches to maintain terrestrial lichen forage and provide for lichen dispersal is being studied (Enns 1990).

Geographic aspects of caribou management

For both mountain and northern caribou, researchers and managers have begun to examine opportunities to use special management practices to maintain or recreate caribou habitat. These practices are experimental and it will be many years before their effectiveness in maintaining acceptable caribou habitat and surviving caribou populations is known. The success of special management practices may depend, in part, on how they are applied at the landscape level. Managers need tools that will help them decide not only what to do, but also where and when to do it.

In the Revelstoke area of southeastern British Columbia, the Ministry of Environment built on previous radiotelemetry studies to develop habitat maps and associated guidelines to meet management objectives for mountain caribou and moose. Simpson *et al.* (1988) defined seasonal habitats for both species, using criteria such as elevation, aspect and forest cover type that could be identified on available maps. The map units were polygons that were labelled with season of use and habitat type. For each map unit, detailed management recommendations included cut/leave ratios, guidelines for timber harvesting, and guidelines for silvicultural practices.

In west central British Columbia, a hierarchical mapping system has been developed for northern caribou (Cichowski and Banner 1990) based on biophysical mapping and radiotelemetry data (Cichowski 1989). The radiotelemetry data allowed the authors to evaluate the importance of the biophysical map units to caribou, and then to develop interpretive maps using a GIS system. The interpretive maps were used to derive Caribou Management Zones. This hierarchical approach allows managers to make decisions on a landscape level (for example, to identify a Management Zone which is to remain undisturbed) and also to make site-specific decisions by overlaying a map of caribou habitat types on a forest cover map.

Managers face several issues having to do with the geographic context of habitat management for caribou. Forest harvesting results in a mosaic of stands of different ages. There is uncertainty about whether the mosaic should be fine-grained or coarse-grained. Edmonds and Bloomfield (1984) reported that caribou in Alberta used clearcuts that were less than two hectares, but did not use larger ones. Eighty-seven percent of all feeding and bedding sites in openings were within 50 m of cover. They developed guidelines calling for small clearcuts, intended to mimic the kind of openings that caribou naturally use.

An alternative approach, used in Ontario, is based on the observation that caribou tend to abandon areas where forest harvesting occurs, and on the concern that forest harvesting alters predator-prey relationships to the disadvantage of caribou (Racey *et al.*, this publication). Accordingly, timber management guidelines for caribou under development in Ontario call for large areas - 100 km² or more - of continuous habitat to be maintained as winter range. Logging is consolidated into very large clearcuts, rather than dispersed over the landscape. This approach is intended to minimize roads, edge, and moose. Managers in British Columbia are considering how these ideas apply to local landscapes.

A second issue that concerns managers is uncertainty about the relationship between area of suitable habitat and numbers of caribou that can be maintained. Habitat managers have difficulty defending their requests for timber deferrals of special management over large areas to benefit caribou. Although it is not difficult to imagine the kinds of studies that would test hypotheses about habitat size and population size, the extensive manipulations that would be required have so far presented insurmountable obstacles.

A third problem faced by managers is the absence of a provincial policy identifying geographic areas in which caribou management is a high priority. Because the costs of conservative management for caribou are high, managers cannot expect to maintain caribou as a high priority species wherever it occurs. Managers need the mandate to make costly tradeoffs in some areas, and not to attempt them in others, and they need a rational basis for making those hard decisions. The issue is currently being addressed by a provincial Ministry of Environment committee.

Conclusion

Decisions about habitat management for caribou may involve significant departures from usual forestry management practices over large areas. These decisions will impact not only the forest industry, but also other wildlife species. Species which thrive on early seral stages and on edge, such as most game species, are likely to be displaced. Another recent development has begun to affect the context in which decisions about caribou research and management are made. As biodiversity becomes a greater public concern, biologists will be expected to create management strategies for caribou that also meet the needs of other «old-growth» species. The biodiveristy issue will add another dimension of complexity to decisions about the management of forested habitats to maintain caribou.

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The Mountain Caribou in Managed Forests Program: Integrating forestry and habitat management in British Columbia.

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Abstract: Caribou in southeastern and east central British Columbia generally use old-growth forests rather than clearcuts or immature stands. During winter, they subsist on arboreal lichens, which are most abundant in old growth. The Mountain Caribou in Managed Forests program was initiated to adress the question: can forest stands be managed, through silvicultural systems and habitat enhancement techniques, to provide both timber and caribou habitat? The program includes radiotelemetry, habitat capability mapping, habitat management trials, and development of an integrated strategy. The management trials are aimed at maintaining arboreal lichens and other key habitat attributes in managed stands. The strategy development component involves wildlife biologists and foresters in developing and implementing solutions to logging-caribou conflicts.

Key words: *Rangifer*, caribou, British Columbia, habitat management, forestry, partial cutting, conflicting interests.

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Introduction

The «mountain caribou» ecotype of the woodland caribou *(Rangifer tarandus caribou)* is widely but sparsely distributed throughout the mountains of southeastern and east central British Columbia (Stevenson and Hatler 1985). During winter the caribou use old-growth forests almost exclusively, feeding on the lichens *Bryoria* spp. and *Alectoria sarmentosa* that grow on mature trees (Antifeau 1987; Edwards and Ritcey 1959; Rominger and Oldmeyer 1989; Seip 1990; Servheen and Lyon 1989; Simpson *et al.* 1985). Habitat management for mountain Caribou has generally been directed at trying to protect old-growth forests from logging (Stevenson and Hatler 1985). Conflicts have arisen between habitat and timber managers, and are increasing as the demand for timber increases. In response, the Mountain Caribou in Managed Forests (MCMF) Program was initiated to address the question: can forest stands be managed, through silvicultural systems and habitat enhancement techniques, to provide both timber and caribou habitat?

Study area

Most MCMF activities take place within an intensive study area of about 19.000 km², located in the Fraser River watershed east of Prince Georg, British Columbia (Figure 1). Elevations range from about 600 to 2200 m. Biogeoclimatic zones occurring in the intensive study area are the Alpine Tundra Zone (AT), the Engelmann Spruce - Subalpine Fir Zone (ESSF), the Sub-Boreal Spruce Zone (SBS), and the Interior Cedar-Hemlock Zone (ICH). In the western portion of the intensive study area, which is characterized by subdued mountainous topography, the ICH is generally absent and the SBS occurs directly below the ESSF. In the eastern portion, where the topography is more rugged, the ICH occurs below the ESSG, and the SBS is restricted to valley bottoms below about 700 m. The major land use activity in the intensive study area is forestry. Most often, stands are clearcut, broadcast burned, and planted with spruce *(Picea glauca x engelmannii)* or lodgepole pine *(Pinus contorta)*.

The two broad physiographic types that oc-

Figure 1. Location of the intensive and extensive study areas of the MCMF Program.

cur in the intensive study area, the mountain and plateau types, also dominate other caribou ranges in southeastern British Columbia (the «extensive study area» in Figure 1). Of the two broad configurations of biogeoclimatic zones, the ESSF-ICH complex is typical of most of the extensive study area. Management strategies developed in the intensive study area apply, with some modifications, to caribou ranges throughout the extensive study area. MCMF is involved in several cooperative projects in the extensive study area.

Rationale

To design suitable habitat for caribou in managed stands, managers must understand the key attributes of stands that caribou use, the function of those attributes, and the circumstances under which they are important. We reviewed studies of radio-collared caribou in southeastern and east central British Columbia to identify the key attributes of forested ranges and their funcitonal importance (Stevenson 1989). We focused on caribou use of early and late winter ranges, because most conflicts with forestry were in those habitats.

The importance of the key attributes varies from one biogeoclimatic zone to another (Table 1). In the ESSF Zone, caribou feed mainly on arboreal lichens from standing trees in winter, although lichens from windthrown trees and litterfall are used when available. At lower elevations (the ICH and SBS Zones), there are fewer lichens on the lower branches of standing trees, and blowdown and litterfall are more important sources of lichen. Caribou may take refuge from deep, soft snow in the ICH, where snowfall is lower, snow interception is greater, and more rooted forage is available. Generally, caribou use the ICH-M more frequently in early winter than the ICH-P or the SBS (see Table 1). In all biogeoclimatic zones, caribou are believed to be affected by access development.

When managers design habitat prescriptions to sustain wildlife populations in the long term, they must provide the attributes that can be funcitonally linked to survival, regardless of whether those attributes are currently limiting populations. Thus, it is important to provide escape cover, even if predator numbers are currently low, and to provide forage, even if food is not currently limiting. Management practices exist that can enhance the habitat attributes shown in Table 1, but they need to be evaluated and incorporated into an overall strategy.

Program overview

The MCMF Program is a co-operative venture of the B.C. Ministry of Environment, Ministry of Forests and the forest industry. The five-year program (1988-1993) is administered by the Ministry of Environment in Prince George. It is directed by two Committees, each with representatives from the two Ministries and the forest industry. A Technical Committee reviews technical content and progress of the program. An Advisory Committee provides comment on program direction, oversees the development of an integrated management strategy for caribou habitat throughout southeastern and east central British Columbia, and recommends policy changes where necessary.

The goal of the MCMF program is to produce integrated management solutions to mountain caribou-mature timber management problems in southeastern British Columbia (Child *et al.* 1991).

Five objectives direct program development and delivery (Figure 2):

1. To determine numbers, recruitment and causes of mortality for caribou (Radiotelemetry component);

Table 1. Estimated importance of key attributes of caribou winter range in various biogeoclimatic zones.

Attributes	ESSF	ICH/ ESSF	ICH-M[1]	ICH-P[2]	SBS
Arboreal lichen produktion	H[3]	H	H	M	M
Blowdown and litterfall	L	H	H	M	M
Snow interception	NA	L	M	L	L
Rooted forage production	NA	L	M	L	L
Access management	H	H	H	H	H

[1] ICH in Rocky Mountain and Columbia Mountain Physiographic Regions
[2] ICH in Interior Plateau Physiographic Region
[3] L - low; M - medium; H - high; NA - not applicable.

2. To describe seasonal patterns of habitat use and selection (Radiotelemetry component);
3. To assess and map habitat capability for caribou (Habitat capability mapping component);
4. To develop methods to create habitat in managed stands (Habitat management component); and
5. To develop an integrated management strategy for long-term management of mountain caribou and timber in consultation with forest managers (Integrated management strategy component).

Radiotelemetry

Seasonal habitat relationships and migrations are investigated through radiotelemetry. Knowledge of habitat use patterns by mountain caribou facilitates integrating habitat needs of caribou in forest developments plans, prioritizing seasonal ranges of caribou in forest management planning, identifying core caribou management zones, and selecting sites for special forest management trials. The presence of radio-collared animals permits studies of population dynamics, herd productivity, and identification and quantification of important morality factors.

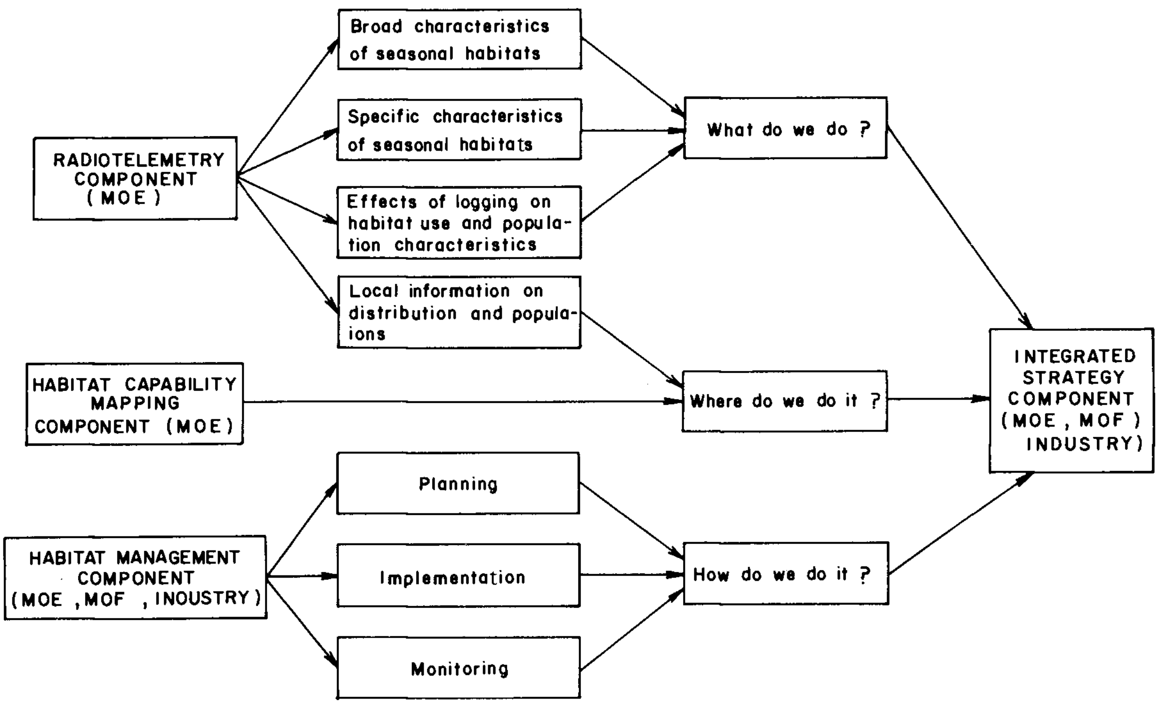

Figure 2. Interrelationship of program components for development of an integrated strategy for caribou and timber.

In addition, the radiotelemetry component has assisted in a more detailed study of micro-habitat selection by mountain caribou in winter in which caribou are tracked on the ground after initial radio relocation (Terry and McLellan 1991). This study was initiated by the B.C. Ministry of Forests (Research Branch) with two main objectives:

The first objective is to provide knowledge of winter habitat selection using micro-habitat characteristics, such as forest stand attributes, lichen abundance and snow conditions, as key attributes affecting caribou use. Using these attributes, the study focuses on two hierarchial levels of habitat selection:

(i) a broader level focusing on selection of foraging areas within the Engelmann Spruce-Subalpine Fir biogeoclimatic zone (ESSF) where mountain caribou are known to spend the winter (Child *et al.* 1991), and;

(ii) a smaller scale focusing on selection of micro-sites within caribou foraging areas.

The second objective is to compare micro-habitat characteristics of unmanaged stands used by caribou to characteristics of managed stands that have been harvested using partial cutting methods. A knowlegde of general habitat use patterns and micro-habitat use by caribou is important to the development of an integrated management strategy for mountain caribou in managed forests.

Habitat capability mapping
The mapping component improves the manager's ability to assess impacts of proposed resource developments on caribou habitats. Capability maps may be used to guide selection of a silvicultural system on a specific site. More importantly, these capability maps assist the manager to delineate core caribou management zones and facilitate decision-making where forest developments are being planned.

Habitat management component
The rationale for the special management practices that are being evaluated in the MCMF program was described by Stevenson (1990). The use of uneven-aged rather than even-aged stand management is a central focus of the program, because it may be possible through partial cutting to maintain the key habitat attributes at all times. Partial cutting leaves a residual stand of lichen-bearing trees that continue to provide forage for caribou, though at a reduced level, and provided lichens fragments to colonize the regenerating trees. A variety of partial cutting prescriptions are being tried, including modified diameter-limit cuts, selective harvesting to produce specific diameter distributions, and group selection systems.

Where caribou ranges are already in second growth, or where uneven-aged stand management is not an option, other management practices may be used to recreate habitat attributes. On some low-elevation ranges, thinning may improve the microclimate for lichen development and enhance the ability of the stand to intercept snow in the future. Midseral stands that already have som lichen may be thinned by girdling instead by felling. Girdling results in standing dead trees that provide a good substrate for lichen, and later a source of litterfall and blowdown. In young seral stands that are remote from a natural source of lichen dispersal, inoculation with lichen fragments may increase future availability of forage (Palmer 1987).

At present, four partial cut projects, one early thinning project, one girdling project, and one lichen inoculation project have been initated through the MCMF program, and several more partial cuts are planned. The program monitors the effects of the special management practices on lichen abundance and growth rates, the use of partial cuts by caribou, and silvicultural impacts. Although it would be desirable to monitor the response of caribou at the population level, it has not been feasible to set up a suitable experimental design.

Effects on lichen abundance
The clump method (Stevenson and Enns 1991) is used to estimate lichen abundance in the treatment and an adjacent control area, before and after partial cutting. A standard clump of lichen is used as a reference for estimating the number of clumps present below 4.5 m on the sample trees. This method gives results that are low in accuracy but relatively precise, providing the lower crowns are readily visible. The method is not precise enough to detect year-to-year changes in lichen abundance due to growth, but is suitable for assessing the major changes in lichen biomass that result from partial cutting.

Similar methods are being used to monitor lichen abundance in partial cuts in the winter micro-habitat selection study (Terry and McLellan 1991). Because of differences in stand structure, lichen abundance, and lichen distribution and the canopy, the clump method has been modified for use at the thinning/lichen inoculation site, and at the girdling site. Lichen litterfall is also measured at the girdling site.

Effects on lichen growth rate

Changes in canopy microclimate resulting from partial cutting may affect the growth rates of the residual lichens. A method has been developed that allows the biomass of living lichen clumps to be repeatedly measured. The study lichens are enclosed in mesh cages, which protect the lichens during transport, prevent them from being eaten by caribou, intercept litterfall, and trap fragments that become detached. Preweighed lichen clumps are attached with silicone seal to a stable substrate of borosilicate laboratory glass, which can be detached from the cage and weighed with the lichens. The lichens are suspended in their cages from trees at the study sites, except when they are brought into the laboratory to be air-dried and weighed. Because differences in relative humidity within a narrow range significantly affect biomass measurements of the lichens, correction factors for humidity are being developed (Armleder and Waterhouse 1991).

Growth rates of lichens are being measured at two partial cuts and the early thinning site.

Use of partial cuts by caribou

In addition to determining whether partial cutting can maintain key habitat attributes for mountain caribou, another important aspect of the management trials is to determine if caribou will use the area once it has been harvested. Partially cut blocks are being monitored for caribou use during the ground surveying of habitat characteristics and radiotelemetry flights (Terry and McLellan 1991, Child *et al.* 1991).

In the intensive study area impacts on caribou use are being addressed through the micro-habitat selection study. Key attributes of caribou use sites such as the distribution of tree diameter classes, lichen abundance, lichen species composition, tree vigour, as well as tree basal area, tree density and blowdown density are being compared to partially cut blocks to determine if caribou habitat has been maintained. Snow conditions including snowpack depths and snow types as well as caribou sinking depths are also being monitored to assess the impact partial-cutting may have on the dynamic relationship of snow conditions and forage availability.

Silvicultural impacts

Assessments of the silvicultural impacts of special management practices are critically important, but are outside the terms of reference of the MCMF program. Wherever possible, silvicultural assessments are carried out through cooperative agreements with the Ministry of Forests. Detailed silvicultural measurements are currently carried out at one site in the intensive study area, and one site in the extensive study area, both in the ESSF. A cooperative project including silvicultural assessments in the ICH is planned.

Integrated management strategy

The final objective of MCMF is to develop an integrated strategy for long-term management of caribou and timber. To direct the development of the integrated management strategy (IMS), seven further objectives have been identified:

1. To set geographic management priorities for mountain caribou populations at a provincial level;
2. To develop integrated forest and caribou management objectives;
3. To ensure the integrated strategy is adopted and implemented at all leves of the planning process;
4. To provide the tools necessary for the implementation of the management strategy;
5. To identify any external problems that hinders full implementation of an IMS and make recommendations for further action (e.g. research needs, policy changes, etc.);
6. To monitor the results of habitat management trials and caribou population status to provide feedback for the modification of the IMS; and
7. To develop an extension program (communication and training).

Because implementation of some of these objectives is beyond the terms of referene of the MCMF program, they have been rèferred to the Advisory Commitee, which has a provincial scope. Objectives 4, 6 and 7 are primarily the responsibility of MCMF.

A set of guidelines relating forest management practices to caribou habitat will be prepared by the MCMF program implementation in the central interior of British Columbia. The guidelines may be applicable to caribou ranges throughout the southeastern portion of the province, but their adoption is at the discretion of regional staff. The guidelines are a product of three component parts.

Firstly, specific geographic zones that are important to mountain caribou will be mapped. Those areas zoned to be of high importance (core caribou ranges) will be protected from logging impacts because of their sensivity, and uncertainty about the impacts of disturbance. Special management practices for caribou and timber will be recommended in medium zones, whereas areas zoned to be of low importance will be managed without special constraints due to caribou.

Secondly, management objectives for timber production and mountain caribou will vary from one site to another as management practices have different consequences on different sites. The guidelines will reflect the ecological classification system used by the B.C. Ministry of Forests for planning and development. The guidelines will indicate silvicultural systems (e.g. uneven-aged stand management) and management practices (e.g. group selection harvesting) that are compatible with caribou habitat values on various sites.

Thirdly, various management practices may be acceptable within a given caribou zone and biogeoclimatic subzone. Considerations that affect the choice of management systems and practices (e.g. stand composition and structure, blowdown risk, arboreal lichen abundance) will be discussed in the guidelines.

The guidelines are envisioned as a first approximation in a continuing program of adaptive management. Results of the habitat management trials may indicate that the guidelines should be modified.

As well as the guidelines, MCMF is preparing reference materials for lichen assessments. To plan for caribou habitat at the site level, managers need information about the abundance and distribution of arboreal lichens. Procedures to assess lichen abundance in association with timber cruises are being developed. A training manual providing photo illustrations of trees with known lichen abundance is in preparation. The results will be usefull to forest managers when planning timber harvesting and the wildlife managers when monitoring special harvesting treatments.

Conclusions

Because the MCMF program is still developing, and field trials are at an early stage, conclusions would be premature. The cooperative organizational structure of MCMF has the potential to replace interagency conflict over management of caribou habitat with at more integrated approach, and to establish a continuing program of adaptive mangement.

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Adapting sampling plans to caribou distribution on calving grounds.

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Abstract: Between 1984 and 1988, the size of the two caribou herds in northern Québec was derived by combining estimates of female numbers on calving grounds in June and composition counts during rut in autumn. Sampling with aerial photos was conducted on calving grounds to determine the number of animals·km^{-2}, telemetry served to estimate the proportion of females in the census area at the time of photography in addition to summer survival rate, and helicopter or ground observations were used for composition counts. Observers were able to detect on black and white negatives over 95 percent of caribou counted from a helicopter flying at low altitude over the same area; photo scale varied between ≈ 1:3 600 and 1:6 000. Sampling units covering less than 15-20 ha were the best for sampling caribou distribution on calving grounds, where density generally averaged ≈ 10 individuals·km^{-2}. Around 90 percent of caribou on calving grounds were females; others were mostly yearling males. During the 1-2 day photographic census, 64 to 77 percent of the females were present on the calving areas. Summer survival exceeded 95 percent in three summers. In autumn, females composed between 45 and 54 percent of each herd. The Riviére George herd was estimated at 682 000 individuals (± 36%; α = 0.10) in 1988. This estimate was imprecise due to insufficiens sample size for measuring animal density on the calving ground and for determining proportion of females on the calving ground at the time of the photo census. To improve precision and reduce cost, it is proposed to estimate herd size of tundra caribou in one step, using only aerial photos in early June without telemetry.

Keywords: caribou, census, aerial photography, Riviére George, Riviére aux Feuilles.

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Introduction

Accurate and precise population estimates facilitate sound wildlife management. For large mammals, aerial counts have been a technique used in various situations to estimate population size. Caribou *(Rangifer tarandus* L.) numbers were mainly derived from strip transects in the sixties and the seventies, although random plots and aerial photography also were used (Siniff & Skoog 1964; Parker 1975). More recently, oblique and vertical aerial photographs have been used, particularly for populations that spend part of their annual cycle on the tundra (Davies *et al.* 1985; Goudreault 1985; Heard 1985; Valkenburg *et al.* 1985; Whitten 1985). Photos have been taken when caribou occupy concentration areas, at parturition or during the following months.

In Québec, population estimates are now derived from vertical photographs taken over calving grounds during the first half of June (Goudreault 1985). Total population size is extrapolated from the number of females present on the calving ground, based on population structure during the following autumn (Heard 1985). A reconnaissance flight precedes photography to delineate boundaries of calving grounds. Because these areas cover many thousands of square kilometres, sampling is necessary. Study areas are stratified according to caribou density and photos are systematically spaced over strata, making it possible to estimate the total number of animals. Simultaneously, sex and age structure of caribou occupying the study area is determined by helicopter sampling because many yearlings and some adult males accompany females. These sex and age structures are used to estimate total number of ≥ 1 year-old females present on the calving ground. Total herd size is estimated during the following rut by cross-multiplication, using the ratio of females ≥ 1.5 years old/total number of caribou in autum, including calves.

Population sizes of caribou estimated by photographing the animals on the calving grounds exhibit variable precision and may be biased. Precision depends on the variability of animal disitribution over study areas, sample size, plot size, sampling fraction, accuracy of stratification and the precision of ratios used to convert the number of animals appearing on the photos into a total population estimate. On the other hand, final estimates may be biased if some animals remain undetected on photos, if snowdrifts or rocks are counted as caribou, if some females are located outside delineated calving areas as the time of the census and if mortality of females occurs between June and November. In this paper, we determine the best plot size when sampling with vertical photographs over calving grounds, we examine conditions necessary to obtain unbiased variance estimates and to achieve acceptable precision levels of estimates of population size, and we estimate correction factors necessary to eliminate bias.

Study areas

Data were collected on the Riviére George calving ground in 1984, 1986 and 1988 and on the Riviére aux Feuilles calving area in 1986 (Fig. 1). The first area covered 8.990, 15.300 and 22.860 km² in 1984, 1986 and 1988, respectively, whereas the Riviére aux Feuilles calving ground occupied 6.300 km². The Riviére George area lay mainly on a hilly plateau where the altitude range between 500 and 750 m, but also

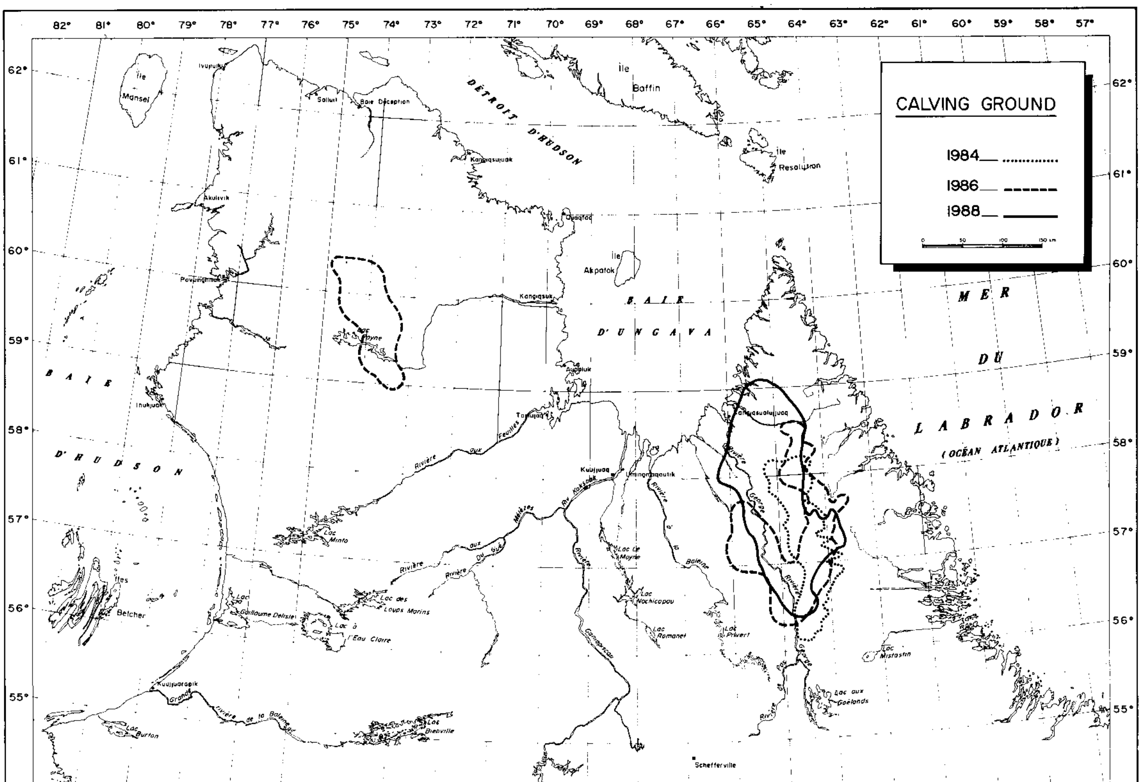

Figure 1. Location of the Riviére George (East) and Riviére aux Feuilles (West) caribou calving areas in northern Québec at the time of their photo census between 1984 and 1988.

covered some lowlands along the river. Barren-ground tundra is the most common cover type and occurs on the high watershed plateaux; forest tundra ecotone occupied tributary branches while lichen-forest occurs along the main river valley and at elevations below 400 m. The Riviére aux Feuilles calving ground, located north of the tree line, occupied a gently rolling plateau of barren-ground tundra averaging 225 m in elevation. Census of the calving ground was intended for the peak of calving. Based on limited information (Le Hénaff pers. comm., Crête *et al.* 1989), calving appears to occur during the first week of June at the Riviére aux Feuilles area, approximately 7-10 days earlier than on the other calving ground. At the time of photography, snow covered, 47, 39 and 34 percent, respectively, of the ground on the Riviére George area the first, the second and the third year, and 41 percent at the Riviére aux Feuilles ground.

Methods

Photography of calving grounds

A reconnaissance flight was conducted during the few days preceding the photography with a twin-engine DC-3 to delineate census areas. The aircraft, carrying one navigator and two observers seated on opposite sides, flew transectlines spaced at 13-40 km intervals, at an altitude of 200 m above the ground. Observers reported the approximate number of caribou seen; moreover the presence of newborn calves and adult females with hard polished antlers was noted as being typical of calving areas. The final boundary of the census area was drawn on the day of photography in 1984 and 1986, but during the reconnaissance flight in 1988.

Photographs were taken with a RC-5 (Wild) camera equipped with a calibrated 157-mm lens, mounted on the DC-3 aircraft. They were distributed systematically along transect lines as this type of allocation was much more practical than random sampling, while being statistically accepptable (Seber 1986). The airplane flew at relatively constant altitude so that the scale of photos varied between 1:3 650 and 1:6 130, as a result of irregular topography. The altitude above the ground was estimated at the centre of each photo with the help of the incorporated camera altimeter and 1:50 000 topographic maps, showing contour lines at 15.3 m intervals. The altimeter was adjusted at each roll change. Photos were taken at 20-25 second intervals to prevent overlap in frames. In addition, photographs were taken with a 35-mm camera (50-mm lens) installed on a Bell 206B helicopter in 1988 on the same day as the RC-5 camera was used. Thirty clusters of 10-20 photos were distributed randomly over the calving ground. The altimeter of the aircraft and topographic maps served to estimate the height above the ground at which photographs were taken.

During photography with the DC-3 aircraft, transect lines were spaced so that 800-1000 photos would systemativally cover each calving ground, requiring two days of photographing effort. Photography was restricted to two days, because animals are highly mobile at this time. Nonetheless, poor weather in early June often impedes aerial photography in northern Québec. As a result, the aircraft flew every second transect line to have a complete coverage of the census area at the end of the first day of work in the case of weather changes that would result in interference. The crew navigator, using the number of observed animals and notes taken during earlier reconnaissance flights, had the task of drawing the final boundary of the calving area and delineating two strata of caribou density during the photography.

At the laboratory, caribou were counted as transparencies on black and white negatives with a 3.5-15x stereoscope; newborn calves were not recorded. At 20x20 cm transparent grid, divided in 100 cells, was superimposed onto the negatives, which covered 23x23 cm, to facilitate the tally and to eliminate distortion at the periphery of photos. The area (A) covered by each photo (m^2) was estimated with the formula: $A = SxH^2/f = 1.274\ H^2$, where S represents the side of the grid (0.2 m), H the altitude above the ground (m), and f the focal distance (0.157 m).

Herd composition on calving grounds

Simultaneously with photography, the sex and age composition of caribou present on the census area was estimated by random sampling from a helicopter. Sampling-plots were rectangular (1x5 or 10 km) and they were flown over slowly to count caribou; animals were aged based on their size, as newborn calf, yearling or adult. Sex of adults could be ascertained by the presence of hard polished antlers for females and the observation of genitalia for antlerless caribou. Sex of yearling was determined by the presence of a vulva patch, which was often difficult to observe from the air because of the frequent clumping in large groups; sex ratio was then obtained from a subsample of easily observable animals.

Proportion of females on calving grounds and summer survival

The proporiton of ≥ 1 year-old females located inside the delineated calving group at the time of the census was estimated using radio-tagged animals. Caribou from the Riviére George herd have been equipped with radio collars since the autumn 1983 and monitored animals appear representative of the entire herd (Hearn *et al.* 1990). Their location was determined a few days before photography. This correction factor could be estimated for the Riviére George herd only, because at the time of the surveys, no animals in the other herd has been radio-collared. In 1988, radio-tagged individuals present in and at the periphery of the calving ground also were located on the day of photography. Telemetry also served to estimate survival between June and early November, as radio-collars had mortality sensors. Immobile radio-collars were generally recovered to confirm the death of animals (Hearn *et al.* 1990).

Autumn composition of herds

Sex and age composition of each herd was estimated in late October and early November. Sampling plots were randomly selected within the accessible area occupied by radio-tagged animals (mostly females) for the Riviére George herd and within the area believed to be used by the Riviére aux Feuilles herd during autumn. Sampling was stratified according to caribou density in 1988. All animals observed from on-ground vantage points in the course of approximately 1 hour were classified as calf, ≥ 1.5 year-old male or ≥ 1.5 year-old female, based on their size, body morphology and the presence or absence of a vulva patch.

Detectability of caribou on photos and scaling with body length

Proportion of caribou visible on photos was estimated by blind comparison of counts on 35-mm black and white negatives with on-site low-level helcopter counts over the same area. The 35-mm camera, installed through the floor of a Bell 206B helicopter hovering at an altitude of 340 m, was equipped with a 85-mm lens, so that photo scale was similar to the one obtained with the RC-5 camera. Each photo covered 1.2 ha. Immediately after taking the photograph, the helicopter, carrying 2 observers plus the pilot, flew at low-level over the same area to count all caribou (except calves). In 1986, 12 and 10 photos of different sites showing between 1 and 33 caribou were taken at the Riviére aux Feuilles and Riviére George area respectively; 30 additional groups were photographed in 1988. The caribou visible on these photos were counted by three independent observers, half-way through the processing of regular photos of each calving ground.

Unlike photos taken with the RC-5 camera, verifying the exactness of the estimated area covered by each 35-mm photo, as derived from the altitude and the focal distance with recognizable landmarks on topographic maps, was not possible due to the small area photographed. Nevertheless, the scale of 24 35-mm photos showing caribou was precisely determined with the help of two readings of a hand-held altimeter graduated at 3 m intervals; one done when photographing, the other on the ground in the centre of the photographed area. The scale equals the focal distance over the altitude (f/h). The length of each animal appearing on the photos was measured with a stereoscope and linear regression relating caribou length with the scale of the photo were computed using the procedure REG of SAS (SAS institute Inc. 1985). Five regressions were computed according to animal posture: standing still, moving, standing head bent, lying stretched, lying grouped.

Selection of optimal plot size on aerial photos

Relative net precision, assuming constant costs per unit, was used to select the optimal size of sampling plots for counting caribou on 20x20 cm aerial photographs (Cochran 1977:234). One subsample of 10 photos was randomly selected in each density stratum on the Riviére aux Feuilles and Riviére George calving grounds in 1986. Comparisons involved plot size covering 2, 5, 10, 20, 50 and 100 percent of the photographs. For each size, one reading was taken randomly per photo to estimate the variance among unit totals (s^2: Cochran 1977:234); variance estimates were corrected for the lack of independence between data sets (Cochran 1977:238). Average sizes of photographs varied between 0.62 and 0.80 km² according to subsamples.

Estimating of standard errors of means
To produce unbiased population estimates, each part of calving grounds must have an equal chance of being photographed. However the area covered by each photo varied between transect lines because of change in cloud cover and irregular topography. Results were then expressed in terms of density (caribou·km^{-2}) for each photo to reduce to minimum positive bias for transect lines flown at above average altitude.

Because we did not use systematic sampling in two dimensions (Cochran 1977:277) RC-5-photos along transect lines were much closer (≈ 1 km) than between transect lines (13-40 km: Fig. 2). The objection was raised that transect lines, not photos, constituted sampling units (D. Heard, pers. comm.), which supposes that within-transect variance is smaller than between-transects. We formed clusters of 10, 20 and 30 consecutive photos on the same transect line and we compared within and between cluster variance by means of a nested analysis of variance (Proc GLM:SAS Institue Inc, 1985). Comparison of within and between variance served to select cluster size producing unbiased variance estimates of mean caribou densities.

As, on the one hand, the select plot size was much smaller than total area covered by 1 RC-5 photo and, on the other, the scale of photos could not be enlarged because of equipment and aircraft constraints, stratified three stage sampling was selected to estimate the number of caribou occupying each calving ground (Cochran 1977:274). The cluster of photos made the primary units, the complete photo, minus margins (20x20 cm) represented the secondary units and an area covering 5 percent of the photo (2x10 cm) made up the tertiary unit. Preliminary computations on 1984 and 1986 data were conducted to estimate the gain in precision obtained when increasing the third stage sampling (f_3 = number of tertiary units counted per photo/20). Because precision increased little when doubling the sampling fraction from 0.5 to 1, caribou were counted on 10 tertiary units per photo (f_3 = 0.5), which saved manpower. In the case of 35-mm photos, the sampling plan was reduced to two stage sampling, the single photo being the secondary unit.

Because the area covered by each photo was variable, calculations of the mean density of caribou per calving ground (and its standard error:SE) had to integrate three stage sampling and ratio estimators (Cochran 1977:150). Separate ratios (y/x = caribou·km^{-2}) were calculated in each stratum as it is the most precise method (Cochran 1977:168), before a weighted density was estimated for total calving grounds. SE of ratios was estimated by computing s_y^2 and s_x^2 in Cochran' s (1977) formulae 6.13 with equation 10.16, and s_{yx} as $r(s_y^2\ s_x^2)^{1/2}$, where r is the coefficient of correlation between y_i and x_i.

Visibility rate of caribou on photographs and proportion of ≥ 1 year-old females on calving grounds and in autumn also were calculated by ratio estimators, as were SE. Proportions derived from telemetry (percentage of females located outside the calving ground and summer survival rate) were estimated, based upon the binomial distribution. Animals were widely spaced and the assumption of independence between individuals was acceptable.

At all steps of the computation to convert caribou densities on calving grounds to a total population estimate, variables were multiplied or divided together. There is a loss of precision associated with such operations, and resulting SE were estimated with formulae used by Créte *et al.* (1986). For compunting confidence intervals, a t distribution was used; when the estimate was the product of 2 random variables, the smaller of the degrees of freedom was taken (Gasaway *et al.* 1986). In the text, means are given with their SE and the sample size.

Results

Except in 1984, photograps could be taken only 1 day for each census due to bad weather. Moreover, a complete photo coverage of the Riviére George calving area was impossible in 1986 (Fig. 2), although the reconnaissance flight and helicopter observations made it possible to stratify south of the area. On the other hand, both series of photos taken in 1986 were slightly overexposed; this problem was partially corrected by using a new processing technique, but photo interpretation remained more difficult than in 1984 and 1988.

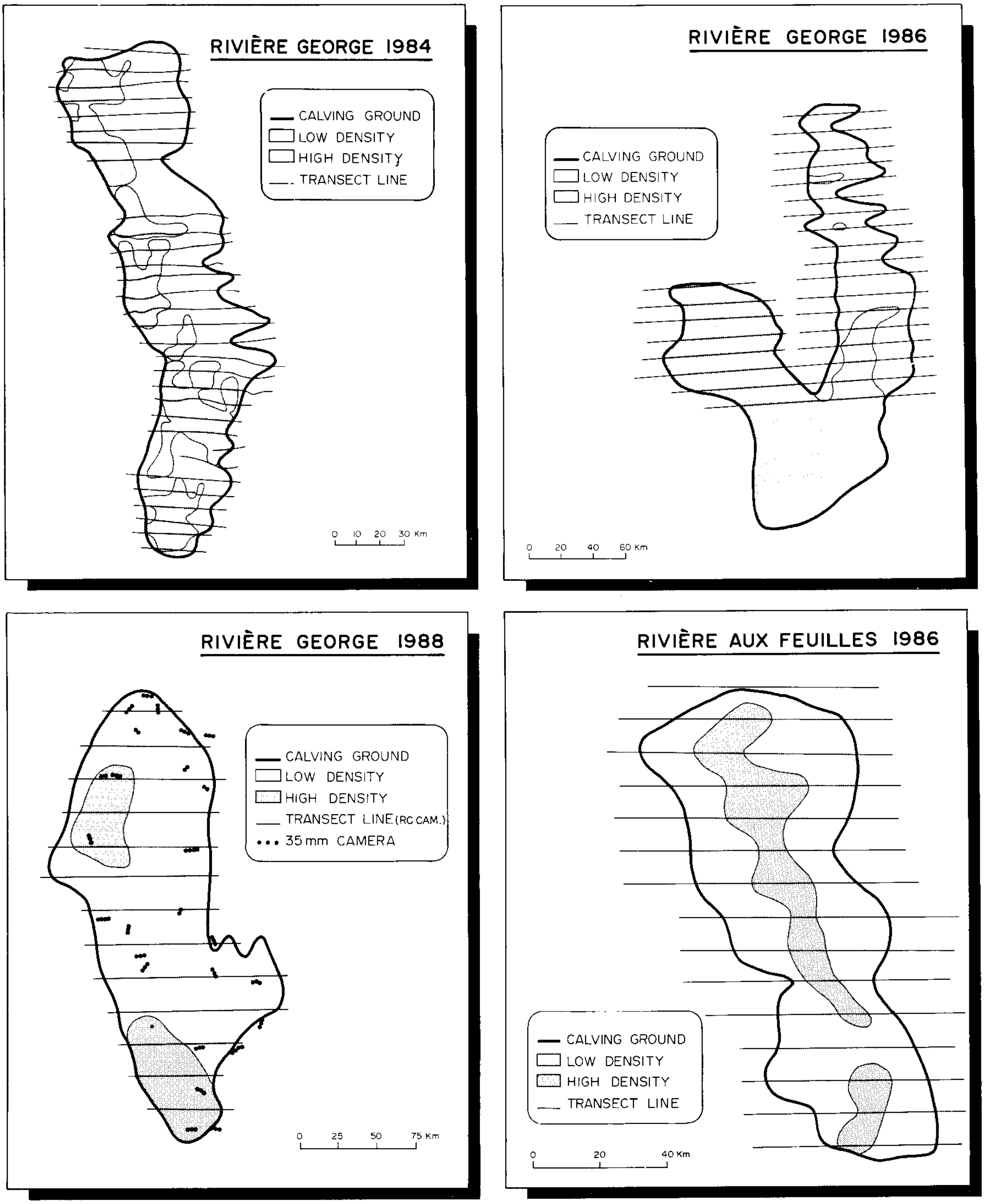

Figure 2. Transect lines along which RC-5 photos were taken over the Riviére George and Riviére aux Feuilles calving areas, and sampling plots used with a 35-mm camera in 1988, according to 2 strata of caribou density, northern Québec.

Selection of optimal plot and cluster size

Although caribou densities varied between the 4 subsamples of photographs, results were consistent (Table 1). In all cases, units covering 5 or 10 percent of the entire photo represented the best sampling area. For practical reasons, a rectangle covering 5 percent of the grid (2x10 cm) was selected as a compromise for third sta-

Table 1. Computation of the relative net precision (Cochran 1976:239) in order to select a sampling unit which, for a given effort, provided the best statistical precision when counting caribou on aerial photos. Riviére George and Riviére aux Feuilles calving grounds, June 1986. For a given row, the highest value of relative net precision indicates the best sampling unit.

	Area covered by 1 photo (km^2)	Number of photos	Caribou km^{-2}	Area covered by sampling units Percent photograph					
				2	5	10	20	50	100
Riviére George									
High density stratum	0.74(0.06[a])	10	11.4	187	303	153	151	100	143
Low density stratum	0.80(0.05)	10	5.0	114	166	125	145	130	100
Riviére aux Feuilles									
High density stratum	0.62(0.04)	10	14.4	325	350	400	350	200	100
Low density stratum	0.64(0.02)	10	5.4	100	141	326	193	228	170

[a]SE

ge plot size when using RC-5 photos. As 35-mm photos covered a few hectares each, they were of adequate size as secondary units when sampling with this type of camera.

Caribou density on consecutive photos along transect lines was more homogenous than that on different lines. Although short transect length often precluded forming clusters of 20 or 30 consecutive photos, comparison of within and between cluster variance (Table 2) helped to select the number of photos per cluster: we chose 20 for the Riviére George area in 1988 and 1986, and 10 for the two other cases.

Table 2. Results (F-values) of an analysis of variance for caribou density on aerial photos taken along transect lines and grouped in clusters of 10, 20 or 30 consecutive photos. The model was: density = line cluster (nested in line). When the ratio F-line/F-cluster approaches 1, it indicates that within and between cluster variability is comparable. Photos taken over the Riviére George and Riviére aux Feuilles calving areas between 1984 and 1988 according to 2 density strata.

Area	Number of photos per cluster					
	10		20		30	
	Line	Cluster	Line	Cluster	Line	Cluster
Riviére George 1988						
High density	13.10	2.35	10.46	0.84	–[a]	–
Low density	.[b]	.[b]	13.41	6.27	13.38	16.73
Riviére George 1986						
High density	5.88	2.91	7.16	6.12	–	–
Low density	5.55	0.61	–	–	–	–
Riviére George 1984						
High density	1.74	3.79	–	–	–	–
Low density	1.87	1.09	–	–	–	–
Riviére aux Feuilles 1986						
High density	–	–	–	–	–	–
Low density	3.93	4.49	–	–	–	–

[a] Insufficient sample size
[b] Not computed

Detectability of caribou on photos and exactness of scale

There was good agreement between the number of caribou counted on photos taken from the helicopter and visual counts made from the same aircraft when flying over the same area at low altitude (Table 3). In general, visibility exceeded 95 percent; small sample size, including a few photos which contained trees, may explain the lower detectability estimated for the Riviére George area in 1986. When there was not perfect agreement between the two counts, deviation was never great.

The exactness of estimating the area covered by RC-5 photos with the altitude and the focal distance could be verified with 21 photos showing landmarks precisely located on 1:50 000 topographic maps. According to the focal distance-altitude approach, the surface averaged 0.60 km^2 (SE = 0.03), as compared to 0.58 km^2 (SE = 0.03) based on landmarks; the two means do not differ statistically ($t = 0.3$; $P > 0.5$). On the other hand, the size of caribou appearing on 35-mm photos was closely related to the scale for the five postures considered (Table 4). There were 73 photos showing caribou among those taken when sampling with a 35-mm camera in 1988. They covered 0.028 km^2 (SE = 0.003) each when the area was estimated with the focal distance and the altitude. The corresponding surface area averaged 0.026 km^2 (SE = 0.002) when the scale was estimated with the size of caribou on negatives, using the linear regression with the highest R^2 (Table 4). The two means are not statistically different ($t = 0.6$; $P > 0.5$).

Caribou density on calving grounds

Stratification was successfull for all surveys with caribou density on the high density stratum at least doubling that in the low one (Table 5). Caribou were particularly concentrated in 1984, averaging 32.7 individuals$\cdot km^{-2}$; in other years, mean density varied around 10 animals$\cdot km^{-2}$. We believe that density estimates were biased downward in 1986, due to the poor quality of photographs. Conversely, the huge difference between estimates made with the RC-5 and the 35-mm camera in 1988 was attributable to different sampling plans, amplified by the relatively small sample size. The two sets of photos were taken over the same area on the same day. Nonetheless, random sampling was used for the 35-mm photos, as opposed to systematic allocation along transect lines for the other type of photos. For the 35-mm photos, two adjacent clusters in the high density stratum fell in an area of very high caribou concentration: 158 animals$\cdot km^{-2}$; in the remaining seven clusters, the density averaged 22 caribou$\cdot km^{-2}$, which is close to the estimate of 18 derived with RC-5 photos. In the low density stratum, the north of the calving ground was oversampled with the 35-mm camera. As this area should have been classified in the other stratum, the average density of the five clusters drawn there (35 animals$\cdot km^{-2}$) inflated the mean of the low density stratum. In the remaining 16 clusters, the density averaged 12 caribou$\cdot km^{-2}$, as compared to a mean of 8 when estimated with the other set of photos. The two 1988 density estimates where combined to improve the precision; the weighting factor was the in-

Table 3. Proportion of caribou detected on 35-mm black and white negatives by three observers (A, B, C) during blind comparison as compared to the number of animals counted during low level flight in helicopter over the same area immediately after photography. Photos taken over two calving areas of northern Québec in 1986 and 1988.

	Riviére George			Riviére aux Feuilles
	1988		1986	1986
	A	B	C	C
Average proportion	0.98	0.96	0.90	0.96
SE	0.02	0.02	0.05	0.04
N	52	52	10	12
% exact concordance	73	73	60	83

Table 4. Parameters of the linear regression y = m x + b predicting the inverse of photo scale (y) with the length (mm) of caribou on photos (x) according to five postures. Measurements taken on 25 photos with known scale.

Caribou posture	m (SE)	b (SE)	R^2 adjusted[a]	n[b]
Standing up,still	-17 641(1136)	11 193(368)	0.80	59
Standing up, moving	-13 928(763)	9 777(290)	0.85	58
Standing up, head bent	-17 333(992)	11 113(330)	0.92	26
Lying, stretched	-24 882(2661)	12 108(5 62)	0.74	31
Lying, grouped	-26 174(3819)	12 073(802)	0.67	23

[a] Procedure REG (SAS Institute Inc. 1985)
[b] Number of caribou measured

Table 5. Area (km²) covered by the 2 density strata in the caribou calving ground used by the Riviére George and the Riviére aux Feuilles herds between 1984 and 1988, and mean caribou density (SE;n) as estimated from counts on negatives of black and white aerial vertical photos taken with a RC-5 or a 35-mm camera.

	Riviére George				Riviére aux Feuilles
	1984	1986	1988		1986
	RC-5	RC-5	RC-5	35-mm	RC-5
Area					
High density stratum	3712	9867	4912	4912	1581
Low density stratum	5278	5451	17945	17945	4777
Caribou·km^{-2}					
High density stratum	58.12(3.74;38)	10.88(2.24;19)	18.12(4.93;11	52.16(20.74;9)	13.71(2.67;11)
Low density stratum	14.75(0.98;55)	4.22(1.08;19)	8.20(1.63;40)	16.73(4.39;21)	6.06(1.21;35)
Weighed mean	32.66(1.65;93)	8.51(1.49;38)	10.33(1.66;51)	24.34(5.64;30)	7.96(1.13;46)

Table 6. Proportion of males and females per age class among caribou present on the calving grounds at the time of the photo census and total proportion of females, northern Québec, 1984-1988.

Area	Adult		Yearling		Proportion (SE;n[a])
	Male	Female	Male	Female	of females ≥ 1 year old
Riviére George 1988	< 0.01	0.78	0.09	0.13	0.91(0.08;33)
Riviére George 1986	0.04	0.56	0.16	0.24	0.80(0.08;25)
Riviére George 1984	0.04	0.71	0.10	0.15	0.86(0.04;32)
Riviére aux Feuilles 1986	< 0.01	0.69	0.07	0.24	0.93(0.16;3)

[a] Number of sampling sites; stratified sampling in 1988, random in order years.

verse of the variance of the mean, while the variance of the resulting mean was computed as the inverse of the sum of the inverse variance of the two combined means: the combined density was 11.45 caribou·km^{-2} (SE = 1.59).

Herd composition on calving grounds

The composition counts conducted by helicopter confirmed the observations made during reconnaissance flights preceding photography; most caribou on calving grounds were adult females (Table 6). Few adult males associated with females there, but many yearlings accompanied them. Among yearlings, sex-ratio favoured females. Animals in this age group often tended to aggregate and this distribution inflated the standard error of the means.

In 1988, it was possible to monitor the movement of many radio-tagged females during the week preceding photography (Fig. 3). Of the six crossings of the calving ground limits, five were inward; in general, animals were converging toward the northwest corner of the survey area. Based on telemetry flights over the complete range of the Riviére George herd during thê preceding ≈ 10 days, proportion of females on the calving ground at the time of the survey was estimated at 77 percent in 1984 and 1986 and at 64 percent in 1988 (Table 7). Proportion of yearling and adult females on calving grounds at the time of the census was very similar.

Table 7. Estimated proportion of adult and yearling females on the Riviére George calving ground at the time of census based on location of radio-tagged caribou during the week preceeding the survey, 1984-1988.

Year	Adult	Yearling	Combined (SE)
1988	20/32	3/4	0.64(0.08)
1986	57/73	4/6	0.77(0.05)
1984	5/6	12/16	0.77(0.09)

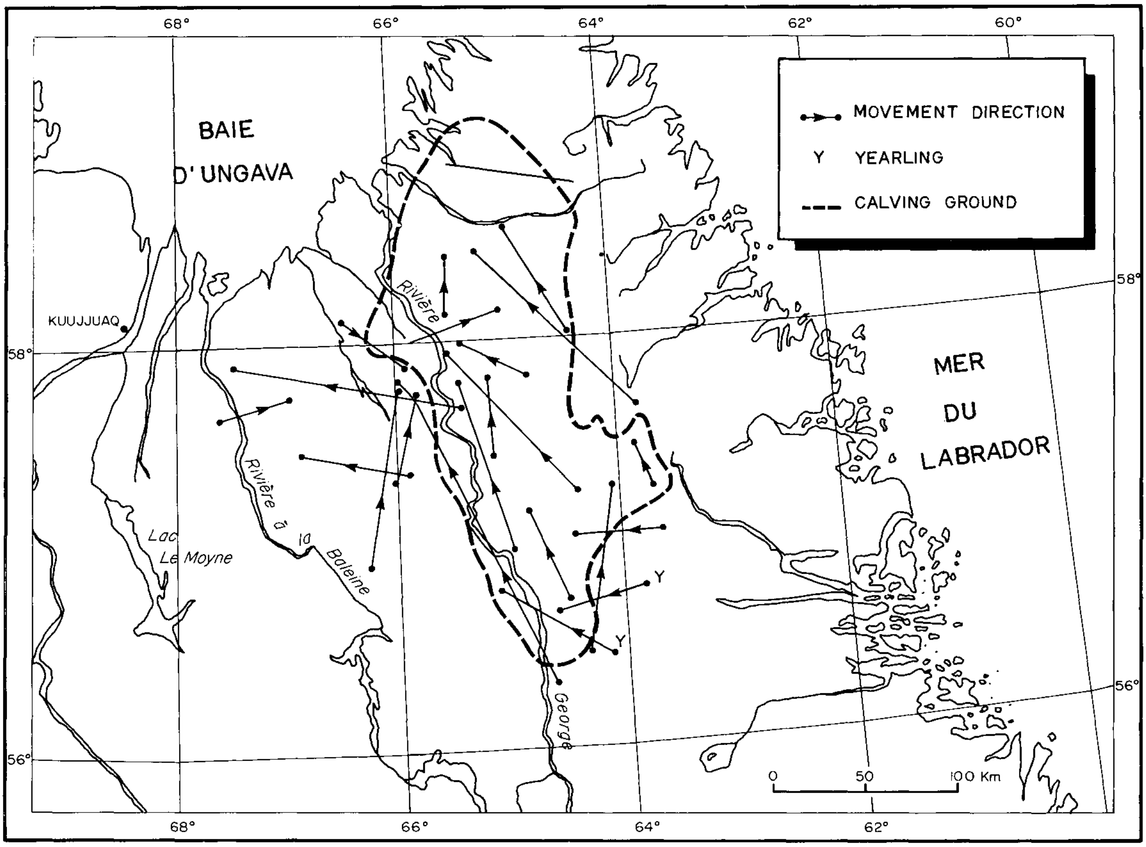

Figure 3. Movement of radio-tagged females at the periphery of the Riviére George caribou calving ground between June 5-6 and 14, 1988.

Summer survival and autumn composition of the herd

Over 95 percent of the radio-tagged females survived from calving time to rut every summer in the Riviére George herd (Table 8). Summer mortality was similar for yearlings and older females. Our survival estimates differ slightly from Hearn's *et al.* (1990) summer rate because we did not take exactly the same period or use the same data base.

Yearlings and older females made up 52(1;12), 51(2;10) and 54(1;11) percent of the Riviére George herd during rut in 1984, 1986 and 1988 respectively. At the Riviére aux Feuilles area, females ≥ 1 year-old composed 45(0.01;5) percent of the herd in 1986. A higher percent of females among Riviére George caribou in recent years resulted from decreasing calf production (Messier *et al.* 1988).

Population estimate

More than 250 000 animals occurred on the Riviére George calving area in 1984 and 1988 during the photo census (Table 9). The best precision was obtained in 1984 because of a larger sample size and a more homogenous caribou distribution over the study area than in the two other years. The 1986 estimate (130 400) is biased due to poor photo quality and incomplete coverage (Fig. 2) (Crête *et al.* 1989). Calf production and survival rate of radio-tagged animals indicated that the herd finite rate of increase decreased from 1.13 to 0.99 between 1983 and 1987, without catastrophic mortality during this period (Hearn *et al.* 1990). Moreover, the 1988 and 1984 data are consist with preceding census (Messier *et al.* 1988; Crête *et al.* 1989). The Riviére George herd probably peaked around 700 000 individuals by 1986-1987, but the 1988 estimate was imprecise. As the 1988 and 1984 estimates did not differ statistically ($t = 0.22; P > 0.50$), they can be pooled to improve the precision of the herd size estimate (Gasaway *et al.* 1986): There were 655 000 (±21%; $\alpha = 0.10$) caribou associated with the Riviére George calving area between 1984 and 1988. In 1984, the greatest lost of pre-

Table 8. Summer survival rate of yearling and adult radio-tagged female caribou belonging to the Riviére George herd, northern Québec 1984-1988.

Year	Adults	Yearlings	Combined[a] (SE)
1988	17/17	4/5	0.97(0.04)
1986	69/73	6/6	0.96(0.02)
1984	9/9	18/19	0.99(0.021)

[a] Weighted according the proportion of yearlings and adults in the herd (Table 6.).

Table 9. Number of caribou associated with the Riviére George calving ground at all steps necessary to estimate herd size. The confidence interval is expressed as percentage of the estimate ($\alpha = 0.10$). For each operation, the variance of the estimate was calculated with formulae used by Crête *et al.* (1986).

	1988	1986	1984
All animals on the calving ground, calves excluded	261 700(±23%)	130 400(±30%)	293 600(±8%)
Females on the calving ground, as counted on photos	238 200(±28%)	104 300(±34%)	252 500(±11%)
Females on calving ground, corrected for animals missed on the photos	243 100(±28%)	115 900(±35%)	260 300[a](±12%)
All females in the herd in June, including the ones outside the calving ground	379 800(±35%)	150 500(±37%)	338 000(±23%)
All females in the herd in fall, excluding calves	368 400(±36%)	144 500(±38%)	334 700(±24%)
All caribou associated with the Riviére George calving area in fall, including calves	682 100(±36%)	283 300(±39%)	643 600(±25%)

[a] Visibility rate used = 0.97 (ES = 0.02).

cision occurred when correcting for females located outside the census area, due to insufficient number of radio-tagged animals. In 1986-1988, the imprecision depended mostly on the too small number of clusters of photos taken over the calving ground; moreover, the estimation of the proportion of females outside the census area resulted in a great lost of precision. The size of the Riviére aux Feuilles herd was not estimated because the absence of radio-tagged animals in 1986 precluded estimating correction factors.

Discussion

The origin of the census technique we used is easy to trace back. Knowing that caribou aggregate on the tundra for parturition at relatively high density and in predictable areas, biologists concluded that it would be easy to census adult femals on calving grounds. However, the accumulation of data, particularly with telemetry studies, revealed that yearlings often accompany adult females there and that not all adult females are present at the same time on calving grounds. Correction factors requiring telemetry are necessary with such an approach to obtain unbiased estimates. In addition, there must be a large number of animals (≈ 100) under telemetry surveillance in each herd to produce an estimate useful for management purposes, i.e. with a confidence interval of ± 20-25% (α = 0.10: Crête *et al.* 1986; Gasaway *et al.* 1986). Moreover, the field work must be conducted in June and October-November with the actual technique, to produce an estimate of the total herd size. Field work is very expensive in the North, particularly on caribou: the actual range of the Riviére George herd exceeds 600 000 km², which necessitates much flying time. Our 1988 census cost more that 200 000 $ and it is imperative to minimize expenses.

Caribou in all sex and age categories often aggregate by the thousands in July on the tundra. The photography of such groups also has been used to estimate herd size (Valkenburg *et al.* 1985). Radio-tagged animals are necessary to lo-

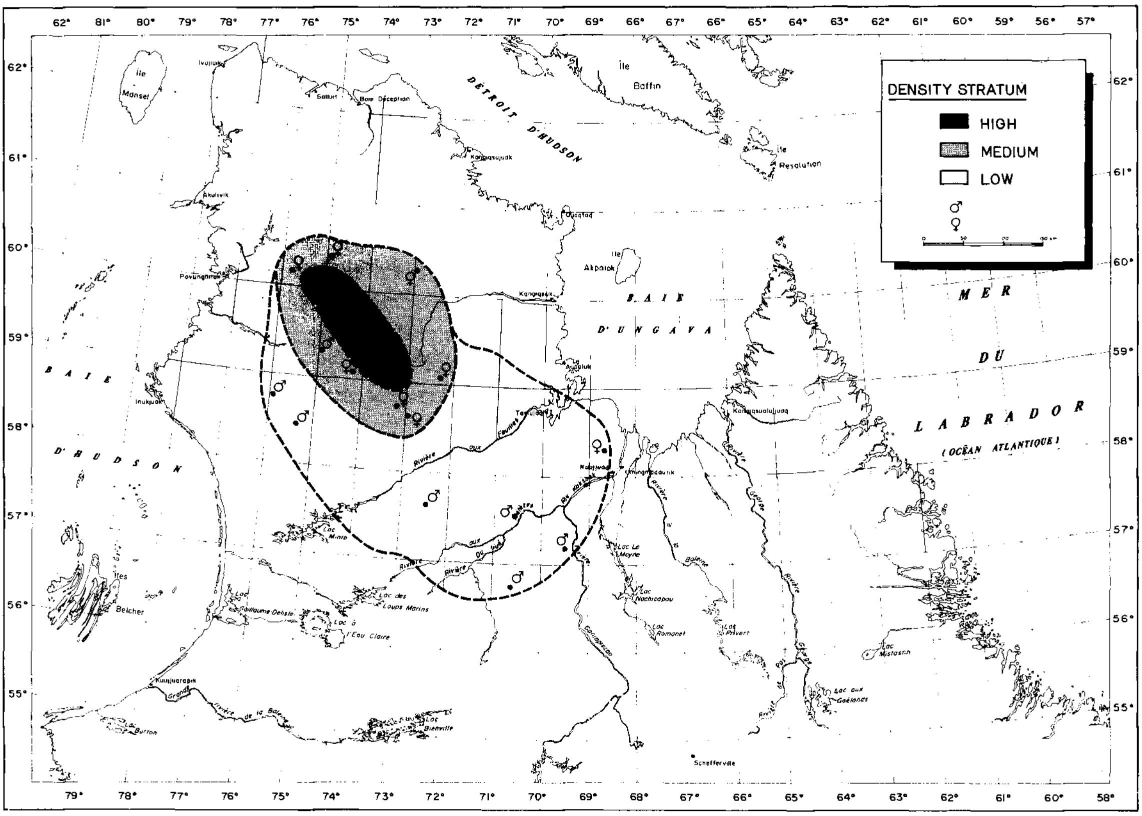

Figure 4. Distribution, according to their sex, of adult caribou from the Riviére aux Feuilles herd in early June 1988, and delineation of 3 density strata.

cate all groups in such a vast herd. This technique assumes that all animals in a census herd are photographed. This assumption is difficult to accept, particularly for a herd numbering more than half a million animals dispersed over thousands of square kilometres. Moreover, caribou do not form large groups in some years (D. Heard, pers. comm.), which complicates survey programming.

Figure 4 shows the distribution of radio-tagged caribou belonging to the Riviére aux Feuilles herd at the time of parturition in early June 1988: most females were concentrated on the calving ground, some others were in the periphery mixed with males, and many males lag behind to the south. This distribution is probably typical of that of most herds at parturition; few males have been monitored in the Riviére George area but they appeared to behave as in the other herd.

To diminish the cost and to improve the precision of herd size estimates for caribou calving on the tundra, we propose to modify the technique to eliminate the use of telemetry and to derive estimates in one step only. A reconnaissance flight, lasting a few days, should precede the census to stratify the area in three density zones (Gasaway *et al.* 1986): calving ground (high density), surrounding areas (intermediate density) and the rest of the range (low density). Caribou density would then be estimated with two-stage stratified sampling. Photos should be taken with a 35-mm camera mounted on a helicopter. The 35-mm camera possesses many advantages over the RC-5: the area covered by one photo is better adapted to caribou distribution, it is less expensive to operate, lens availability permits flights at lower altitudes which allows censuses to proceed despite low cloud ceilings, and the variety of films is greater; in particular, colour slides allow counting newborn calves. Helicopter is preferable to twin-engine fixed-wing aircraft because of its better manoeuvrability, because it is independent from airstrips and because composition counts can be done in parallel with photo census. There should be 10-30 photos per cluster and the cluster should be allocated systematically in two dimensions (Cochran 1977:227). The problems created with random sampling in 1988 with the 35-mm camera (Table 5) and the homogeneity between consecutive photographs on transect lines well illustrated the necessity to space sampling sites equally. To reach the target precision of ±20-25 percent of the estimate (Crête *et al.* 1986; Gasaway *et al.* 1986), 150 clusters of photos should suffice. If the target precision could not be reached, or if the costs were too high, the census could be restricted to the calving ground and the surrounding areas, and the estimate limited to the number of females in the herd.

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The relationship between weather and caribou productivity for the La-Poile Caribou Herd, Newfoundland.

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Abstract: To describe the relationship between weather and caribou *(Rangifer tarandus)* productivity, we compared weather variables (snow on ground, winter temperature and measures of growing season) with measures of productivity (calves seen by hunters, calves and yearlings in the harvest and percent calves and yearlings and pregnancy rate for caribou classified during fall and spring surveys) for the LaPoile Caribou Herd in southwestern Newfoundland. Hunter statistics reliably estimated changes in population demography. Percent calves seen by hunters was correlated with calves/100 females classified in fall. Weather may have influenced productivity for the LaPoile Caribou Herd in Newfoundland. Colder winter temperatures were associated with fewer calves the next fall and pregnancy rates and yearlings/100 females in the spring were negatively correlated with snow on ground the previous winter. These relationships appear to be density related.

Keywords: caribou, *Rangifer,* weather, productivity, LaPoile Caribou Herd, Newfoundland, density dependence.

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Introduction

Studies indicate that forage limitations during late gestation may reduce birth weights, delay birthing schedules and reduce maternal milk production in a variety of ungulates, including *Rangifer* (Verme 1969; Blaxter and Hamilton 1979; White 1983). These variables have in turn been correlated with calf survival, and where present, may retard future somatic development and impair life time reproductive success (Haukioja and Salovaara 1978; Skogland 1983; Eloranta and Nieminen 1986). Extreme winter conditions have, in addition to their less immediate effects on forage availability, been associated with direct mortality of both juvenile and adult caribou and reindeer (Klein 1968; Bergerud 1971; Skogland 1984).

This study examines the relationship between weather and caribou *(Rangifer tarandus)* productivity in insular Newfoundland. We compare productivity and weather measures for the La-Poile Caribou Herd which occupies the coastal barrens of southwestern Newfoundland, a region with extreme winter conditions (Mahoney *et al.* 1989).

Methods

Weather data

We obtained daily weather data for the Burgeo meteorological station (Fig. 1) from 1960-1989 from the Scientific Services Branch of the Federal Department of Environment.

The following parameters were used to measure annual variation in weather: (1) length of the growing seasons in days; (2) mean daily snow on ground for days with snow; (3) number of days with snow on ground; (4) cumulative snow on ground during the winter; and (5) mean winter temperature.

Stewart *et al.* (1976) calculated growing season as the length (days) of the period between leaf flush and leaf abscission each year. We used maximum daily temperature (h) greater than 54°F (12.2°C) to calculate a mean level of 75 degree days ($\sum(h-54)/2=75$) which Stewart *et al.* (1976) considered the level of heat units necessary to initiate leaf flush. We considered the termination of positive energy balance to occur when the ambient temperature reached -5°C. Larcher (1973) considered -5°C the temperature required to cause cellular destruction or lysis in leaves of woody plants. The number of days from the initial spring accumulation of 75 heat units to the first fall minimum temperature of -5°C was thus accepted as the period of positive energy balance or growing season.

Three measures of growing season were calculated: (1) growing season length; (2) deviation from mean date of spring leaf flush (e.g. a positive number indicates the number of days *beyond* the mean spring leaf flush date before accumulation of 75 heat units); and (3) deviation from mean date of autumn leaf (e.g. a positive number indicates the number of days *beyond* the mean autumn leaf fall date before a minimum -5°C war recorded).

Three measures of snow accumulation on the ground were calculated: (1) total number of days snow was recorded on ground; (2) total cumulative snow on ground for all days over winter; and (3) mean daily snow on ground for days of the year with snow.

Mean minimum winter temperature was calculated using daily minimum temperatures for 1 November of the preceding year to 31 March of the year in question.

Productivity data

Three types of information were used to measure caribou productivity: (1) calves and yearlings per 100 females in the harvest (sample of mandibles sent in by hunters); (2) percent calves seen by hunters as reported on license questionnaires; and (3) calves and yearlings per 100 females and pregnancy rate derived from spring and fall classification surveys.

Lower mandibles were collected from hunters at check stations, via the mail, or from hand deliveries. Age was determined from tooth eruption pattern for calves and yearlings and by counting cementum annuli of the first incisor from older animals (Miller 1974).

Hunters were obligated to complete questionnaires attached to their licenses which provided the following information: hunter name, address, area hunted, length of time hunted, number and types of caribou and other wildlife observed, and for successful hunters, the date of kill, location of kill, age (adult or calf), sex and number of antler points for males. From this information we calculated the weighted mean percent calves seen by either sex and male only license holding hunters that voluntarily returned their questionnaire.

Caribou were classified as to age (calf, yearling, adult) and sex either from the ground using 15X-60X spotting scopes or from helicopter (Bell 206b or 206l). Classifications were conducted in fall, spring and at calving. Females were classified as pregnant based on the presence or absence of an udder.

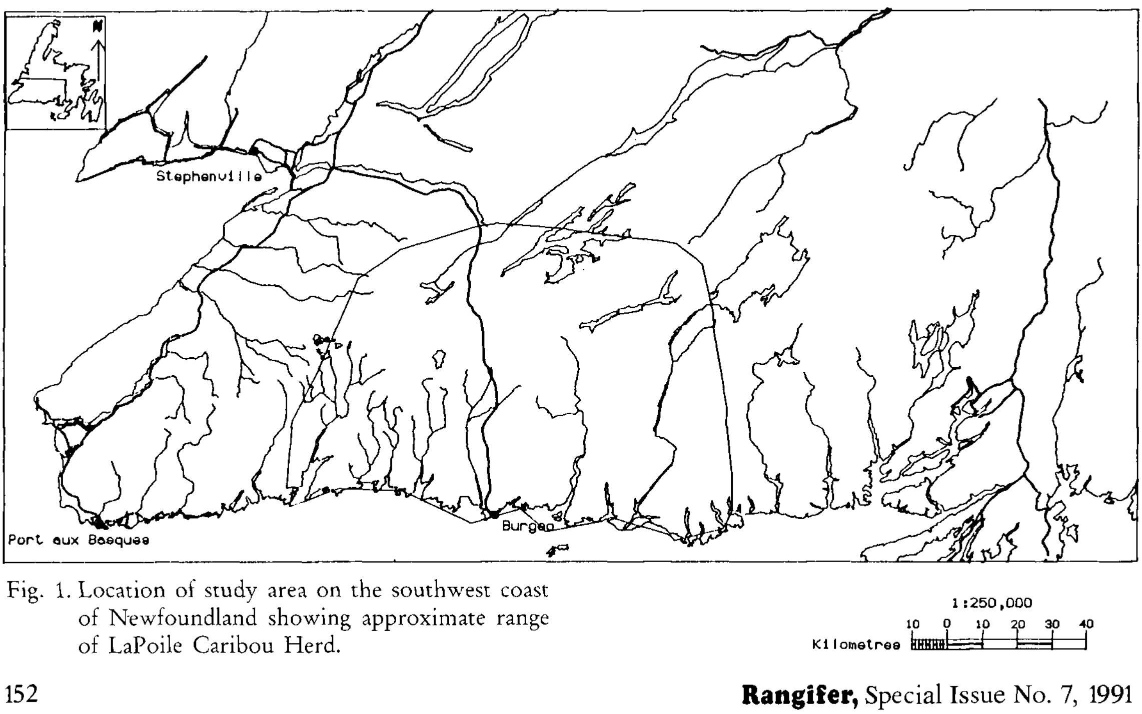

Fig. 1. Location of study area on the southwest coast of Newfoundland showing approximate range of LaPoile Caribou Herd.

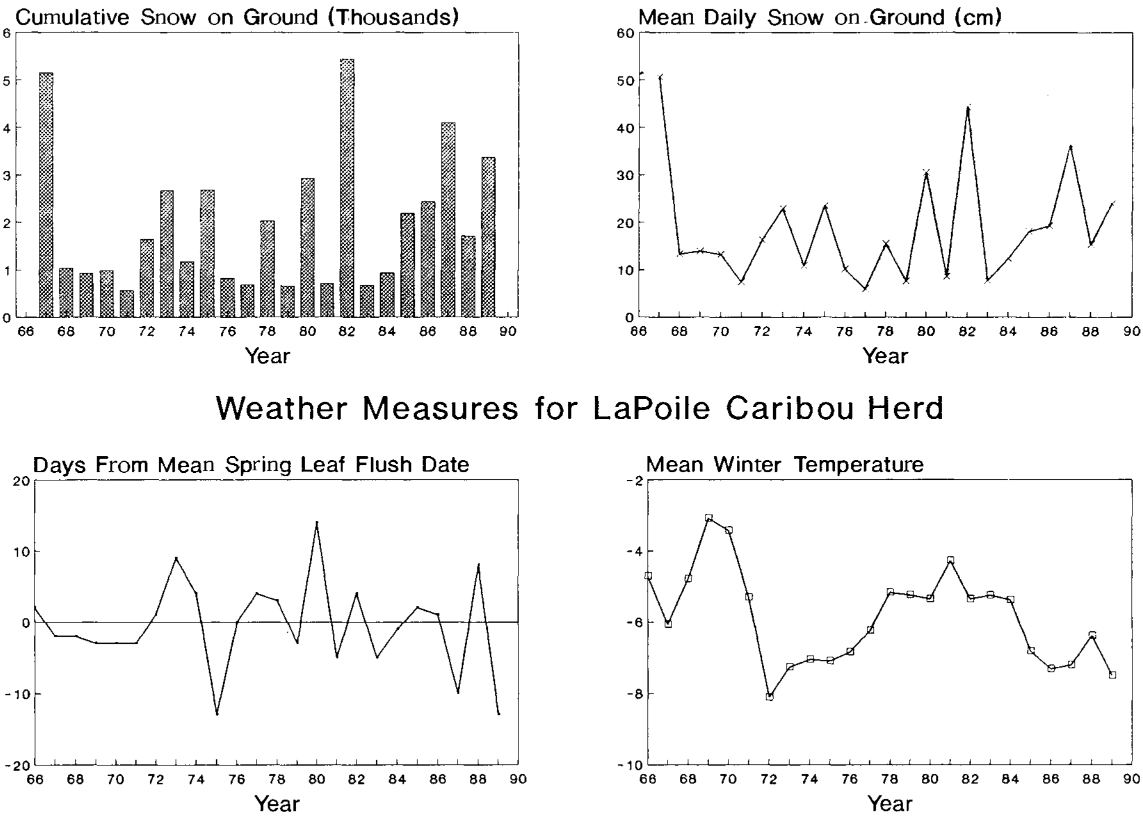

Fig. 2. Weather measures for LaPoile Caribou Herd range, 1966-1989. Includes (1) cumulative snow on ground (1000 cm); (2) mean daily snow on ground (cm); (3) difference from mean date of spring leaf flush; and (4) mean daily minimum winter temperature.

Statistical analysis

Data were organized and statistical analyses performed using micro SAS statistical packages (SAS Institute 1987). Standard parametric analysis of variance and regression analysis tests was used (Sokal and Rohlf 1969). Correlations were tested using the Pearson product-moment correlation coefficient. The least square technique was used to fit the variables to regression models.

The number of independent variables entered into the multiple regression functions were determined according to three criteria: (1) the absolute critical values for each independent variable entered stepwise (t test for significance of partial regression coefficient at $p<.10$); (2) comparison of value of residual mean squares and adjusted R^2 for different models; and (3) by plotting Mallows' (1973) C_p statistic against p (number of parameters including the intercept) and choosing the model were C_p first approaches p.

Weather/productivity schedule

Weather could conceivably affect caribou productivity in a number of ways. Parameters such as growing season length, could, for example, affect the ability of a female to conceive, or to carry a pregnancy to term, or to give birth to a viable calf. We therefore decided to compare all productivity measures directly with that year's timing of spring, snow on ground and winter temperature and with the previous year's timing of spring, snow on ground and winter temperature and with the previous year's timing of fall and growing season length. In addition, we also tested for a relationship between yearlings classified in spring and yearlings in the fall hunter harvest with weather variables from the previous year.

Results

No trend in the timing of leaf flush was documented for the LaPoile area although substanti-

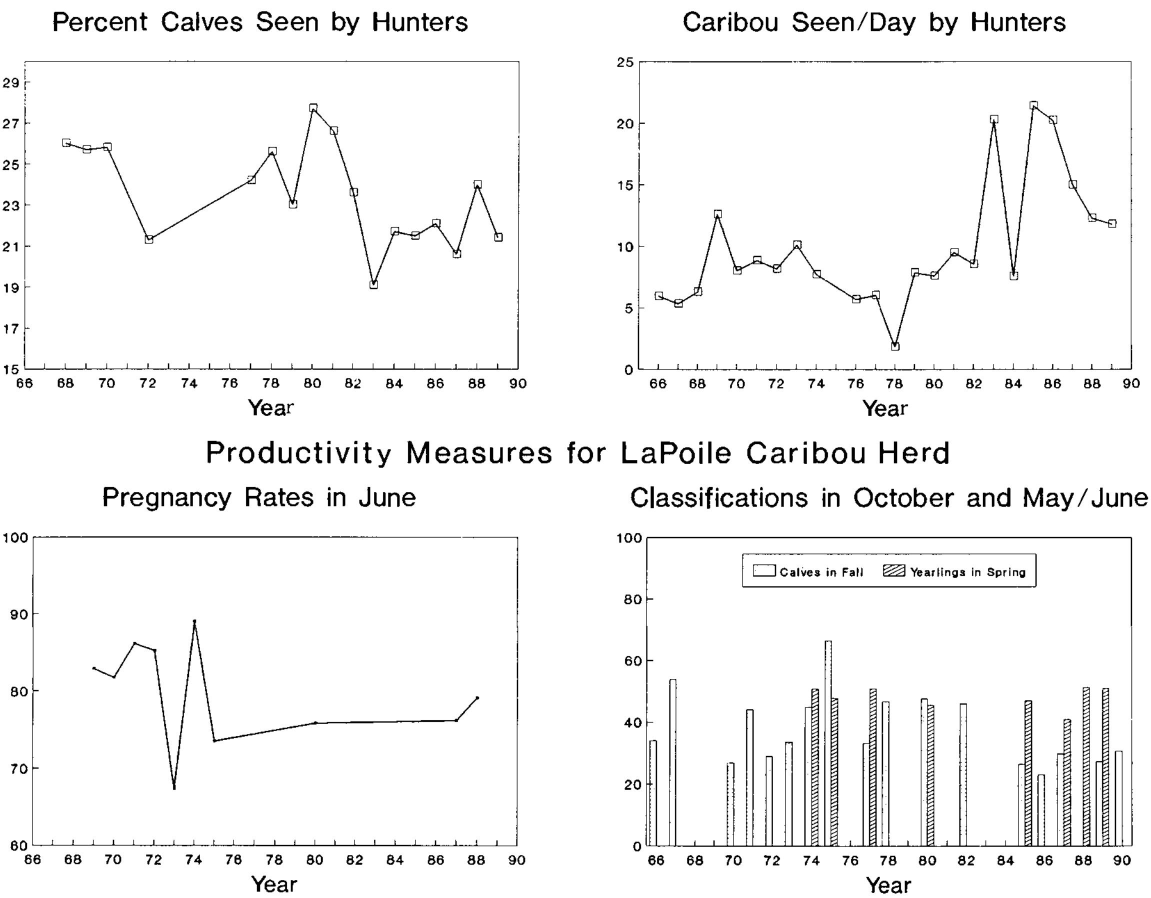

Fig. 3. Productivity measures for LaPoile Caribou Herd, 1966-1990. Includes (1) percent calves seen and (2) total caribou seen/day by resident hunters in the fall; (3) percent females that were observed to have calved in June classification survey; and (4) calves and yearlings/100 females observed on fall and spring classification surveys respectively.

al annual variation occured (mean date 11 July; range, 30 June to 26 July; Fig. 2). Cumulative (mean = 1980 cm) and daily snow (mean = 18.6 cm) on the ground also varied annually but 1967 (50.6 cm), 1982 (44.3) and 1987 (36.3) were years of appreciably deeper snow (Fig. 2).

Table 1. Multiple regression models predicting Y (caribou productivity) with X-variables (density and weather measures)[a]. (Dependent variable: Percent calves seen by hunters in fall).

Parameter	Coefficient value	S.E.	Beta values	Partials	R^2	R_a^2	VIF
Intercept (b_0)	30.6	1.93	–	–	–	–	–
Caribou seen/ Day (b_1)	-0.19	0.09	-0.430	0.446	–	–	–
Mean daily winter temperature (b_2)	0.86	0.35	0.468	0.297	0.391	0.487	1.15

[a] Basic model, adjusted (R_a^2) and unadjusted (R^2) coefficients of multiple determination, standardized regression coefficients (beta values), coefficients of partial determination (partials), variance inflation factors (VIF), and standard error of the regression coefficients.

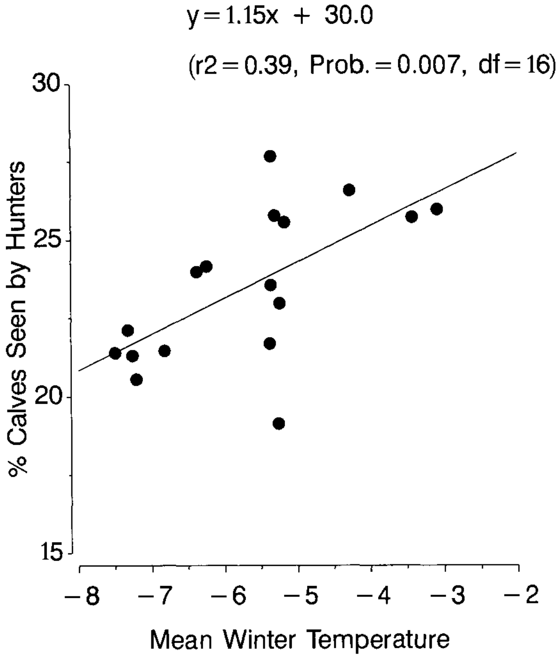

Fig. 4. The relationship between calves seen by hunters and mean winter temperature.

Winter temperatures (mean=5.7) were colder during the mid 1970's (1972-1976); mean=-7.3) and the late 1980's 1985-1989 (mean=-7.0; Fig. 2).

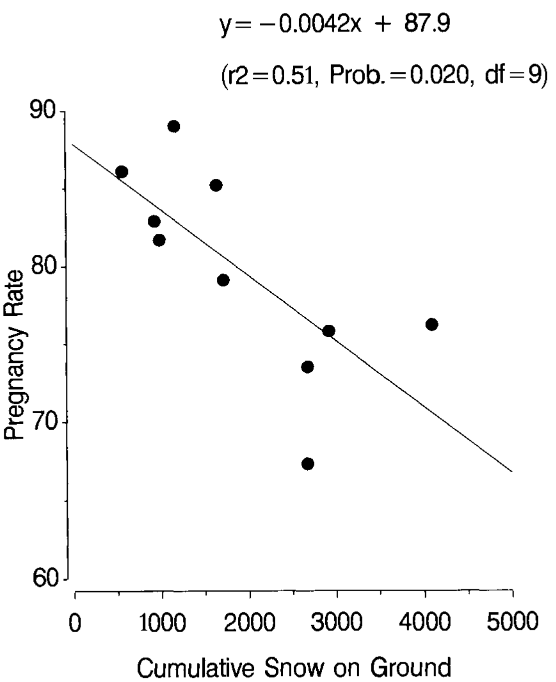

Fig. 5. The relationship between female pregnancy rate and cumulative snow on the ground (1000 cm) that winter.

For the LaPoile Caribou Herd, hunters reported seeing more caribou and fewer calves during the past decade (Fig. 3). Pregnancy rate in May-June surveys indicate fewer pregnant females since 1974 (Fig. 3).

Among weather variables, mean daily snow on the ground and cumulative snow on ground were highly correlated ($r^2=0.94$, $p=0.001$, $df=22$). Among caribou productivity variables, calves seen by hunters was correlated with calves/100 females classified in fall ($r^2=0.45$, $p=0.025$, $df=10$).

Productivity measures derived from hunter statistics were significantly correlated with weather variables provided that caribou density (caribou seen/day hunted) was included as an independent variable (Table 1). The dependent variable, percent calves seen by hunters in the fall was (1) negatively correlated with caribou density (model $p=0.04$ and (2) positively correlated with winter temperature (model $p=0.03$; Fig. 4; Table 1).

The productivity measures, derived from spring classifications, were also correlated with weather variables. Pregnancy rate of females in May-June was negatively correlated with cumulative snow on ground ($r^2=0.51$, $p=0.02$, $df=9$; Fig. 5). Yearlings/100 females in May- June was negatively correlated with mean daily snow on ground the previous year ($r^2=0.67$, $p=0.02$, $df=7$; Fig. 6).

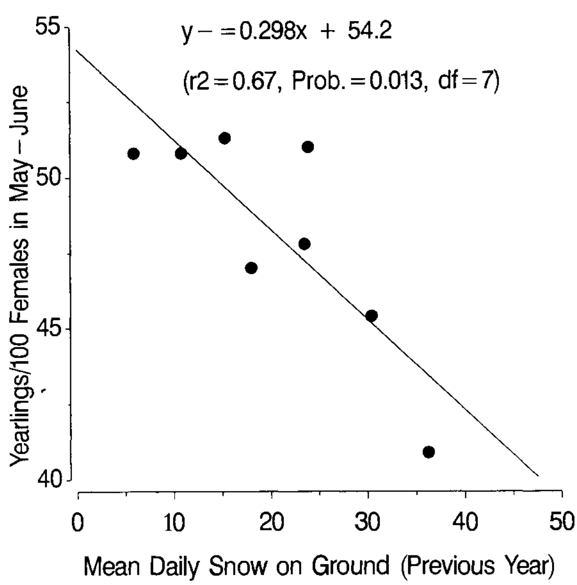

Fig. 6. The relationship between yearlings/100 females in spring and mean daily snow on the ground (cm) the previous year.

Discussion

Bergerud (1983) in a review of caribou population control suggested that caribou populations are limited by weather (1) on the northern edge of the species range in the tundra biome where severe weather (ice, snow and wind) resulted in mortality and decreased reproduction regardless of density (Vibe 1967; Miller *et al.* 1977; Thomas and Broughton 1978); (2) on islands (Scheffer 1951; Klein 1968; Bergerud 1971; Burris and McKnight 1973; Ferguson *et al.* 1988); and (3) in maritime conditions where icing can substantially reduce available food. This study documents the possible influence of weather on caribou demography for a maritime population in southwestern Newfoundland, although such influences appear to be density dependent.

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Range monitoring using exclosures on Southampton Island (N.W.T., Canada): The effect of exclosures on snow condition

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Abstract: Snow drifting and its potential consequences on the vegetation, is believed to be a problem associated with the use of exclosures in the Arctic. Surprisingly, previous studies using exclosures as an experimental tool to analyze the impact of *Rangifer* grazing did not discuss this problem. The objective of this paper is to test the effects of the exclosures on snow characteristics.

The exclosures (5 m x 5 m; n=13) were made of heavy farm fencing (9.5 gauge galvanized wire), 100 cm high with horizontal strands about 15 cm apart with vertical stays every 41 cm, and 45 imp gal barrels (n=4) filled with rocks served as fence posts. We measured snow characteristics (depth and hardness) at each exclosure twice in winter (March and May 1990) using a Ramsonde penetrometer. Outside the exclosures, snow characteristics were measured at 4 m and 5 m away from the fence on each side, for a total of 8 readings. Inside the exclosures, 8 readings were taken every meter along two perpendicular transects. To analyze the snow melting chronology in the spring we visited 3 exclosures at the end of June 1990 to observe snow disappearance on the ground within the exclosures relative to the surrounding areas.

Snow was significantly deeper inside the exclosures (March: 55.8 cm vs 51.5 cm; May: 65.3 cm vs 61.1 cm). Within 20 cm of each drum snow depth was shallower. Snow hardness was slightly lower inside the exclosures, although the difference was not significant (March: 34.5 kg vs 34.7 kg; May: 32.7 kg vs 37.6 kg). Ram resistance, an integrated measure of snow depth and hardness correlated to the watercontent, did not differ significantly (March: 1925 kg·cm vs 1787 kg·cm; May: 2135 kg·cm vs 2297 kg·cm). Apparently, snow disappeared on the ground within the exclosures at the same rate as it did from surrounding areas, except in the immediate periphery (30 cm) of each drum, where the snow melts faster.

Snow depth was influenced by the presence of exclosures. However, the integrated ram resistance, an important paramenter as it is correlated to water content, did not differ within and outside the exclosures. In the immediate periphery of each drum snow condition as well as the snow melting pattern were affected. To minimize this potential problem, we suggest to establish a one meter buffer zone around each drum where the vegetation characteristics are not considered. Under the conditions prevailing during the study, we conclude that the use of exclosures can not be discarded on the basis of their potential change to snow conditions, and should be considered as a valuable tool to monitor range conditions.

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Body condition and pregnancy rates of the expanding Southampton Island caribou herd

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Abstract: Caribou (*R. t. groenlandicus*) were common on Southampton Island (N.W.T., Canada) until the early 1900's. However, caribou were rare by 1935 and the last individual died in 1953. In 1967, 48 caribou were introduced on Southampton Island. With the current growth of the herd the estimated carrying capacity of the island will be reached within five years if there is no significant increase in the hunting quota. Based on the demographic behavior of some *Rangifer* populations introduced on other islands a substantial depletion of winter food followed by a dramatic crash, can be considered a possibility for the Southampton Island herd. To document the increase of the herd and to better manage this resource, we are currently monitoring several biological indicators, including the physical condition of the caribou.

We assessed body condition, through fat reserves, and pregnancy rates of 74 females (5 calves, 11 months old; 15 yearlings, 23 months old, and 54 older animals, ≥ 35 months old) collected in spring (May) 1988 (n=24), 1989 (n=22), and 1990 (n=28). Most females (68 of 69) were pregnant, including all 15 yearlings. Calves averaged 0.6 cm of backfat and had a mean Riney kidney fat index of 22. The corresponding values were respectively 2.0 cm and 75 for yearlings, and 2.2 cm and 92 for adults. Fatness was similar in 2 year old and older animals.

Age specific fat reserves and pregnancy rates obtained for females from Southampton Island are greater than ever previously recorded for caribou in late winter. Our data suggest that being pregnant as a yearling does not prevent reproduction as a 2 year old. Results support the view that fertility is related to a combination of factors. We suggest that fertility in female caribou is influenced by body weight and fatness. Age might also be a factor as the calves were not pregnant.

The current estimated number of caribou on Southampton Island (about 13 000) can provide an adequate yield for the local community. Animals are in excellent physical condition at the end of winter suggesting no over-exploitation of the habitat. Consequently, we suggest that the hunting quota should be increased to restrain the growth of the herd.

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Cover changes, during the 1954–1990 period, in the alpine vegetation used by the Gaspesie Provincial Park caribou herd

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Abstract: The Gaspesie provincial park (P.Q., Canada) caribou herd, classified as threatened, is the only remaining native caribou population on the continent, east of the St. Lawrence River. The alpine belt of the range, such as the Mt. Albert plateau (the largest alpine area of the park, 16 km^2), is heavily used by caribou in summer and in the fall. In 1954 and in 1963, the alpine vegetation cover of Mt. Albert was surveyed by Moisan (1974; Changements dans la vegetation de l'alpage du Mont Albert, M.T.C.P. Report no. 3. p. 292–297). We repeated this study in 1990 to monitor vegetation changes of Mt. Albert over the last three decades and their management implications for the caribou herd.

Most of the vegetation categories decreased significantly relative to the previous two surveys suggesting a reduction in total vegetation cover on the plateau. Mean vegetation cover was 62% and 53% respectively for 1954 and 1990. However, lichen cover increased from 8.6% in 1963 to 14.6% in 1990.

Interpretation of changes in the alpine vegetation cover of Mt. Albert during the last 37 years should be viewed in light of the following potential forcing factors: caribou grazing, climatic changes, and plant succession dynamics. From 1954 to 1963, the alpine vegetation showed a decrease in lichen cover and a slight increase in other plant categories. This trend was attributed to caribou grazing by Moisan (1974). It is likely that utilization of the plateau by caribou decreased in the 1963–1990 period relative to the previous one as the caribou population has declined. Significant increase in lichen during the 1963–1990 period would thus support the caribou grazing hypothesis.

However, the link between the observed pattern of cover change and caribou razing on Mt. Albert is questionable: 1) Reduction in grazing pressure, as suggested by an increase in lichen cover, should not be correlated with a decrease in total vegetation cover. 2) Despite a probable decrease in grazing pressure in the last four decades, grazing pressure is still relatively high as $\simeq$ 60 caribou are observed each fall on the plateau. 3) The low lichen cover on the plateau suggests that caribou might not selectively feed on lichens. Consequently, we suggest that other factors might have also influenced the observed cover changes. Casual observations indicate that tree line is regressing in the study area suggesting an increase in climate harshness. Such climatic stress could partially explain the overall decrease in plant cover, setting favourable conditions to pioneer species, such as the lichens, by reducing competition.

Recent investigations suggest that the alpine belt of the range is a key component for the survival of that threatened population. However, its importance to caribou feeding ecology remains to be shown. It is possible that the role of the plateau as escape habitat from predators might be more crucial to caribou survival than its use as a feeding ground.

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The influence of snow depth and hardness on winter habitat selection by caribou on the southwest coast of Newfoundland.

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Abstract: LaPoile Herd caribou winter in the coastal margin of their range in southwestern Newfoundland. Reduced snow depths near the coast (0-20 km inland), as a result of moderated winter temperatures and low elevations, appear to provide more favourable foraging conditions than do areas further inland. In the latter areas greatly increased snow depth and hardness combine to create very extreme winter conditions and these areas are avoided by caribou throughout the winter period.

Keywords: Caribou distribution, snow depth, Newfoundland, grazing.

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Introduction

The depth and hardness of snowcover are important factors which not only affect caribou *(Rangifer tarandus)* feeding strategies (Brown and Theberge 1990), but also affect caribou movements, distribution (Pruitt 1959) and social behaviour (Vandal and Barrette 1985). LaPerriere and Lent (1977) stated that neither depth nor hardness alone determine caribou wintering aeas, but that both factors influence selection of feeding areas.

LaPoile herd caribou, on the southwest coast of Newfoundland, winter in the coastal region of their range and rarely are animals found more than 20-25 kilometres (km) inland from the coast during this time of year (Mahoney *et al.* 1989). This preference is believed to be related to the availability of winter forage, particularly as influenced by snow depth and hardness. This study presents the preliminary findings of an ongoing investigation into snow characteristics on the LaPoile herd's range gathered between February 1988 and February 1990.

The study was conducted while simultaneously studying the effects of the Hope Brook Gold Mine on the LaPoile caribou herd. Funding was provided by both Hope Brook Gold Inc. and the Government of Newfoundland and Labrador.

Study area

The study area is located on the southwest coast of Newfoundland (Figure 1). The area is characterized by barren lands interspersed with forested river valleys, ponds, and shallow bogs. While portions of the coastline are rugged, much of the inland area is of gentle relief with occasional high summits.

The ocean has a moderating effect on the climate of the entire area with the strongest marine influence occuring on the southern portion (0-20 km inland) where elevations are higher (range 300-650 m above mean sea level) and the moderating effect of the ocean is progressively diminished resulting in colder winter temperatures. Reported mean temperatures for the southern section (0-20 km inland) of the study area are -4.4 C (January) and 14.4C (July). The mean annual precipitation is 127 cm with 19.6 cm, water equivalent, occuring as snowfall. With distance from the coast snow cover usually increases in extent and persistence, at least during most winters.

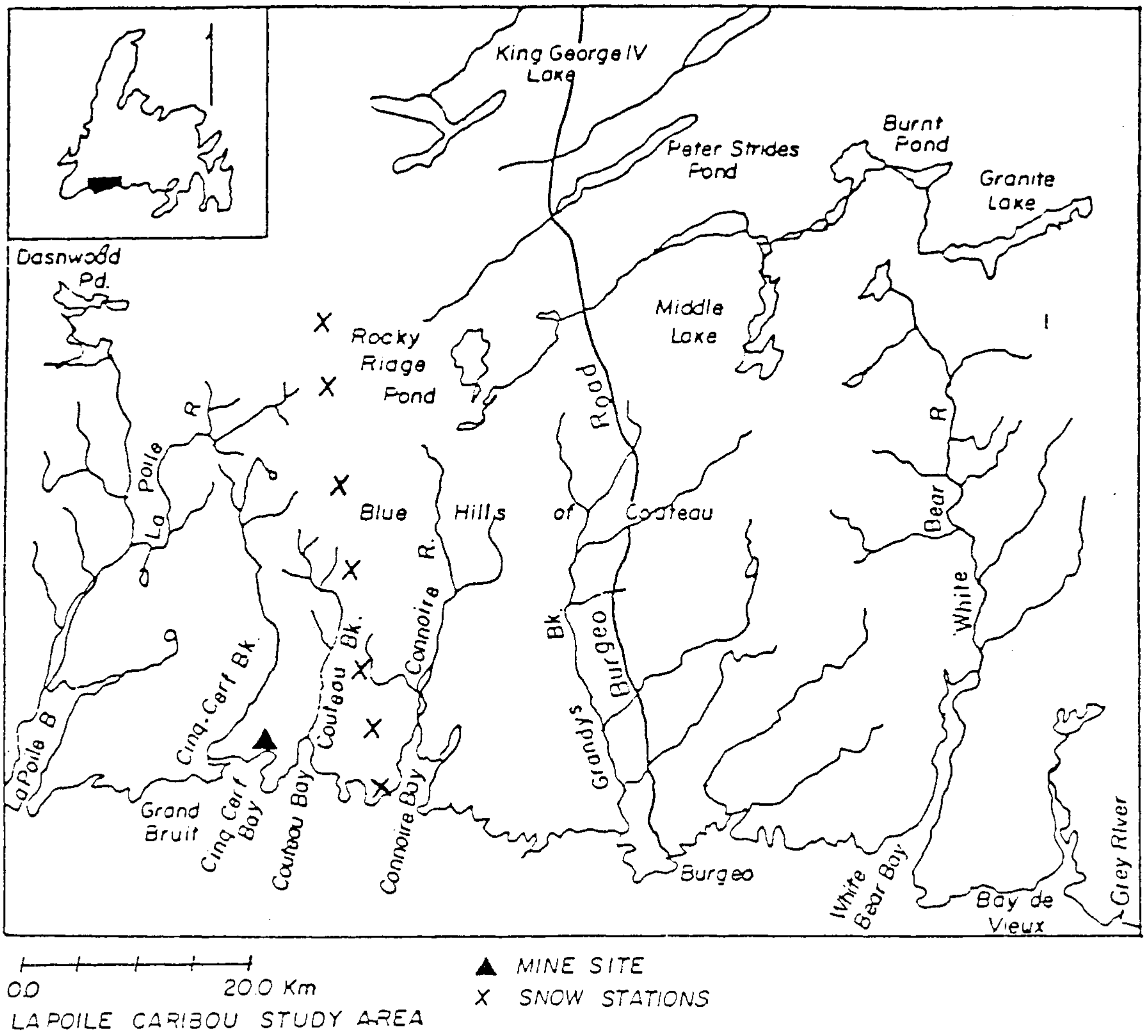

Figure 1. The location of the seven permanent snow stations in the LaPoile caribou herd study area located on the southwest coast of Newfoundland.

Methods

In 1988 seven permanent snow stations were established along a north-south transect running through the range of the LaPoile herd (Figure 1). At each snow station eight measurement sites were chosen so as to ensure coverage of all microrelief conditions. A wooden stake, maked at ten centimetre (cm) intervals, was driven vertically into the ground at each site. These stations were visited on seven occasions between February 1988 and February 1990. During each visit snow depth, measured at each stake, and snow ram hardness, measured using a Ramsonde penetrometer and calculated using an equation by Skogland (1978), were determined.

At each snow station the eight snow depth measurements were averaged to obtain mean snow depth while all ram hardness scores were averaged to derive a mean snow hardness value. In addition, average snow depth and average snow hardness per station were multiplied together to produce an integrated ram hardness score.

All visits were made by helicopter and snow measurements at all stations were usually completed within two days.

Results

On every occasion that snow characteristics were measured, a general increase in snow depth was observed as distance from the coast increased (Figure 2). Mean snow depths within 1 km of the coast ranged from 6 to 41 cm while mean snow depths 36-42 km inland from the coast ranged from 55 to 118 cm.

Mean snow ram hardness for each of the snow stations are shown in Figue 3. With the exception of the Feb. 25, 1988 data, which for some unknown reason appears highly anomalous, maximum snow hardness generally occurred between 20 and 36 km inland from the coast (average 53 kg, range 5-201 kg). Near the coast (0-20 km inland) hardness values were slightly lower (average 44 kg, range 4-149 kg) while hardness values 42 km inland were lower still (average 36 kg, range 14-66 kg).

A general increase in snow integrated ram hardness was recorded as distance from the coast increased (Figure 4). Again, with the exception of the Feb. 25, 1988 data, maximum integrated ram hardness was generally found 20 to 36 km inland (average 3,804 kg.cm, ange 0-40,200 kg.cm). Near the coast (0-20 km inland) snow integrated ram hardness averaged 1,563 kg.cm (range 0-29,055 kg.cm) while it averaged 2,564 kg.cm (range 0-13,200 kg.cm) 42 km inland.

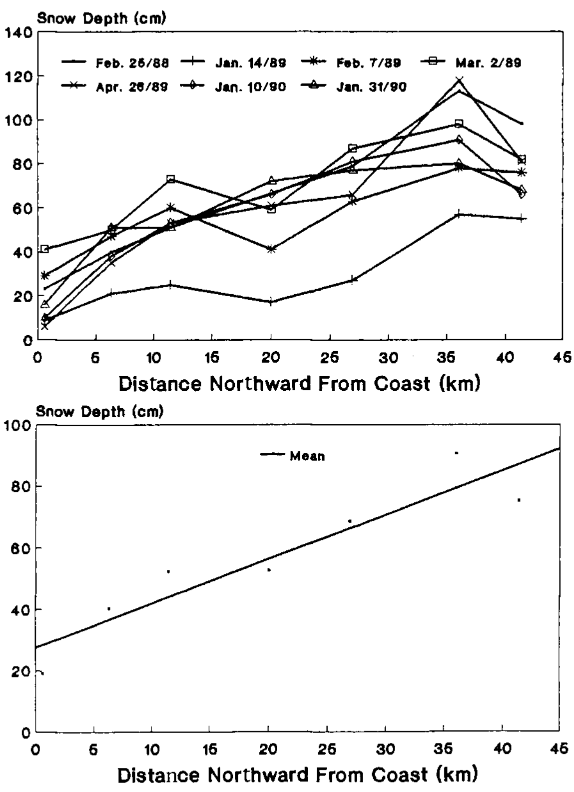

Figure 2. Mean snow depths measured at snow stations running north-south through the range of the LaPoile caribou herd.

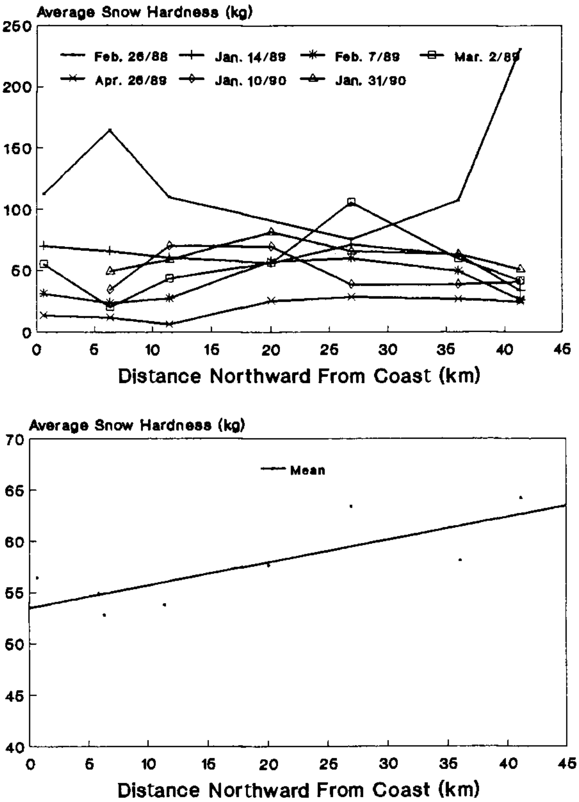

Figure 3. Mean snow ram hardnesses measured at snow stations running north-south through the range of the LaPoile caribou herd.

Discussion

The vast majority of the LaPoile caribou herd, now estimated to number over 11,000 animals, winter within 25 km of the coast over an area of 1,800 km² (Mahoney *et al.* 1989). The reasons for this selection are believed related to snow conditions with snow depth and hardness considered to be the two most influential factors.

In the range of the LaPoile caribou herd snow depth increases as distance from the coast increases. Along the coast winter temperatures are moderated by the ocean and occasional thaw periods and winter rains reduce snowfalls and impede accumulations. Inland the moderating effect of the ocean is progressively diminished while elevation increases, resulting in colder temperatures. These colder temperatures result in the majority of the precipitation falling as snow leading to greater snow accumulation and a more persistent snow cover.

Due to the different climatic conditions between inland an coastal areals snow ram hardness in the range of the LaPoile caribou herd does not increase proportionally with distance from the coast. The milder temperatures in the coastal margin (0-20 km inland) result in winter rains leading to the development of ice layers in the snow cover. These ice layers cause the snow nearer the coast to be harder than that of further inland (42 km from the coast) where the formation of ice layers in the snow is much reduced. Thus, snow inland, although much deeper than that near the coast, is generally softer than that found in the coastal margin.

In the intermediate zone (20-36 km from the coast) the moderating effect of the ocean is still sufficient to produce significant ice layers in the snow. Furthermore, in this zone higher elevations lead to greater snowfalls and accumulations resulting in greater snow depths compared to coastal areas. Essentially this «transition zone», 20-36 km inland, combines the influence of ice layers and increased snow depths resulting in greater snow hardness and the most extreme foraging conditions to be encountered in the herd's range.

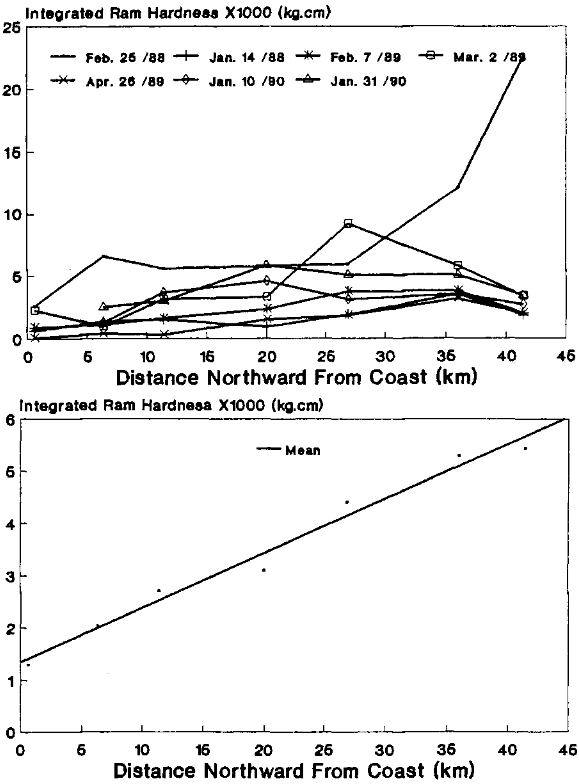

Figure 4. Mean snow integrated ram hardnesses measured at snow stations running north-south through the range of the LaPoile caribou herd.

Although snow hardness varies with distance from the coast, snow hardness in most areas of the LaPoille range is so great that caribou can walk and run on the snow without fracturing the upper surface. The wet conditions near the coast, in addition to the high winds both near the coast and inland, result in compacted hard snow which is typical of the enitre area during the winter. In the intermediate zone, and further inland, these conditions appear sufficiently severe to prohibit caribou winter time use. These nival conditions appear to substantially restrict the total range available to caribou in this region of Newfoundland during winter and thus may ultimately influence the maximal size of resident populations. Confirmation of such a relationship will necessitate forage evalution studies, planned for the summers of 1991 and 1992.

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The use of satellite images to estimate snow depth and distribution on the forested winter range of the Beverly caribou herd.

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Abstract: Satellite imagery of passive microwave emissions from the earth accurately determined both snow depth and distribution on the Beverly caribou herd's forested winter range.

Keywords: caribou, snow depth, satellites, microwaves, pastures

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Introduction

Snow cover has a profound influence on caribou energetics. Snow depth and distribution affects both food availability and the amount of energy required for locomotion and cratering (Pruitt 1959, Skogland 1978, Fancy 1986). Snow also affects caribou distribution. Between 1982 and 1989 Thomas and Kiliaan (1989) monitored snow depth in relation to the winter distribution of the Beverly caribou herd. They concluded that by late winter snow was usually deeper on the eastern portion of the range and that caribou had adapted to that snow distribution pattern by using the eastern portion of their range early in the winter, moving westward to occupy areas where the snow was shallower in late winter.

The use of satellite imagery to determine snow depth would help to clarify the effects of snow on caribou ecology because snow conditions could be monitored, not just sampled, more frequently and over larger areas than has been practical with direct field measurements. For over 20 years it has been possible to determine the extent of snow cover using visible sensors on NOAA satellites (Chang *et al.* 1990) but only when there is no cloud cover (see Lent 1980, Fleck and Gunn 1982, Eastland *et al.* 1989). Recently, algorithms have been developed to estimate snow depth and distribution from satellite imagery of passive microwave emissions from the earth which have been collected and archived since 1978 (Chang *et al.* 1990, Goodison *et al.* 1990). Microwave emissions are unaffected by clouds but they are influenced by snow moisture content, topography and tree cover.

Our objective was to examine the ability of satellite imagery to determine snow depth and distribution on the forested winter range of the Beverly caribou herd by comparing archived satellite data to Thomas and Killiaan's (1989) direct snow depth measurements.

Methods

Satellite images of passive microwave emissions in the 37Ghz range were obtained from Scanning Multichannel Microwave Radiometer data aboard the Nimbus-7 satellite. Ph.D. Associates Inc. (Calgary, Alberta) did the data processing, based on algorithms developed by Dr. B. E. Goodison (Canadian Climate Centre, Atmospheric Environment Service, Downsview, Ontario), and produced snow depth maps for March 1982 (Fig 1), 1983, and 1984, and January 1983, 1984, and 1985. Algorithms did not account for regional habitat differences within the study area which included boreal forest from 59.5° to 62° N latitude by 104° to 111° W longitude. Snow density was assumed to be constant at 0.2 gm/cm³.

Snow depth data from the satellite and from ground stations measured by Thomas and Kiliaan (1989) were entered into a geographic information system (Tydac SPANS). The satellite snow depths were contoured with SPANS to provide estimates of

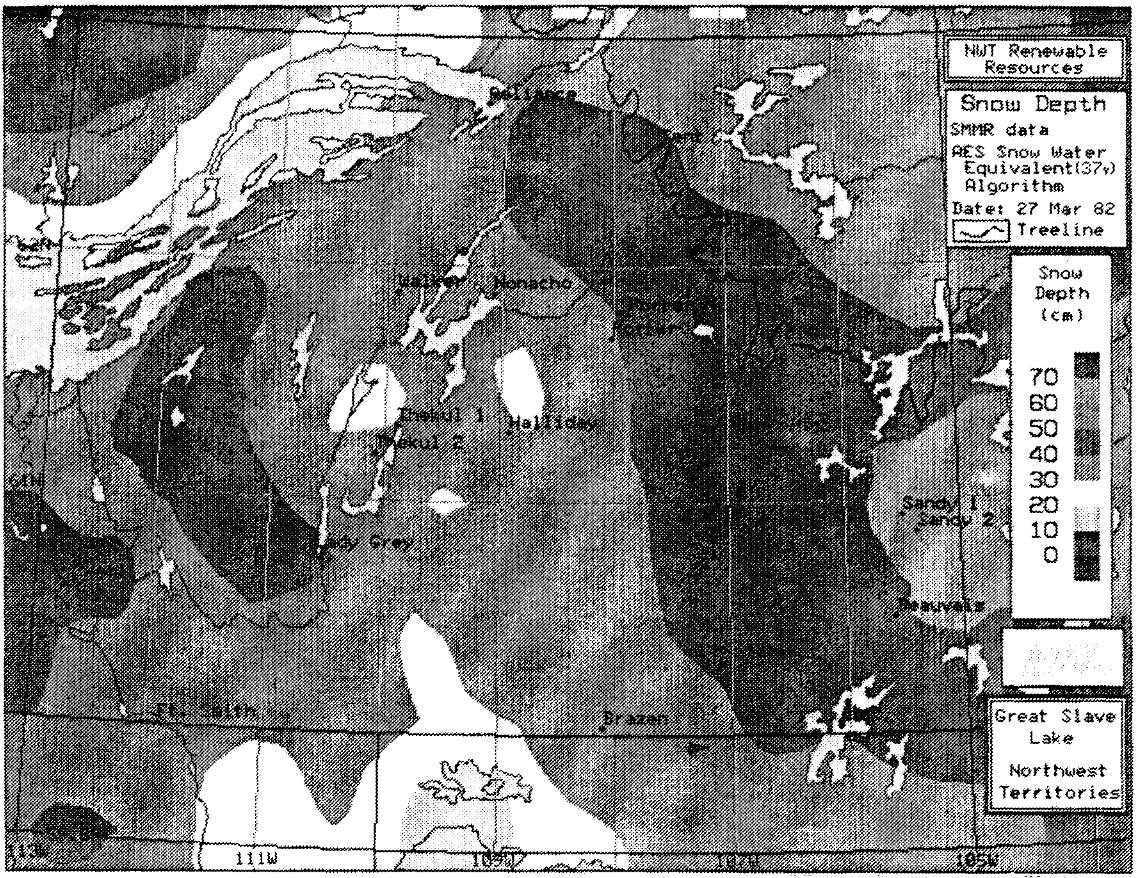

Figure 1. Depth and distribution of snow on the Beverly caribou herd's winter range 27 March 1982 based on a satellite image of microwave emissions from the earth.

snow depth to compare with the ground stations measured by Thomas and Kiliaan (1989) in March 1982.

Results and discussion

Satellite snow depth (SSD) estimates were correlated but significantly lower than measured snow depths (n=20, r=.504, P=0.023, t=9.49 P=0.0001) but can be modified on the basis of the March 1982 data so that the regression of corrected snow depth (CSD) estimates on measured snow depths passes through the origin with a slope of one (CSD = 1.715 SSD -11.85, Fig 2).

Satellite and measured snow depths showed the same trend with longitude for all 6 sampling periods

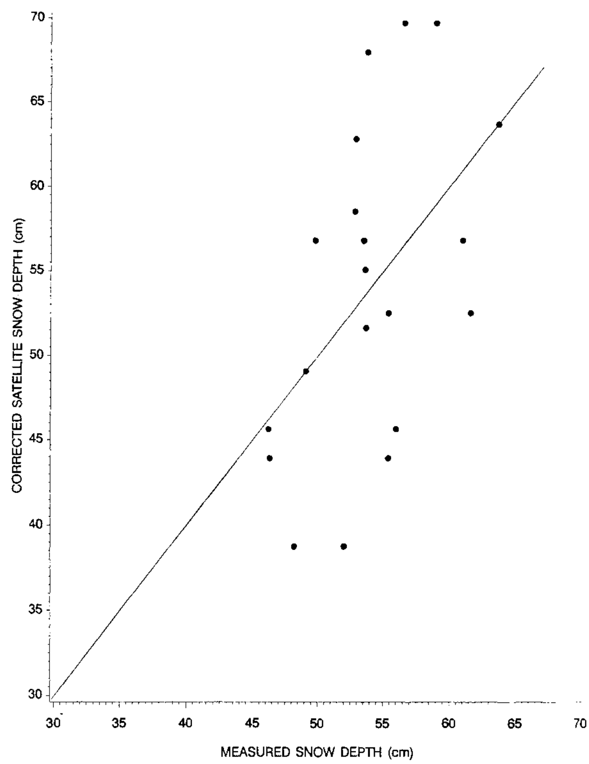

Figure 2. Relationship between the corrected satellite estimates of snow depth and snow depths measured by Thomas and Kiliaan (1989) at 20 sites on the forested winter range of the Beverly caribou herd in March 1982.

examined. Both the measured and satellite estimated snow depths for March 1982, 1983, 1984, and January 1984 declined with increasing longitude (probability that the slope being zero, $P < 0.05$ except for measured snow depths in March 1983 when $P = 0.067$). In January 1983 and 1985 neither the measured or the satellite estimated snow depths were related to longitude ($P > 0.10$).

Because microwaves are affected by trees, and water (both snow moisture content and lakes), the accuracy of snow depth estimates may be improved by taking into account regional differences in forest cover density, time of year (as an index of snow density and snow moisture content), large lakes, and lake density.

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