

**HABITAT USE AND POPULATION ECOLOGY OF THE
CORNER BROOK LAKE CARIBOU HERD**

**A Cooperative Research Project
of the
Western Newfoundland Model Forest
and the Newfoundland and Labrador Wildlife Division**

**INTERIM REPORT
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Abstract

During the winter of 1994, 14 adult caribou were radio-collared and during the spring 1994, 9 caribou calves were radio-collared in the Corner Brook Lake area. Ages of adults ranged from 1-9 years. Four adults died within one year of being collared; 3 unknown and 1 due to severe lungworm infection. Three calves had slipped collars, 2 were unknown mortalities and 2 were bear predated. All collared animals remained resident within the Corner Brook Lake area from March 1993-March 1994. Average home range size was 70.7 km² with no difference between males and females or between females with and without calves. Habitat composition of home ranges had both males and females selecting barren and overmature timber; males selected 61-80 year old timber; both sexes avoided 21-60 year old timber and mortality timber was used in proportion to availability. Chi-square analysis on telemetry data showed preferences for barren and mortality timber and avoidance of young timber and scrub. Population levels are estimated at 350-450 caribou with 10-11% calves. Annual adult and calf survival was 76% and 27%, respectively, and the calculated rate of increase is -0.11. With 88% calf production (i.e. pregnancy) the low recruitment of calves into the population is thought to be a result of predation and not limiting forage, yet the major predator on caribou is the wolf which is absent from this area. Current timber harvesting is reducing the amount of caribou habitat in this area. With >20% of the area in second growth, integrated resource management must sustain timber harvesting and caribou habitat.

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Introduction

The typical range of woodland caribou, *Rangifer tarandus caribou*, includes both open barrens (heathlands) and those climax boreal forest stands of spruce (*Picea spp.*), balsam fir (*Abies balsamea*) and white birch (*Betula papyrifera*) where tree and ground lichens are present (Miller 1982). Declines in the number and distribution of woodland caribou, since the late 1800's, have coincided with reductions in climax coniferous forest (Shideler *et al.* 1986, Cumming and Beange 1993) leading to the hypothesis that logging and declines in caribou are related in a cause and effect manner.

Caribou feed on a broad range of plants, including lichens, fungi, sedges, grasses, forbs, and twigs and leaves of woody plants (Miller 1982). During spring, caribou feed on leaves and graminoids on exposed sites, free of snow, then select plant species, according to phenology, for greening leaf buds and flower buds (Edwards and Ritcey 1960, Bergerud 1972, Miller 1982). There is generally a seasonal shift in diet from foliose and fruticose lichens, which are predominant in the diet during fall and early winter, to arboreal lichens, as snow deepens in late winter. Should lichens be essential forage items for forest-dwelling caribou during winter then caribou movements are expected to be closely associated with habitat providing adequate lichen supplies, including mature and overmature forest.

Winter survival is often considered a weak link in the longevity of caribou populations and great emphasis is placed on management of wintering habitat. The type of wintering area used by woodland caribou varies with location. Various studies of British Columbia caribou found that 80% of the caribou leave the barren grounds when the vegetation is covered with snow to search for arboreal lichens in mature or over mature balsam forest (Servheen and Lyon 1989, Rominger and Oldemeyer 1991); that caribou use mature timber during winter for travel corridors, arboreal lichen range and cover (Antifeau 1985); and Boonstra and Sinclair (1984) described no habitat

preference for caribou but attributed this to the universal availability of lichens in the area. Studies in Ontario found that caribou use old-growth forest almost exclusively during winter, feeding on lichens that grow on mature trees (Cumming and Beange 1987, Cumming 1992).

Summer survival may also become significant in localized areas where timber harvesting is removing most of the mature and overmature forest stands. Cutovers on caribou summer range in central Newfoundland, for example, were used by both sexes and age classes although females with calves were more sensitive to logging disturbance than males (Chubbs *et al.* 1993, Mahoney and Tucker unpub). Thus, it is vital to know the importance of mature and overmature forest to caribou, both as a percentage of their total range and as a winter and summer food supply.

Few studies have been designed to determine how various forest cutting regimes affect the ecology of caribou on a long term basis. Most studies of caribou response to disturbance by forestry operations, have found that caribou can tolerate some logging within their home range although fidelity to specific areas of wintering and calving habitat can be disrupted (Cumming and Beange 1987, Edmonds 1988, Racey *et al.* 1991, Cumming 1992). However, loss of winter habitat appears to have more long-term impacts. In northern Ontario, caribou did not use cut portions of traditional wintering areas for at least 12 years after cutting and attempts to modify cutting patterns have failed to prevent abandonment of cut areas (Cumming and Beange 1993) leading to recommendations that all cutting in caribou wintering areas be deferred to ensure survival in commercial forest. Racey *et al.*(1991) found that conifer stands were not useful as caribou habitat until 40 years of age when stand density decreases and terrestrial lichens become abundant.

Although habitat may determine calf production, predation is usually the greatest mortality factor for caribou calves (Bergerud 1980) where wolves (*Canis lupus*) are present. Thus, identifying calving behaviour and the factor(s) that dictate calf survivorship, and ultimately

population size, is critical to the management of caribou herds. Anti-predator behaviour of cows with calves differs depending on availability of escape cover (Cumming 1992). In open country, calves with cows are part of large post-calving aggregations which present predators with so many food items at one time that a relatively small portion are taken (Bergerud 1971). In forested country, however, caribou cows with calves will disperse to increase the search time by predators (Fuller and Keith 1981). Seip (1992a) presents a dramatic example of the influence of wolf predation on caribou in southern British Columbia. Where wolves were present and uncontrolled, calf survival to October was low (2.5 calves/100 females), whereas calf survival in areas where wolves were reduced or absent was much higher (39 calves/100 females). In the Mealy Mountain caribou herd, which is subject to wolf predation, calf mortality was 44-60 % annually (Hearn and Luttich 1987). In Quebec's Gaspesie Park caribou herd, which has black bear (*Ursus americanus*) and coyote (*Canis latrans*) as predators but not wolves, calf mortality was 57% in the first 6 weeks (Crete *et al* 1991). However, in insular Newfoundland, where black bear and lynx (*Felis lynx*) are the major predators, caribou calf mortality in the first twelve months of life was 23.1 % (Mahoney *et al* 1990).

Traditional forest management in western Newfoundland has concentrated on timber production and largely ignored or left to chance other resource values. Thus, the development of an integrated resource management plan as a tool to resolve conflicts between resource managers is the ultimate goal of the Western Newfoundland Model Forest program. A significant part of the Model Forest program is the integration of wildlife and timber management objectives. Since timber management is a major manipulator of wildlife habitat, it is essential to identify habitat requirements of wildlife species such that we can assess impacts of timber harvesting on wildlife and design timber harvesting strategies to achieve wildlife objectives.

The woodland caribou which inhabit part of the Western Newfoundland Model Forest area along the western edge of Grand Lake were described by Grant in 1902, as members of a

race distinct from other herds on the island. Research and management programs since then have virtually ignored this relatively sedentary ecotype which is reported to be structurally smaller and to have smaller antlers than other Newfoundland caribou (Grant 1902). Absence of migratory behaviour in this group may have important consequences for habitat utilization and population dynamics as animals in this area have been observed wintering and calving in timber but little is known about the proportion of animals that winter or calve in such habitat nor the location of wintering and calving sites with respect to logging disturbance.

The goals of this study are to describe the habitat use of a small, non-migratory caribou population with emphasis on winter range and to identify the importance of mature timber as seasonal habitat. Population dynamics, distribution and movement patterns are described and related to habitat use. Data from this study and others in North America will identify habitat variables required to develop a Habitat Supply Model (Appendix B). This model is part of the Model Forest strategy to target habitat types for the integrated resource management of timber and wildlife.

Methods

Study area

Situated on the west coast of Newfoundland the 543 km² study area extends north-south between Grand Lake and the Trans Canada Highway and east-west from Pinchgut Lake to Northern Harbour (Figure 1). The topography is rugged throughout and to the north features a large plateau, rising to 650 m. The plateau to the north is divided by steep sided valleys containing the drainage for Copper Lake, Valley of the Lakes and Steady Brook Lake. The bedrock underlying the plateau area is primarily semipelitic schist and psammitic gneiss whereas the southern part of the study area has a bedrock of platformal sedimentary rocks (Whalen and Currie 1988). Numerous small ponds are dispersed throughout the study area.

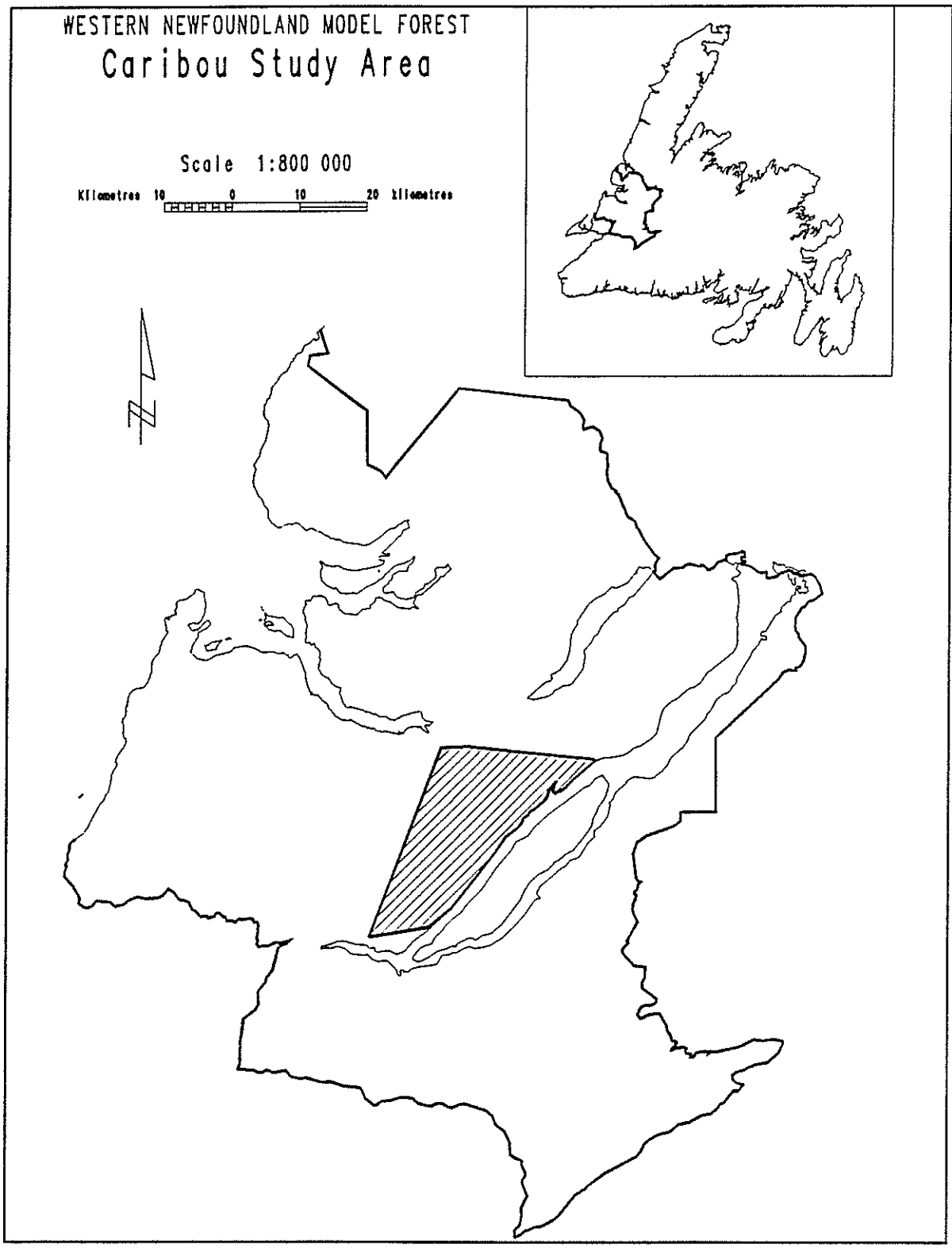


Figure 1. Study area of the Corner Brook Lake woodland caribou project within the Western Newfoundland Model Forest.

The study area includes two climatic zones, Central Uplands and West Coast (Banfield 1983), indicating substantial variation in temperature and precipitation, usually associated with differences in elevation. On average, there are > 400 cm of snowfall each winter, and more at higher elevations. The snow season extends from December to April. Mean annual precipitation ranges from 1000 - 1250 mm. The mean daily air temperature is between -4°C and -10°C in February (colder at higher elevations) and between 10°C and 20°C in July.

Most of the northern plateau falls into the Central zone and the southern part of the study area into the Western zone of Damman site classification (J. Gosse, pers. comm.). Forested areas are dominated by the Taxus-Balsam Fir and Dryopteris-Rhytidiadelphus-Balsam Fir forest types (Meades and Moores 1989). At least 30% of the study site is composed of non-forested areas including extensive rock barrens on the plateau and barren hilltops along the edge of Grand Lake. There are numerous small (< 0.5 km²) wetland and riparian areas interspersed among barren and forested habitats. A large 3 km² bog called Yellow Marsh lies in the northern part of the study area.

Logging operations have been ongoing in the area since the early 1920's and have altered most forested areas to the north, west and southwest of Corner Brook Lake. Clear cutting has always been the harvesting technique employed although the method of transporting the wood has changed over the years. Originally, horses were used in the early winter to pull the logs to the nearest large stream or river. From there, the trees were floated down a series of waterways to the mill itself or to an access point on the railway. In the 1940's, tractors replaced horses and could be used year-round. After 1963-64, trees were no longer cut into lengths on site, but instead were dragged by skidders to a central bulldozed 'landing' where they were cut up and loaded onto logging trucks for transport to the mill. These changes in technology resulted in increasing terrain and soil disturbance both because of the nature of the machinery and because operations occurred year round.

The use of skidders and logging trucks resulted in greater trail and road requirements and presently an elaborate network of these exists near Comer Brook Lake and the area to the West, behind Pinchgut. Within the next 5 years, plans include cutting the Copper Lake valley and Valley of the Lakes which lie to the east of Comer Brook Lake. Cutover size, primarily determined by the distribution of stands in relation to wetland and riparian zones, averaged 130 ha in 1993 (VanDusen, pers. comm.). Yearly cuts range from 10 ha to 200 ha but may, in effect, be larger when cuts from consecutive years are adjacent.

Silviculture operations, which include precommercial thinning, herbicide treatments and gap planting, were started in 1978. Balsam Fir forests are largely self-stocking once cut, and thinning is used in most regenerating cuts in the study area after about 12 years to reduce the number of stems to 2000 trees/ha. Under such practices, a stand is considered suitable for reharvesting after a period of 60 years. Forest stands which follow a natural successional path begin to decline after 80-100 years, usually becoming affected by various insect infestations. Second generation cutting within the study area began in 1986 (Sutton per. comm.) in areas damaged by the hemlock looper (*Lambdina fuscicollaria*) and make up less than 10 % of areas with merchantable timber.

Caribou capture and radio-tracking

Capture and radio-collaring of caribou were carried out March 7-23, 1994. Adult caribou were darted from a Bell 206L helicopter and immobilized using xylazine hydrochloride at a dosage of 5 mg/kg of body weight. The drug was administered using a darting syringe (Cap-Chur syringe, Kane Veterinary Supplies, Cambridge Ont.) fired from a CO₂ pistol (Palmer Chemical and Equipment Co., Douglasville, Ga.). Animals were located in an open part of the study area, and individuals were pursued for a period not exceeding 2 minutes. Once a caribou was darted, the helicopter pulled away to reduce disturbance as much as possible. Animals were revived with an antidote, RX-821002, administered intramuscularly or intravenously at a

dosage of 0.02 mg/kg body weight to reverse the effects of the immobilizing drug.

After immobilization, caribou were fitted with mortality sensing radio-collars, transmitting at individual frequencies between 149-151 MHz (Lotek Engineering, Newmarket, Ont.), and plastic numbered ear tags (large Allflex Standard I.D. ear tags, Kane Veterinary Supplies). An incisor tooth was extracted for aging (Matson's Laboratory, Milltown, Montana) using the cementum annuli technique (Miller 1974), and standard body measurements were taken (see Appendix A). Body weight was measured by placing the caribou in a sling (custom made by Canvas Repair shop, Corner Brook, NF) hung from a spring scale (model TD-5, John Chatillon & Sons, New York, NY) and suspended by helicopter.

Radio-collared females were usually assessed for pregnancy from helicopter, on May 26, 1994 based on girth and presence of an udder. Pregnant females were checked again every 2 days thereafter for the presence of a calf. Once a calf was observed, it was captured, ear tags were applied, an elasticised radio-collar slipped over its head and standard body measurements were taken. The age of the calf was estimated (in days) based on hoof wear and condition of the umbilicus. Calves, other than those of radio-collared females, were captured opportunistically.

Radio tracking was conducted using a Cessna 185 equipped with a Lotek radio-frequency telemetry receiver (model SRX_400) and 2 directional H-antennae mounted on the wing struts. Flight altitudes ranged between 2000-4000 ft. Locations were positioned using an on-board GPS (Global Positioning System) unit and were also plotted by an observer on 1: 50 000 topographic maps. The location for each animal was broadly described in terms of habitat and, if a sighting was made, group size and activity were also recorded.

Monitoring flights were conducted approximately every 2 weeks between March 30 and late May, 1994; thereafter flights were conducted every 2 days until all calves were collared; flights were then made once a week for the rest of June. From July to October, flights were carried out every third week and from November to March 1995, flights were again conducted on

a weekly basis.

Additional telemetry locations were obtained from snowmobile during late March 1994, and February-March 1995. Using a hand-held antenna, bearings from 2 positions were used to estimate caribou locations; where possible visual observations were made of collared caribou. During ground telemetry, all tracks encountered were recorded along with notes on cratering activity and habitat features such as vegetation, bedding sites, aspect, slope and snow depth.

To estimate accuracy of radio locations 9 test collars were distributed in a variety of locations: roadside, middle of bog, edge of forest and cutover and regrowth area. Locations were determined precisely from the ground using a GPS unit and were assumed to be the "actual" location. The test collars positions were then plotted from aircraft using the onboard GPS unit and by the navigator on 1:50,000 topographic maps (observer location). The differences between the actual location and the two locations determined from the air were calculated and the accuracy of the GPS location as compared to the observer location was analyzed using the Student *t*-test.

Habitat choice and food habits

Caribou home range sizes were determined using the minimum convex polygon (MCP) estimator and the software program Home Range (Ackerman *et al.* 1990). The MCP estimator was chosen for ease of integration with the Geographic Information System (GIS) habitat composition analysis available for the study area and for comparability with other studies investigating caribou home ranges.

Radio-telemetry locations were plotted on GIS and overlaid on the Newfoundland Forest Service (NFS) inventory database which included mortality timber and disturbance areas as digitized in 1992. Based on the accuracy of test-collar location, a 250-m radius buffer was established around each point (Young and Ruff 1982) and a habitat breakdown within the buffer determined. Locations were assigned a habitat type if > 50% of the buffer was comprised of 1

habitat type. If the buffer did not have a dominant habitat type then the point was excluded from the analysis. Habitat types in the study area were described as follows: bog (bogs and treed bogs), lakes, barren (soil and rock barrens), scrub (soft and hardwood scrubs), cutover (harvested area < 20 years old), timber (forested areas > 41 years old), and mortality timber (disturbed areas with > 26% mortality timber). Timber areas ranging from 21-40 years old were excluded from analysis since it comprised < 1% of the average habitat composition of adult home ranges.

Chi-square analysis (and Bonferroni confidence intervals) was used to test for goodness of fit between habitat use and availability (Neu *et al.* 1974, Byers *et al.* 1984, Zar 1984, White and Garrott 1990). We tested 2 null hypotheses; H_{01} : habitat use occurs in proportion to availability, considering all habitats simultaneously. H_{02} : habitat use occurs in proportion to availability, considering all habitats separately. Available habitat refers to all habitats within the entire study area and not the individual home range. This decision was appropriate due to the relatively low number of telemetry points and the error associated with convention telemetry resulting in the compounded error in home range estimates for use in habitat analysis (White and Garrott 1990).

Although the calving period was defined as the last week in May and the first 2 weeks of June; based on 1994 calving dates, the actual habitat description of calving areas was either observed directly or defined as the location of the doe and calf one day after birth, as calves move very little in the first 12-24 hours.

Caribou scats estimated to be less than one week old were collected opportunistically. The scat location, vegetation in the area and signs of foraging were recorded as well as information on group size and activity. Scats were frozen and forwarded to the Composition Analysis Laboratory of the Range Science Department, Colorado State University for composition analysis using microhistological techniques as described by Sparkes and Malehek (1968).

Population size and survivorship

To estimate population size and composition a standard strip census was modified into a capture-recapture estimation (White and Garrott 1990). In March 1994, 27 transects, 1 km apart and 15 km long, running north-south between the Trans Canada Highway and Grand Lake were flown in a Bell 206L helicopter. In March 1995, the census area was expanded based on distribution of radio-collared caribou and 34 transects were flown. During the censuses 2 rear seat observers scanned a strip approximately 500 m wide on each side of the aircraft; providing 100% coverage. The navigator tallied caribou encountered, checked for radio collared animals and classified the animals as adult male/female/unknown, calf male/female/unknown, or unknown/unknown. Whenever possible, the entire group was classified. When some individuals could not be identified, the whole group was classified as 'unknown' to prevent bias of easily identifiable animals, ie. does and calves. Caribou tracks were followed to locate all animals, sometimes necessitating deviation from the transect pattern. The location of each sighting was recorded on a 1:50,000 topographic map. Locations were plotted on the GIS database and habitat descriptions of each point were provided along with a 250-m buffer habitat breakdown. All observations were made after a fresh snowfall and under good to ideal weather conditions.

The standard assumptions for the Lincoln-Peterson estimate were made to estimate population size (White and Garrott 1990:255):

- 1) All marked animals are identified as such if encountered.
- 2) No birth and immigration occurs between marking and census.
- 3) Marked animals have an equal chance of dying or emigrating as unmarked animals.

We consider these assumptions reasonable for this census. Collared animals were tagged with large orange ear tags and were easily identifiable. In addition, collared animals were monitored on the first day of the census to confirm that all 'marked' animals were alive and in the census area.

Once a radio-collar was detected in mortality mode, the site was visited to determine the cause. Animal remains were examined and the surrounding area was carefully searched for information about cause of death. If no external signs were obvious, and the amount of decomposition was still minimal, an autopsy was performed either in the field by project biologist or, when the animal could be transported, by a veterinarian at Pasadena.

Annual mortality (survival) rates for adults and calves were calculated using the program Micromort (Heisey and Fuller 1985) which compares the number of mortalities to the number of radio-days pooled for all collared animals. For adults, the rates were also calculated separately for males and females. The survival rate for calves was also calculated separately for two periods: the 4 weeks after birth (to the end of June) and the rest of the year. Census data, calculated survival rates, and fecundity rates, were used to calculate the demographic vigour, i.e., survival-fecundity rate of increase, r_s (Hearn et al. 1990).

Results

Caribou capture and radio tracking

A total of 14 adult caribou were collared, 10 females and 4 males, ranging in age from 1 to 9 years (Table 1). Nine calves (5 male:4 female) were also collared, 4 of which were offspring of collared females. Adult and calf body measurements are presented in Appendix A.

Thirty-four monitoring flights recorded 295 locations for 12 adult caribou having > 10 relocations. Two adult caribou died after just 1 relocation. One female died after 13 locations, another after 16 locations and a male died after 23 locations were recorded. For the remaining 9 active animals, the mean number of locations was 26.8 (S.D. = 2.7). Twenty-two of the 34 monitoring flights recorded 70 calf locations. Six calves died or had slipped collars with ≤ 6 relocations and 1 died after 12 relocations. The remaining 2 calves had 19 and 21 relocations (Table 1).

Table 1. Summary of calving and home range information for caribou in the Corner Brook Lake study area, WNMF for the period March 1994-March 1995. Adult caribou were captured between March 7-23, 1994; calves were captured between May 28 and June 5, 1994. The only calves included in this table are those whose mother was not collared.

Frequency	Sex	Age	Pregnant	Calf status	Number of relocations	Homerange ¹	Fate
151.189	F	1	No	—	26.0	52.7	
150.495	F	3	Yes	Yes	30.0	40.3	
150.425	F	3	Yes	Yes*	29.0	47.5	
151.466	F	4	Yes	Uk.	28.0	93.9	
151.043	F	6	Yes	Yes*	13.0	28.5	Dead
151.575	F	5-7	Yes	Yes*	16.0	27.7	Dead
151.446	F	9	Yes	Uk.	1.0	—	Dead
151.456	F	Uk.	No	—	25.0	111.1	
151.200	F	Uk.	Yes	Yes*	29.0	88.6	
151.486	F	Uk.	Yes	Uk.	28.0	52.6	
151.155	M	3	—	—	24.0	59.4	
151.564	M	8	—	—	—	—	Dead
151.556	M	3-5	—	—	23.0	168.9	
150.456	M	Uk.	—	—	22.0	77.2	
149.354	M	calf	—	—	19.0	18.8	
149.364	M	calf	—	—	7.0	48.7	Slipped
149.375	F	calf	—	—	21.0	56.6	
149.295	F	calf	—	—	12.0	37.5	Unk.

* Calves of these females were also radio-collared.

1 Minimum convex polygon (Ackerman et al. 1990)

Home range, habitat choice and food habits

All collared animals remained resident within the study area from March 1994 to March 1995. Mean home range size for adults was 70.7 km² (SD = 40.5), 101.8 km² (SD = 58.8) for adult males and, 60.3 km² (SD = 30.1) for adult females. Mean home range of females with calves was 43.2 km² (SD = 21.9), and females without calves was 77.6 km² (SD = 29.6). No difference was detected in the home range size of males and females ($p = 0.24$) or for females with and without calves ($p = 0.38$). Home ranges of all animals in the study area overlapped extensively.

Based on habitat composition of home ranges (Table 2), both male and female caribou selected barren and overmature timber, with no difference between the sexes; $p=0.198$ and $p=0.950$, respectively. Males selected for 61-80 year old timber while females avoided this habitat type; $p=0.042$. Both male and female caribou avoided 21-40 and 41-60 year old timber, with no difference between the sexes; $p=0.195$ and $p=0.112$, respectively. Mortality timber was used in proportion to availability by both sexes.

Habitat use did not occur in proportion to habitat availability within the study area, considering all habitats simultaneously (Chi-square analysis). Considering habitats individually however we cannot reject H_{02} for bog and lake habitat types but we can for barren, scrub, timber and mortality timber as avoidance and/or preference was illustrated. The Bonferroni intervals show that barren and mortality timber were used more than would be expected by chance for 8 individuals and that scrub was used less than would be expected by chance for 3 individual caribou. Timbered areas were used more than expected by chance for 2 caribou and less than expected by 4 caribou (Table 3).

During radio tracking in March 1994 and 1995, 21 cratering sites were investigated. All sites were on barren knobs where wind had prevented snow accumulation. Inspection of these foraging areas revealed the caribou were cratering in 5-10 cm of snow, where vegetation was protruding. At these sites, they appeared to have been feeding on *Cladonia* spp., and the leaves and twigs of *Kalmia angustifolia*, *Empetrum nigrum* and *Chamaedaphne calyculata*.

Table 2. Habitat composition of the Corner Brook Lake study area and the average of 3 male and 9 female woodland caribou home ranges as defined by the minimum convex polygon (Ackerman et al. 1990) overlaid with the Newfoundland Forest Service inventory database. Mean percent habitat composition provided with standard deviation.

Habitat	Study area	Habitat Composition (%)		
		Male (n=3)	Female (n=9)	Combined (n=12)
Bog (including treed bogs)	4.3	4.1(2.0)	3.9(2.1)	4.0(2.0)
Water (ponds, rivers, etc...)	11.6	7.1(3.6)	8.4(2.2)	8.0(2.5)
Scrub (Soft and Hardwood)	22.4	23.4(2.7)	23.0(5.9)	23.1(5.2)
Barren (Rock and soil)	10.2	15.2(12.8)	25.2(7.2)	22.7(9.4)
Recent cutover (1-20 years)	5.0	2.5(1.6)	2.6(2.7)	2.6(2.4)
21-40 year old timber	4.1	1.1(1.0)	0.5(1.3)	0.7(1.2)
41-60 year old timber	9.2	6.9(3.6)	2.1(2.0)	3.3(3.2)
61-80 year old timber	9.3	11.4(4.3)	4.6(2.6)	6.3(4.2)
81+ year old timber	17.4	23.1(7.7)	24.4(3.6)	24.1(4.5)
Mortality timber	5.5	4.9(3.3)	5.2(1.8)	5.1(2.1)
other (cleared land, sand, etc...)	1.0	0.3(0.5)	0.1(1.9)	0.2(0.3)

Table 3. Summary on habitat preference and/or avoidance of 11 woodland caribou of the Corner Brook Lake caribou population in the Western Newfoundland Model Forest. Bonferroni confidence intervals were set at $p = 0.10$ (White and Garrott 1990).

Caribou number	Chi-square statistic	degrees of freedom	Probability	Habitat					
				Bog	Lake	Barren	Scrub	Timber	Mortality timber
0425	136.7	5	<0.001				Avoid	Avoid	Prefer
0456	11.5	5	<0.05					Prefer	
0495	15.3	5	<0.01						
1155	26.3	5	<0.001						Prefer
1189	93.4	5	<0.001					Prefer	Prefer
1200	29.1	5	<0.001			Prefer			Prefer
1456	31.1	5	<0.001			Prefer		Avoid	
1466	47.7	5	<0.001						Prefer
1486	86.5	5	<0.001			Prefer	Avoid	Avoid	
1556	21.1	5	<0.001				Avoid		
1575	30.8	5	<0.001			Prefer		Avoid	
Combined	366.0	55	<0.001						

Population size and survivorship

During the 1994 census, 158 caribou were observed within 468 km² including 5 of 13 radio-collared animals. The population was estimated at 345 ± 250 caribou (95% CI) and mean density was 0.74 caribou/km² (0.20-1.27 caribou/km²). We classified 63% of all observed animals; of these 40% and 50% were adult males and females respectively, and 10% were calves. During the 1995 census, 236 caribou were observed within 543 km² including 6 of 13 radio-collared animals. The population was estimated at 440 ± 300 caribou (95% CI) with a density of 0.81 caribou/km² (0.26-1.36 caribou/km²). Classification of 78% of observed caribou indicated 38% and 50% adult males and females respectively and 11.4% calves (Table 4).

Radio-collared females calved between May 27 and June 05, 1994. Visual checks of collared females at calving time revealed that 7 of 8 mature females were pregnant (88% pregnancy) (Table 1). It was confirmed that 5 of the 7 successfully gave birth to a calf (71% success). One of the 2 remaining females was observed with afterbirth hanging from the vulva, but a calf was never located; we do not know if the calf was stillborn or killed shortly after birth. The other female remained alone, in heavy timber, for the duration of the calving period. Although she appeared pregnant, we never observed a calf. Overall, 62.5% of mature females successfully produced a calf.

As calving time approached, pregnant females separated themselves from other caribou and remained in isolation during the birth of their calf and in the days that followed. Group size varied significantly between pre-calving, calving and post-calving periods ($F = 6.484$; $p = .003$); mean group sizes were 4.9, 1.3 and 3.8 caribou/group respectively.

Calving location was identified for 5 of 7 parturient females: all calved in mature timber. For two females whose calves were not observed, one was located on a wooded hillside surrounded by barrens and the other was in a large, wooded area where no observations could be made. Some non-radiocollared females however did calve on open barrens or grassy fens scattered amongst clumps of scrubby black spruce (tuckamore).

Table 4. Winter census and classification results of the Corner Brook Lake caribou population. Results from studies of the Lapoile, Middle Ridge and Buchans herds are provided for comparisons of migratory populations of woodland caribou herds in Newfoundland (Newfoundland and Labrador Wildlife Division, unpublished). The Corner Brook Lake population is a non-hunted group of animals whereas the other herds described are hunted populations.

	Corner Lake	Brook area	Lapoile	Middle Ridge	Buchans
Year of Last Classification	1995	1994	1989	1989	1983
Number of Animals Classified	184	100	1014	743	330
% Calves	11.4	10.0	27.3	22.9	20.7
Calves/100 Does	28	20	51.3	40.5	37.7
Stags/100 Does	75	80	36.5	36.1	44.7

Adult mortality

One male and 3 female caribou died between March 1994 and March 1995; the one male died within 3 days of capture and was excluded from survival analysis. The estimated adult annual survival rates based on 13 months of radio-days was 76.5%. Survival rates for adult males and females was 100% and 69%, respectively. Seasonal survival rates for males was 100% for summer and winter, however females rates varied from 68% in summer to 100% in winter (Table 5). All 4 of the adult mortalities ranged in age from 5 to 9 years (Figure 2). None of the remaining collared animals are > 5 years of age.

The male caribou noticed to be lethargic when collared March 16 was found dead on March 20, 1994. An autopsy was conducted by a provincial veterinarian on March 22. The cause of death was aspiration of rumen contents which occurred after the animal fell down a steep slope (DuivenVoorden, pers. comm.). There was also extensive lung damage resulting from parasitic pneumonia caused by lungworm, *Dictyocaulus viviparus*. It appeared that the animal did not completely recover from the immobilizing agent, possibly in part due to the parasitic infection (DuivenVoorden, pers. comm.). Impaired lung function was likely the reason that the caribou did not run from the helicopter during the immobilization procedure.

Three female caribou died, all of unknown causes. The first was located on May 24, 1994 in a mature birch/fir forest on a relatively steep (10-15°) slope. There was little decomposition, no signs of predation and only limited scavenging into the abdominal cavity. An on-site autopsy did not reveal the cause of death. The second female was found on June 25 in open tuckamore scrub on the barrens. The carcass was intact but in advanced decomposition. This female had a calf which died one week before the mother, the remains indicating mastitis as a possible cause of death. On August 18, a third female was located in mature fir forest. There were no signs of predation or scavenging but, again, advanced decomposition prevented further investigation of the cause of mortality. This female had a collared calf which also died, 3 months later.

Table 5. Summer (May 16-October 31), winter (November 01-May 15), and annual survival rates and radio transmitter days (RTD) for radio-collared caribou from Corner Brook Lake caribou herd for 1994-1995. Survival rate calculations from program Micromort (Heisey and Fuller 1985).

Age group	Season	FEMALE			MALE		
		Survival rates	RTD	95% CI	Survival rates	RTD	95% CI
Calves	spring*	0.65	76	0.27-1.00	0.52	102	0.21-1.00
	summer	1.00	246	1.00-1.00	1.00	246	1.00-1.00
	winter	0.41	169	0.07-1.00	1.00	285	1.00-1.00
	annual	0.22	491	0.03-1.00	0.32	633	0.06-1.00
Adults	summer	0.68	1296	0.43-1.00	1.00	507	1.00-1.00
	winter	1.00	1662	1.00-1.00	1.00	621	1.00-1.00
	annual	0.69	2958	0.45-1.00	1.00	1128	1.00-1.00

* First 4 weeks post-calving

Overall calf survival rate = 0.27 (0.08-0.97)

Overall adult survival rate = 0.76 (0.56-1.00)

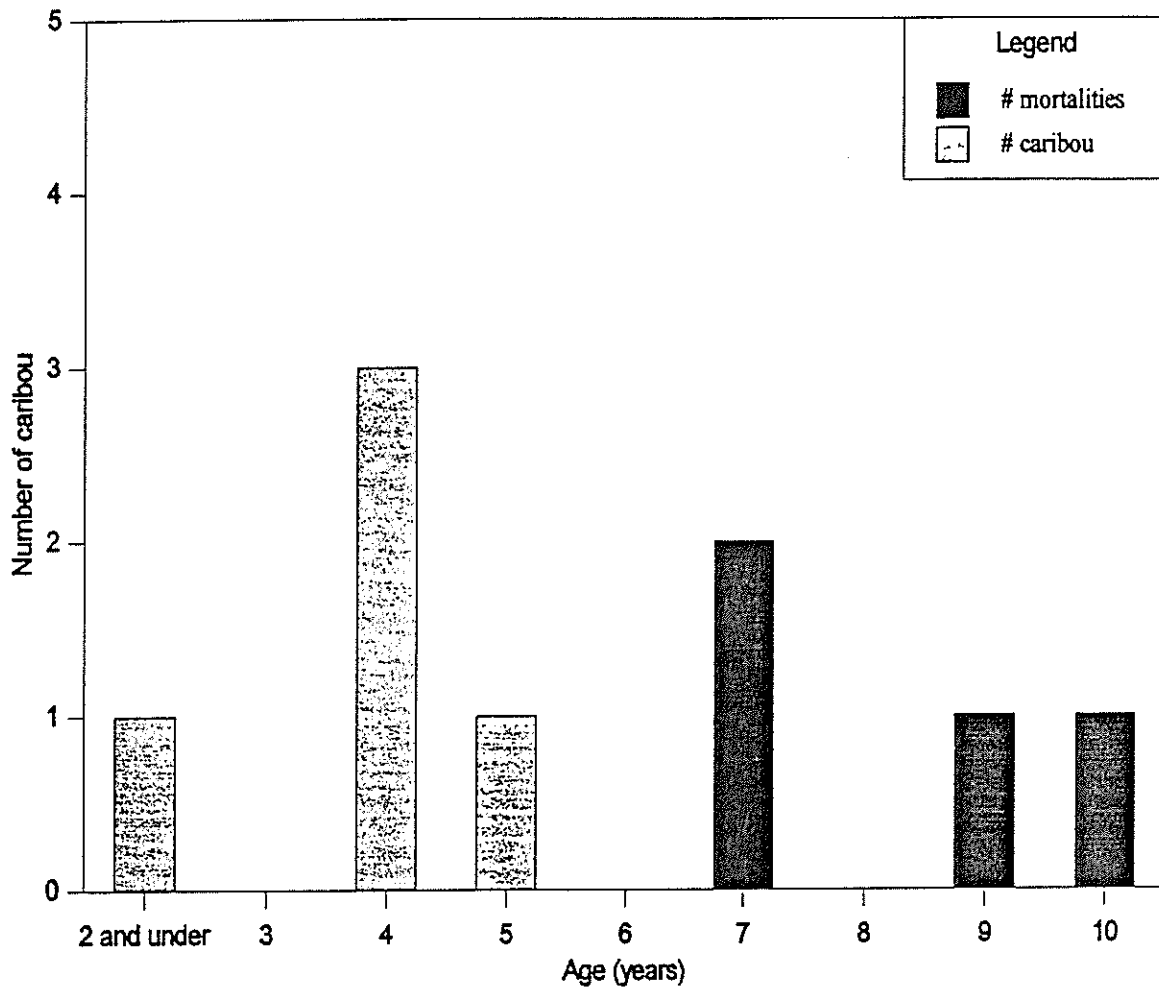


Figure 2. Age distribution of 9 radio-collared woodland caribou in the Corner Brook Lake Herd, along with age-specific mortality. Age determination through cementum analysis of teeth collected during immobilization of the caribou.

Calf mortality

Three of 9 collared calves died in the first 2 weeks after birth. A fourth calf slipped its collar during this period and 2 other calves slipped their collars afterwards, and 1 calf died of unknown causes approximately 3 months after the mother died. Calf survivorship was 56% to one month and thereafter 63% until 12 months of age. Total annual calf survivorship was 27% (Table 5).

Two of the calf deaths appeared due to predation. In the first case remains consisted of bone fragments and part of a hoof located in a small clearing in open, mature fir forest. Predation by bear was assumed since a large bear scat was present about 1 m from the kill site. This calf survived 9 days after collaring. In the second case the lower parts of the front legs and half a calf jawbone were found in a clearing in very open woods 12 days after collaring. No scat or other evidence was found on site to identify which predator was involved, although remains were similar to the bear predated calf above. At the time of capture a large fox (*Vulpes vulpes*) was seen running from the site where the calf, which was estimated at one day old, was located, thus providing strong evidence that fox predation occurred.

The third calf mortality was located in open balsam fir/black spruce forest 12 days after collaring. Although some scavenging had taken place, the skeleton was still intact, and fur covered the head and legs. The midsection had been incompletely eaten. The actual cause of death is unknown. The mother of this calf died 6 days later which suggests that a health problem in the mother affected the survival of the calf. As previously mentioned, mastitis in the mother could have led to calf starvation.

A fourth calf may have died at 7 months of age, 3 months after the mother. The collar alone was found buried under 18 inches of snow and no carcass was located. The collar was left in site; a return trip is planned to try and locate any remains or to determine if it was a slipped collar.

The demography of this herd based on calculated survival and fecundity rates has a rate of increase of $r_s = -0.11$ (Table 6).

Table 6. Calculation of survival-fecundity rate of increase, r_s (Hearn et al. 1990) for the Corner Brook Lake caribou herd for 1994 from census data, calculated survival rates and fecundity data, starting with a hypothetical population of 1000 animals.

1994 precalving population	1000
adult population (1000-10% yearlings)	900
adult female population (900-40% males)	540
Recruitment to population	
calf production (540 x 0.88)	475.2
annual calf survival (475.2 x 0.27)	128.3
annual adult & yearling survival (1000 x 0.76)*	760.0
1995 precalving population (760.0 + 128.3)	888.3
Rate of increase, 1994-1995 [$\ln(888.3/1000)$]	-0.11

* Yearling survival is unknown, therefore combined with adult survivorship

Discussion

Home range and habitat use

The Corner Brook Lake caribou occupy essentially the same range year round. This lack of migration is exhibited by many other forest dwelling woodland herds in North America: northeastern Alberta (Fuller and Keith 1981), southeastern Manitoba (Darby and Pruitt 1984), Quebec and Labrador (Brown et al. 1986) and Ontario (Cumming and Beange 1987). However, year round range is more restricted than for these other herds; 468 km² for the Corner Brook Lake herd vs >1400 km² for the other North American forest dwelling herds. Also, mean home range size for males and females in this study, 101.8 km² and 60.3 km² respectively, are much smaller than those stated by Fuller and Keith (1981), 1196 km² and 539 km² for males and females respectively.

Within home ranges, both males and females used barrenland and overmature timber (81 + year old timber) in greater proportion than availability. Although no difference occurs in use of barrenland, between the sexes, incidental observations, during monitoring flights, indicate that females make greater use of barrenland than males. During the winter and calving period, when telemetry is intensified, the majority of the males are located on the fringes of the barren or in the timber whereas the majority females are located more on the open barrens during winter and will only drop calves in the timber and then move onto the barrens when the calves are 2-4 days old. The 3 collared males moved off the barrens in December and remained, for the entire winter season, in mature and overmature timber with pockets of mortality timber scattered throughout. Male home ranges have greater proportions of all timbered areas combined than that of females.

For chi-square analysis, five caribou habitat types, based on available habitats, were defined in the study area; bog, barren, scrub, timber and mortality timber. A strong preference by caribou was indicated for the two habitat types, barrenland and mortality timber, which provide the main winter forage items; ground lichen, ericaceous shrubs and arboreal lichen. Aerial census data indicated 17.2% of the caribou in 1994 and 25.4% of the caribou in 1995 were located in mortality

timber which comprises only 5.5% of the census area, and that 33.8% of the caribou in 1994 and 39.7% of the caribou in 1995 were located on barrenlands which comprise only 10.2% of the censused area. Brown *et al.* (1986) described caribou using upland tundra for loafing in late winter and returning to lichen woodlands to feed. Mortality timber provides opportunities for foraging on lichen rich windfalls as reported by Rominger and Oldemeyer (1991) for the Selkirk Mountain herd.

Mature timber is important to caribou by providing forage, thermal cover, predator avoidance and calving habitat. This habitat type appears essential to the annual survival of the caribou population yet mature timber is avoided by 4 animals in the analysis. Mature timber plays a more important role in caribou behaviour than the results indicate and the avoidance of mature habitat is a consequence of the analysis performed on the data. A fallout of the Bonferroni confidence intervals is that with preference of one habitat type there is usually avoidance of another habitat type as a function of habitat type proportions and the fact that mature timber comprises most of the study area, it is here that the avoidance will likely be evident. Also the grouping of the 3 mature stand ages; 41-60, 61-80 and 81+, may have reduced the vigour of the test but with low numbers of telemetry data, the grouping was necessary.

The majority of Corner Brook Lake caribou appear to select mature timber as calving habitat. Brown *et al.* (1986) described calving sites for woodland caribou in Labrador as forest-wetland habitat that had small open wetland (< 1km²) surrounded by timber. Calving sites selected by Corner Brook Lake study animals were more often in mature forest rather than on an open wetland, as appears to be the case in Labrador. As well, some females were observed calving on open barrens in this system, whereas Brown *et al.* (1986), investigating a system impacted upon by wolf predation, observed no calving activity on upland tundra. Bog habitats may have a seasonal importance, such as calving sites and rutting locations, that would not be evident in this analysis as habitat use was based on relatively low numbers of annual telemetry data.

The avoidance of scrub might reflect the minimal cover and forage provided in this habitat type but could also result from the 250-m error ellipses associated with telemetry locations and the juxtaposition of barren and scrub habitat.

Identifying mortality timber as an important habitat component of caribou range may create conflicts with timber management strategy. Timber harvest strategies target the oldest timber first for cutting will reduce mortality timber as will the looper spray programs. Fortunately observations in the field indicate caribou are using mortality timber in our study area which is totally inaccessible to timber harvesting, being located primarily along the steep-sloped shoreline of Grand Lake. Presently mortality timber comprises only a small portion of the study area and through natural succession, these forage areas will eventually disappear. Approximately 5.5% of the Corner Brook caribou population range is comprised of mortality timber, and therefore maintaining at least this proportion appears reasonable given our current knowledge base, if the goal is to maintain the current caribou population. Unlike mortality timber, barren habitats are usually not included in forest management strategies and thus few conflicts will arise, as is the case with bog and scrub habitat types.

Greater than 20% of the study area is currently in second growth (21-80 year old timber). This forest type is predominantly located south and east of Pinchgut Lake. At present caribou are not using this area as forage availability is limited. However, in the near future, this area will provide the majority of caribou habitat in the Corner Brook Lake area. It will also be targeted for timber harvest in the near future, as a result an integrate resource management plan must be developed if both timber and wildlife objectives are to be maintained

An interesting feature of the data is the relatively equal distribution of preferences for barren and mortality timber. An unknown in the database is the relative amount of time an individual will remain in a habitat type and the movement pattern associated with foraging behaviour. Thus, trying to draw inferences on population habitat use, based on individual caribou, is difficult as habitat use, as defined above, may be an individual behaviour pattern that cannot be projected over the entire

population given the obvious habitat use discrepancies. One of the problems with conventional telemetry is that the results are based on a snapshot of time with the goal to gather many telemetry points so that this bias is reduced. However, a more appropriate approach, to eliminate this bias, is to use GPS collars. This technology will inject a temporal scale on habitat use and movement patterns that will result in a more definite definition of habitat use.

Population characteristics

The ratio of males to females in the Corner Brook Lake herd is much higher than in other herds in Newfoundland (Table 3) or, indeed, in North America (Bergerud 1980). Two factors may be largely responsible. First, this is a non-hunted population leading to improved survival of adult males, the cohort normally preferred by sportsmen and second, it is hypothesised that woodland caribou occupying forested areas during the rut may exhibit a different mating strategy than other caribou herds (Mahoney, pers. comm.). Individual male caribou, in the Corner Brook Lake area have been observed following individual female caribou through heavy timber during the rut (Mayo, pers. comm.). This type of mating strategy, in comparison to a situation with a single dominant male attempts to control access to a large harem of females, would reduce the number of male conflicts and associated mortality, while increasing the number of males with an opportunity to successfully mate. Death from fighting during the rut is reported by Bergerud (1971) as the single greatest cause of mortality, excluding hunting, for adult males in many Newfoundland caribou populations.

There appears to be little variation in birth rates between caribou herds or between years (Bergerud 1980). The average pregnancy rate for North American herds is 82% (Bergerud 1980) which is very similar to the 88% pregnancy rate for adult females in the Corner Brook Lake herd. Klein (1968) suggested that reproductive success and body size are determined by summer forage whereas winter range supports maintenance and determines population size. Since summer range does not appear to be limiting, except in a handful of cases (Reimers 1980), the reproductive rate probably approaches the intrinsic rate for the species for most North American herds, the current

population included.

Comparison of calf recruitment in the present study with recent counts of the Lapoile, Middle Ridge and Buchans herds (Table 3) show that the Corner Brook Lake caribou have low recruitment, with less than half the percentage of calves present in other populations. The low recruitment rate, 10% calves, indicates a declining population or at best a borderline stable population (Bergerud 1980). A 12% recruitment has been suggested as the point at which caribou populations remain stationary (Bergerud and Elliott 1986).

It is unclear, however, if the percent calves in the population is typically this low or if there will be a wide variation between years. Counts of the Humber herd in the winter of 1959 and 1960 produced calf percentages of 35.7 and 10.0 respectively (Bergerud 1971). Similarly, a census of the Northern Peninsula herd in February, 1976 indicated a low calf recruitment of 9% (Greene 1976). However, when this was averaged with the previous 2 estimates, the mean percent calves in the herd was 16%. In this study, classifications in 1994 and 1995, and the calculated rate of increase, suggested low recruitment which it appears is the result of low calf survival, given that productivity (i.e. pregnancy at calving) is high.

Female caribou in the Model Forest dispersed individually from their winter groupings just prior to calving, but formed small post-calving aggregations of 2-3 cow-calf pairs. This change in social grouping behaviour, and the calving strategy in general, appears to be typical of woodland caribou herds observed elsewhere in North America (Fuller and Keith 1981; Darby and Pruitt 1984; Edmonds 1988). The present study indicates that calves are most likely to die during the first two weeks of life. In a study on the south coast of Newfoundland, Mahoney *et al.* (1989) also recorded that the highest mortality of calves (43%) occurred in this initial period followed, in the ensuing weeks, by a decline in mortality rate. Bergerud (1971) reported a high mortality of calves in the first month post parturition, in the same Newfoundland herd, and a sharp decrease in calf deaths thereafter. Across North America, most caribou mortality occurs in the first few months of life with predation listed as the

principle; other factors include stillbirths, birth defects, exposure to weather, drowning and accidents (Bergerud 1980). In this study and the work by Mahoney *et al* (1989), predation also appeared to be the chief cause of death. Bergerud (1971) listed 'actual' predation as only a small fraction of mortality factors, although the majority of deaths appeared to result from an infection in wounds sustained during attack by lynx. Whether the predators in our study were lynx or bear is not entirely clear, when compared to the descriptions of kill sites in Mahoney *et al.* (1989). Neither kill site had remains of the intact pelt, as is common for bear kills, but the presence of a large scat in one case strongly implicated black bear in the death of that calf.

Bergerud (1980) reviewed North American population dynamics and noted that herds exposed to predation usually lose 50% of their calves or more after the first 6 months, whereas herds with little predation experience less than 50% calf mortality and generally show an increase in population. Mahoney *et al.* (1989) felt that an overall calf mortality rate of 23% would not depress a caribou population otherwise in good health. Considering the above figures, the calf mortality rate observed during the first 10 months of this study (37%) does not appear high enough to significantly depress the population in the Model Forest area, given the absence of wolves and human hunting.

The majority of adult caribou deaths in the present study were not linked to predation, in contrast to a study in central Newfoundland, which implicated black bears in most of their adult mortalities (McGrath and Fong 1986), and a study in Alberta which linked 75% of mortalities to wolf or bear predation (Fuller and Keith 1981). Earlier investigations of caribou mortality in Newfoundland by Bergerud (1971) indicated that death during calving was the largest mortality factor for adult females. As mentioned previously, death by fighting during the rut was the single greatest cause of mortality for males. Neither factor has been confirmed as a cause of death for any study animals in the Corner Brook Lake herd. Death from complications during parturition is a possibility for only one of the three females which died.

The adult mortality rate (24%) in this study, based on a small sample size and only 13 months of monitoring, is much higher than the 6% mortality rate reported by McGrath and Fong (1986). A 5-6% mortality rate is the average in North America for herds not affected by predation, especially by wolves (Bergerud 1980). Further, the age at death for females reported here is much lower than the lifespan of female caribou (Bergerud 1971). In general, the mortality rate appears to be high and the mortality factors remain largely unknown for this population. Additional study animals and further monitoring are required before accepting the trends suggested by the data so far. In comparison, the study by McGrath and Fong (1986) involved 51 adult caribou which were radio-collared and monitored for 3 years.

Discovery of one animal heavily infected with lungworm indicates that this parasite is likely to affect other members of the Corner Brook Lake herd. The larvae, which are the infective stage of this organism, are passed with the feces, remaining viable for long periods, and can move onto the sporangia of fungi that grow on the faecal material and are dispersed when the sporangia explode (Noble *et al.* 1989). The larvae may be ingested into the rumen during foraging thus infecting other members of the herd (DuivenVoorden, pers. comm.). It is suggested that mortality caused by lungworm can occur in caribou which are nutritionally stressed (Skoog 1968). The sick and old caribou are the most likely to become heavily burdened with the lungworm (Fong, pers. comm.) and, in fact, the male in this study which was infected with this parasite was 10 years old, the oldest caribou we captured. This parasite is fairly common among caribou herds in Newfoundland but does not usually result in severe infections and death (Fong, pers. comm.). Gibbs (1960 cited in Broughton and Choquette 1969) found signs of lungworm in barren-ground caribou but also concluded that the animals were unlikely to have died from the infection.

During the census in 1995, 4 adult caribou were observed to be very lethargic and did not run from the helicopter, indicating that other members of the population are possibly affected by this parasite and that it may be a factor influencing population growth. The physical effects of this

parasite are usually apparent only when an animal has a heavy infection although the parasite is probably wide spread, with cross infections being facilitated by the limited range and movements of this herd.

The determination of which factor(s) help control or regulate the Corner Brook Lake caribou population is critical to the development of resource management strategies. A number of studies have concluded that populations are primarily effected by predation or of limited forage supplies (Bergerud 1980, Shideler *et al.* 1986, Cumming 1992, Seip 1992a, Seip 1992b, Cumming and Beange 1993). Caribou herds that are not regulated by predators usually maintain high population densities of 4-8 caribou/km² (Bergerud 1980) or 2-9 caribou/km² (Seip 1992b). Herds regulated by predation, on the other hand, usually have densities < 1 caribou/km² (Bergerud 1980, Seip 1992b).

Based on these findings density levels of the Corner Brook Lake herd (0.7 caribou / km² in 1994 and 0.81 caribou / km² in 1995) would imply that they are predator regulated, although wolves, the major predator of caribou in many other areas are not present in Newfoundland and our data do not support this hypothesis. On caribou ranges where wolves are present, the lichen supplies usually far exceed the needs of the population (Cumming 1992). However, in Newfoundland, at this point, we have no measure of available lichen.

In attempting to determine limiting factors that control the Corner Brook Lake caribou population, three potential factors that can work independently or simultaneously have been identified. The first probable factor is predation. Although wolf, the main predator on caribou, is absent from the area, the low density indicates that predation must be an influence on the population. Survivorship data shows a relatively high adult mortality but investigations have provided little information on causes of death. Although density figures are low across the entire study area, the figure becomes much higher when calculated over the areas of preferred habitat, barren and mortality timber. These habitat types only include 15.7% of the entire study area and will increase the density > 5 caribou/km². As a result of this increased density, the second probable factor of forage may be

limiting this caribou population. The third factor, parasite transmission, may be influencing the population, especially if the caribou are heavily utilizing these proportionately small areas of forage availability allowing for easy transmission of parasites like the lungworm. The fact that these caribou utilize this area year-round will increase the potential of these factors to act detrimentally on this population.

It is still unclear, at this stage, whether the population in the Model Forest is controlled by predators, forage abundance or parasites and disease. Cumming (1992) recommends that each local population be examined independently to determine the effects of both predation and forage availability on the caribou. To develop a model of this caribou population, and to produce relevant management strategies, both the forage and the predator theories must be investigated. Although the data presented to date is statistically weak, it is only preliminary data that can provide some direction and focus of research needs.

Summary - Progress on Project Objectives

1) Estimate density, sex ratio and age structure of the woodland caribou population in the study area for the purpose of relating these population parameters to habitat quality and habitat alterations resulting from timber harvesting. In March 14 caribou were collared and a caribou census and classification was conducted, March '94 and '95. We estimate there to be approximately 400 caribou in the Corner Brook Lake population with a density, 0.74-0.81 caribou/km². The classification results have been compared to other woodland caribou herds in Newfoundland revealing a very low calf recruitment and a higher proportion of stags in the population. The caribou are concentrated in a small portion of the study area (15.7%) and the caribou make heavy use of the areas of mortality timber. As a result, caribou management and timber management must be integrated to protect portions of mortality timber and these areas coming on line.

2) Estimate annual survival and reproductive rates, and document sources of mortality. Relate these parameters to habitat quality and availability within areas affected by timber harvesting. Two males and three female caribou died between March '94 and March '95. The estimated annual survival rates based on 13 months of radio-days are 52% for males and 69% for females. The caribou which died were all older members of our study group between the ages of 5 and 9 (Fig. 3). None of the remaining collared animals are older than 5 years of age. Visual checks of collared females at calving time revealed that 7 of 8 mature females were pregnant (88% pregnancy) (Table 1). In a similar fashion, it was confirmed that 5 of the 7 successfully gave birth to a calf (71% success). There has been one mortality which was traced to parasitic pneumonia and 3 unknown causes of mortality.

3) Determine size and habitat composition of home ranges of radio-collared caribou and relate habitat use to forage availability. Habitat use did not occur in proportion to habitat availability within the study area, considering habitats simultaneously, as all caribou rejected the null hypotheses; H_{01} (Table 2). Based on the Bonferroni confidence intervals at $p=0.10$ we cannot reject the second null hypothesis (H_{02}) for bog and lake habitat types. However, we can reject H_{02} for barren, scrub, timber and mortality timber as avoidance and/or preference was illustrated. The Bonferroni intervals show that barren and mortality timber were used more than would be expected by chance for 8 individuals and that scrub was used less than would be expected by chance for 3 individual caribou. Timbered areas were used more than expected by chance for 2 caribou and less than expected by 4 caribou (Table 2). Barren and mortality timber provide the major forage; ground and arboreal lichen and ericaceous shrubs. It is the authors opinion that mature timber plays a more important role in caribou behaviour than the results indicate and the avoidance of these areas is a consequence of the analysis performed on the data.

4) Assess the relative abundance of arboreal lichens in stands of different ages, including recently harvested areas which may have available lichen on downed trees. A lichen survey did not appear feasible at this time and assumption were made that mortality timber provides the greatest availability of arboreal lichen with increased availability with increased age of the stand, starting at 41+. It was also assumed that harvested areas only provide lichen forage during the first 2 years after harvest.

5) Relate snow depth and hardness to short-term movements and choice of habitat of radio-collared animals. Preliminary information on the effects of snow on caribou movement and habitat selection, on barren grounds, shows that caribou are concentrating their foraging behaviour in areas that will reduce energy expenditures due to cratering. The lowest integrated ram hardness values occur in higher elevation areas where wind is able to reduce snow accumulation. All cratering sites observed were located on exposed ridge tops or areas of little snow accumulation where ericaceous shrubs and ground lichen can be accessed easily.

6) Determine the effect of sex or reproductive status on caribou response to human activity, both logging operations and recreational use of logging roads. This data will be collected in the continued monitoring on the caribou and their avoidance behaviour to specific regions in the study area. Logging operations are currently being conducted in areas which are identified as calving sites.

7) Review sources of information available from the Wildlife Division about other caribou herds in the Model Forest, particularly about herd size and seasonal movements. There is a continuous flow of information between researchers in the Wildlife Division and the Model Forest.

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Appendix A. Capture data from adults and calves of the Corner Brook Lake herd collared during winter and spring 1994.

Date collared	Collar freq.	Doe freq.	Sex	Weight (kg)	Total length (mm)	Heart girth (mm)	Shlder height (mm)	Foot length (mm)**	Fate 31/3/95
ADULTS									
07/03/94	151.456		female	85	1745	1145	1145	550	
07/03/94	150.495		female	100	1815	1185	1260	570	
07/03/94	150.446		female		1875	1235	1185	445	unk. mortality
07/03/95	150.425		female		1820				
15/03/95	150.456		male	110	1880	1220	1250	570	
15/03/94	151.486		female		1870	1230	1245	575	
16/03/94	151.564		male		2150	1285	1295	600	mortality*
22/03/94	151.466		female	100	1910	1165	1190	535	
22/03/94	151.200		female						
22/03/94	151.189		female	70	1680	1000	1100	520	
22/03/94	151.155		male		1955	1190	1270		
23/03/94	151.043		female	90	1870	1130	1190	560	unk. mortality
23/03/94	151.556		male						
23/03/94	151.575		female		1950	1210	1270	570	unk. mortality
CALVES									
28/05/94	149.354		male	9.0	800	450	540	360	
28/05/94	149.295	151.575	female	7.5	785	455	600	340	unknown
28/05/94	149.274	151.200	male	7.5	810	440	520	330	slipped collar
28/05/94	149.375		female	8.6	770	470	580	350	
30/05/94	149.284		male	9.5	839	495	680	360	bear pred.
30/05/94	149.364		male	9.5	860	480	600	360	slipped collar
05/06/94	149.394	151.043	female	7.5	800	490	630	350	unknown
05/06/94	149.225		female	10.5	880	500	650	340	slipped collar
05/06/94	149.335	150.425	male	5.0	690	380	490	300	bear pred.

* Cause of death was aspiration of rumen contents. Severe lungworm infection; never recuperated from immobilization procedure.

Appendix C.

Development of a preliminary HSI for woodland caribou in the Western Newfoundland Model Forest

This preliminary model was developed for woodland caribou in the Western Newfoundland Model Forest, particularly the population within the Woodland Caribou Study Area (Figure 1). The variables identified take into consideration those habitat features which may be measured or derived using the attributes of a forest cover type map (NFS 1994), annual information on silviculture and harvest areas, as well as Damman site type information (Meades and Moores 1989).

An existing HSI for woodland caribou, developed for the Manitoba Model Forest (Palidor and Schindler 1994), was used as a template for the development of this HSI model. Food quality and quantity and calving strategy are assumed to be the driving forces behind habitat selection for woodland caribou in this area. The variables for this model evaluate the stand composition within the area to be evaluated and are based on preliminary assumptions about the quantity and quality of food availability in those habitats.

Overview

Life requisites for the woodland caribou from only the winter season are considered in this model. Although winter cover does not appear to be a strong influence on habitat selection, cover requirements for both winter and calving periods are assumed to be met in a forage driven HSI for this species. The variables in this model are dependent on the availability of arboreal lichen, ground lichen and ericoids, as they are the most important components of the winter diet for caribou. Winter feeding behaviour of caribou is governed by forage availability and snow conditions. Through cratering in early winter, ground lichen and ericaceous shrubs are the bulk of the caribou diet. However in late winter, when ground and ericaceous shrubs are less available, arboreal lichens are the main forage item.

The diet shift from ground to arboreal lichens is dependent on snow type and depth in the barren ground and forested areas. Thus the relative importance of each type of lichen is also dependent on annual variation in snow type and depth. This model assumes that at some point during the winter season the caribou will ultimately be limited to foraging on arboreal lichens only. There will be a time period when arboreal lichens will be the only available food source to these caribou.

Arboreal lichens are assumed to be more abundant in mature softwood dominant stands with an open canopy. Fallen trees and blowdowns in insect kill areas and new cutovers provide foraging opportunities on arboreal lichen that otherwise would not be available to the caribou. Ground lichens and ericoids are available on barren grounds made accessible through cratering. Variable 1 (Figure 2) deals with the species composition of the stand. Softwood dominant stands are given the highest weight based on the assumption that arboreal lichen growth will be greater in those stand types. As the hardwood component increases, the amount of arboreal lichen will decrease. Soil barrens are weighed relatively high as they provide ground lichen and ericoids that through cratering will be available to the caribou.

The relationship between stand age and lichen growth is demonstrated in variable 2 (Figure 3).

Overmature stands are assumed to provide abundant, preferred forage for woodland caribou while stands between 0 - 40 years of age are assumed to have no forage value to caribou. However, new cutovers between 1 -4 years old will provide forage opportunities through fallen trees and blowdowns. This relationship is demonstrated in variable 3 (Figure 4).

Variable 4 illustrates the assumption that a more open canopy will increase forage available to the caribou. It is assumed that an open canopy will promote arboreal lichen growth, as well as ground lichen and forest floor vegetation.

HSI Equation

The equation is:

$$\text{HSI} = [V_3 + (V_1 \times V_2 \times V_4)^{1/3}]$$

where

- V_3 = cut age
- V_1 = species composition
- V_2 = age class
- V_4 = crown closure

Cut age (variable 3) is additive to the equation because the NFS database was completed in 1986, thus any stands that were harvested since this time have not yet been inventoried. The only attribute assigned to these stands is cut age, Therefore these stands must be access independent of the inventoried stands.

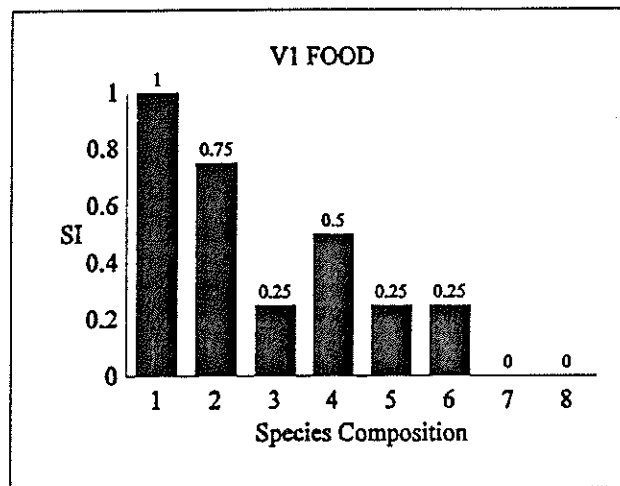


Figure 1. Variable 1 (V_1): Stand species composition

Species Composition Legend: 1 = Softwood stands (bF, bS, wS, and combinations of)
 2 = Softwood dominant stands (bF__, bS__, and bFbS__)
 3 = Hardwood dominant stands (wB__, and yB__)
 4 = Soil barren (Sb)*
 5 = Rock barren (Rb)*
 6 = Softwood scrub (Scs)
 7 = Hardwood scrub (Sch)
 8 = Hardwood stands (wB and yB)

Figure 1 illustrates the assumption that ideal availability of food will be provided in softwood and softwood dominated stands. Soil barrens also provide good forage availability.

* Attempting to include barren habitat within this variable may be difficult because these stands have no other measurable attributes (i.e. age or crown closure) that are included in the HSI equation and will therefore be multiplied by 0.

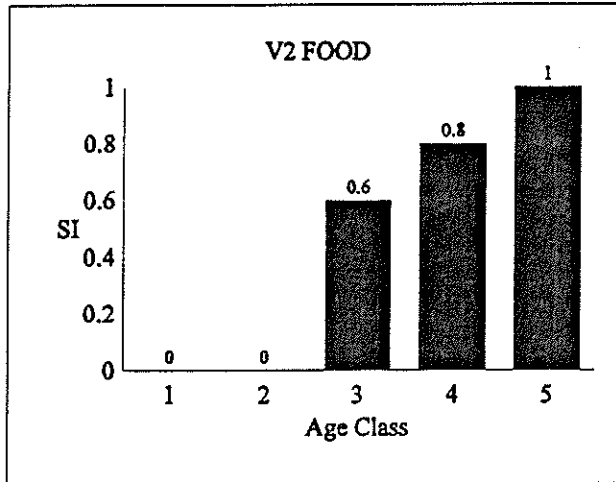
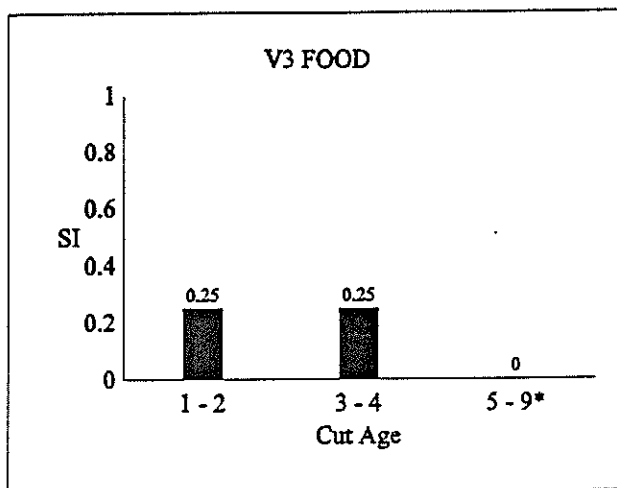


Figure 2. Variable 2 (V_2): Stand age class.

Age Class Legend:

- 1 = 0 - 20
- 2 = 21 - 40
- 3 = 41 - 60
- 4 = 61 - 80
- 5 = 81 +

Figure 2 illustrates that older forest stands are assumed to provide abundant, preferred forage for woodland caribou.



Variable 3 (V_3): Cut age.

Figure 3 illustrates the assumption that young cutovers provide forage for woodland caribou. In these stands, residual fallen trees and the increased number of blowdowns, typically found in these habitats, provide forage opportunities on arboreal lichen that otherwise would not be available.

* cutover age only includes cut ages up to 9 years because the forest inventory was updated in 1986, therefore cuts since this time will not be classified. These cuts will have no other measurable attributes and thus must be additive in the HSI equation.

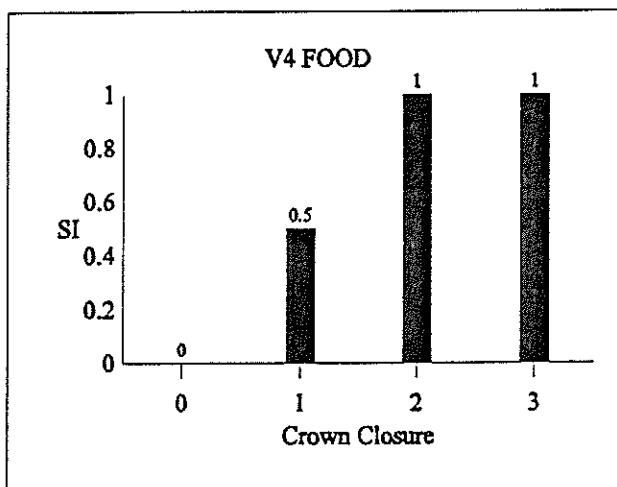


Figure 4. Variable 4 (V_4): Crown Closure Class

Crown Closure Legend:

- 0 = unclassified
- 1 = > 75%
- 2 = 51 - 75%
- 3 = 26 - 50%

Figure 4 illustrates the assumption that forage availability increases with a more open canopy. It is assumed that the more open canopy will promote lichen growth.