SUMMARY OF MOUNTAIN CARIBOU SURVEYS WITHIN THE QUESNEL HIGHLAND AND CARIBOO MOUNTAINS, CARIBOO REGION, UP TO AND INCLUDING 2001

photo by Jim Young

by

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Abstract

In order to monitor mountain caribou population trends and calf recruitment within the Quesnel Highland and Cariboo Mountains, five total count surveys were undertaken from March 21 to April 4 of 2001. Within the Wells Gray North sub-population, a total of 154 caribou were observed: 127 adults and 27 calves. This sub-population consisted of an estimated 215 caribou (corrected for sightability) with 95% confidence limits of 164 to 435 animals and a density of 0.037 caribou/km^2. The percentage calves was 17.53. Within the portion of the census area identified as the Quesnel Lake Study Area, there were 88 caribou observed: 71 adults and 17 calves. The percentage calves was 19.32. When corrected for sightability, the study area had an estimated 175 animals with 95% confidence limits of 99 to 813 animals and a density of 0.081 caribou/km^2. The Barkerville sub-population consisted of an estimated 35 caribou (corrected for sightability) with 95% confidence limits of 35 to 65 animals and a density of 0.017 caribou/km^2. Thirty-five caribou were observed within this sub-population: 26 adults and 9 calves, with 25.71 percent calves. Twenty-three caribou, 1 calf and 22 adults, were observed in the Northern Cariboo Mountains sub-population. Population trend and recruitment statistics suggest caribou numbers are declining slightly.

Key Words: Cariboo Mountains, caribou, late winter survey, mark/resight estimates, *Rangifer*, recruitment, Quesnel Highland, total count, population.

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Introduction

Mountain caribou are an ecotype of the Woodland Caribou (*Rangifer tarandus caribou*) found in Southeast British Columbia. Mountain caribou differ from other types of caribou in the habitat they occupy, their dependence on arboreal lichens, and their behavioral adaptations to their environment. In 2000, mountain caribou became red-listed provincially and were designated as threatened nationally. Mountain caribou are considered an old growth obligate species due to their dependence on arboreal lichens during winter. As arboreal lichens are most abundant within old coniferous forests, clear-cut harvesting is regarded as incompatible with maintaining winter habitat values for caribou. Due to winter forage requirements and the need to remain at low densities during summer to avoid predation, it has been assumed that caribou numbers are influenced by the amount of suitable habitat available to the population (Bergerud 1992). Understanding the relationship between reductions in the availability of suitable habitat, through clear-cutting and/or displacement due to winter recreation, with changes in caribou numbers is essential. Therefore, the caribou population must be monitored to observe any numerical response to changes in habitat condition or availability and to evaluate the effectiveness of recovery efforts.

During the mid 1980's a radio telemetry study was undertaken within the core of the census area (Quesnel Lake Study Area) providing baseline caribou population information (Seip 1992). In February and March of 1993, 19 female adult caribou were fitted with radio collars as part of a population-monitoring program for this area and were subsequently surveyed in March 1993. Within weeks of this initial survey, one of the caribou collars failed. Four additional collars were placed on caribou in March of 1994 resulting in a sample size of 22 marked animals. Over the following year, three animals died, two did not return to the census area from their summer range, one collar failed, and four additional collars were placed on caribou during February and March of 1995, leaving 20 functioning collars in 1995 within the census area. Between the 1995 and 1996 surveys six animals died, one collar failed, and four additional caribou were collared (March of 1996). As one of the collared animals was outside of the survey area, a sample size of 18 was maintained during the 1996 survey period. In the year prior to the 1997 surveys four animals died, three collars failed and an additional three caribou were collared leaving 15 functioning collars in the caribou study area. Four collared caribou died, one animal left the study area and nine new animals were collared between the 1997 and 1998 March surveys bringing the 1998 survey sample size up to 19 marked animals. Between 1998 and 1999 there were no additional animals collared, five collared caribou died, and two were out of the survey area leaving 13 functioning collars. No collars were added and three deaths occurred resulting in a sample size of 12 collared caribou to locate in the March 2000 survey. Over the last year, one collared caribou died and one collar failure occurred leaving a radio-collared sample size of ten at the time of the March 2001 survey.

The primary objectives of this year's census were:

- To obtain a population estimate derived from a sightability index based on observed collared caribou; and
- To obtain an estimate of calf recruitment for the population.

We would like to acknowledge Pat Dielman, Lara Roorda and Cathy Greenhalgh for serving as observers during the 2001 surveys. Thanks are extended to Dale Seip for permission to use his unpublished data from the Quesnel Lake Study Area as well as to Ian Hatter and James Quayle for statistical advice they provided. Funding for the 2001 March caribou survey was provided by Forest Renewal British Columbia (FRBC) in cooperation with West Fraser Mills Ltd, Williams Lake. Previous funding for this project was provided by British Columbia Parks, British Columbia Environment, FRBC, the Habitat Conservation Fund (HCF) and the Corporate Resource Inventory Initiative (CRII).

Census Area

The census area is located within south central British Columbia and includes portions of the Quesnel Highland, Bowron Valley and Cariboo Mountains Ecosections. The Bowron Valley and Quesnel Highland Ecosections are in the Columbia Highlands Ecoregion, while the Cariboo Mountains Ecosection is located within the Northern Columbia Mountains Ecoregion, all within the Southern Interior Mountains Ecoprovince. Wet climate and relatively high snow depths characterize this mountainous area. Climatic moisture increases in an easterly direction and with elevation. Continuous, extensive high elevation caribou winter ranges occur on rounded sub-alpine mountain tops throughout the Quesnel Highland and Bowron Valley Ecosections. Within the higher and increased rugged terrain of the more easterly Cariboo Mountains, high elevation caribou winter ranges are present, but are more restricted and discontinuous in nature. The census area is comprised of several biogeoclimatic zones including the Alpine Tundra (AT), Engelmann Spruce Sub alpine Fir (ESSF), Interior Cedar Hemlock (ICH) and Sub-Boreal Spruce (SBS) zones.

During recent surveys the area was divided into five census blocks designated as Barkerville, Stevenson, Junction, Horsefly and Bowron (Figure 1). This year's survey area encompassed all habitat presently occupied by mountain caribou within the eastern part of Region 5 and a small portion of Region 3 (Wells Gray Park), which is contiguous with the remainder of the adjacent (Horsefly and Junction) census blocks. The Quesnel Lake Study Area described by Seip (1992) overlaps portions of the Stevenson and Junction census areas. The approximate area of each census block varies and is outlined in Table 1.

Table 1. Census block areas and corresponding Provincial caribou sub-populations.

Census Block	Area	Provincial Sub-population
Bowron	1,650 km2	N. Cariboo Mtns. (a portion of)
Barkerville	2,020 km2	Barkerville
Stevenson	1,640 km2	Wells Gray North
Junction	2,230 km2	Wells Gray North
Horsefly	2,000 km2	Wells Gray North
Sub-total	5,870 km2	Wells Gray North
Total	**9,540 km2**	
Quesnel Lake Study Area	2,150 km2	Wells Gray North

For conservation and management purposes Simpson (1997) divided the provincial population of mountain caribou into 13 sub-populations (Figure 2). Portions of three of these sub-populations are found within the Cariboo Region. The North Cariboo Mountains sub-population includes the Bowron census block and a larger contiguous area to the north and east within the Omineca region. The Barkerville sub-population includes the Barkerville census block and the Wells Gray North sub-population includes the Junction, Horsefly and Stevenson census blocks. There is believed to be some mixing of animals amongst all three of these sub-populations.

With the exception of the Bowron Block, which follows an administrative boundary on its north and east borders, each mountain complex contains an area of winter range in which caribou generally remain throughout an entire winter. However, populations within each block are not discrete, as several shifts between blocks by radio collared caribou have been recorded. Thus, at least some animals winter in different blocks during different years.

Figure 1. Quesnel Highland and Cariboo Mountains Survey Area, March 2001.

Figure 2. Thirteen mountain caribou sub-populations identified in British Columbia (Simpson 1997).

Methods

A Bell 206 Jet Ranger helicopter was employed for the surveys. Mountain complexes were flown in a counter clockwise manner so that those observers on the left side of the aircraft could scan the high-density stratum, or sub alpine forest for caribou. The observer in the back right-hand seat provided additional coverage when necessary. Generally only one pass was made of each slope for caribou that were in the sub alpine forest near tree line. Caribou were classified as bulls, cows or calves. There was no attempt to distinguish between male and female calves. When large groups were encountered, or when the animals were in dense forest, caribou were only recorded as adults or calves. Animal group locations were derived from the helicopter's onboard Global Positioning System (GPS) and manually recorded on 1:250 000 topographic maps during the flight. Flight data was also recorded with Trimble GeoExplorer II handheld GPS units and a digital map of flight paths and caribou observations were produced after survey completion. It should be noted that over the years, survey areas and boundaries have been refined and adjusted based on animal movements during winter. Numbers found in this report reflect the most recent block boundaries.

The first of seven complete flights occurred on March 21, 2001. The flight included Pat Dielman (navigator), Nicola Freeman (rear left), Lara Roorda (rear right) and pilot Tom Arduini. A total of 6.4 hours were flown allowing for completion of the Stevenson Census Block. Observation conditions were excellent with patches of high cloud in sunny skies, a temperature varying between –5 and –10 degrees Celsius, 5 km/hr south-westerly winds and fresh snow within the last 24 hours.

The Horsefly Census Block was completed over two days: the southern portion was flown on March 23 for 6.3 hours and the northern portion was completed in 5.9 hours on March 24, 2001. The first flight included Pat Dielman (navigator), Nicola Freeman (rear left), Lara Roorda (rear right) and pilot Tom Arduini. The second flight had Cathy Greenhalgh as the rear right observer. On March 23, survey conditions were excellent with clear sunny skies, a temperature of –5 degrees Celsius, light wind and fresh snow within the last 48 hours. Visibility conditions were the same for the second day with temperatures ranging from –6 and +4 degrees Celsius, south-westerly winds from 15 to 25 km/hr and fresh snow within the last 72 hours.

The fourth and fifth flight occurred on March 26 and 28, 2001. The crew included Pat Dielman (navigator), Nicola Freeman (rear left), Lara Roorda (rear right) and pilot Tom Arduini. Observing conditions on March 26 were moderate-to-poor with 60 percent cloud cover, scattered snow showers, a temperature of –3 degrees Celsius, light wind and fresh snow within the last 12 hours. Deteriorating weather and snow flurries resulted in the flight being terminated; the remaining area was completed on March 28 under moderate conditions with 80% cloud cover, intermittent snow flurries, a temperature of –6 degrees Celsius, 30-35 km/hr north-westerly winds and fresh snow within the last 12 hours. A total of 7.8 hours were flown to complete the Barkerville Census Block.

The sixth flight, a total of 7.8 hours, was flown on April 3 with the crew Pat Dielman (navigator), Nicola Freeman (rear left), Lara Roorda (rear right) and pilot Tom Arduini. Observing conditions for the Junction Block were excellent with clear sunny skies, 30-35 km/hr north-westerly winds, temperatures ranging from –4 to 0 degrees Celsius and fresh snow in the last 48^{+} hours. Due to the large area encompassed by the Junction block, the survey had to be completed the following day.

The final flight on April 4 included the same crew and pilot. Observing conditions were considered good with high haze in the morning, clear skies in the afternoon, a temperature of –3 degrees Celsius, light-moderate winds and fresh snow within the last 72-96 hours. The Bowron Block and the remaining portion of the Junction Block were completed in 8.8 hours.

Population estimates were derived using the Joint Hypergeometric Estimator (JHE) and the NOREMARK computer statistical package by Gary White. The JHE is an extension of the Peterson Method (White & Garrot 1990), which was used in population reports prior to 2000, and is now the Resource Inventory Committee (RIC) standard method for mark recapture estimates in closed populations with only one sighting occasion. A sighting occasion is an attempt to view animals in a population, keeping track of the number of marked and unmarked animals observed. This model assumes that individual marked animals have the same probability of sighting as every other individual within the population on a given occasion.

The joint maximum likelihood estimator of mark-resight is the value of N that maximizes the likelihood:

$$£(N \mid M, n_i, m_i) = \prod_{i=2}^{k+1} \frac{(M/m_i) \times [(N-M)/(n_i-m_i)]}{(N/n_i)}$$

where n_i and m_i are the total number of animals observed and the number of marked animals observed, respectively, on sighting occasion i, i=2, . . . , k+1. The number of available marked animals located within the survey area at the time of the i^{th} sighting, are defined as M. Computerised optimization is required to find N, the estimated population size. The 95% confidence interval is constructed directly from the likelihood. As such, estimates of the lower and upper confidence bounds are the values of N that produce values of the log likelihood which are 2 units less than the value of the log likelihood at the maximum (White & Garrot 1990). With this type of confidence interval the lower confidence bound is never estimated at a value less than the minimum number of animals known to exist.

Population growth rates were calculated using the formula $\lambda = (N_t/N_0)^{1/t}$; where λ is the finite rate of increase, N_t is the number of caribou in year t, N_0 is the number of caribou in the initial year, and t is the number of years between N_0 and N_t (Caughley 1977).
Caribou survival rate estimates for the Wells Gray North and Quesnel Lake Study Areas were determined using the Kaplan-Meier product limit estimator.

$$S(t) = \prod_{j=1}^{n_0} \frac{r(T_j) - d(T_j)}{r(T_j)}$$

Where $S(t)$ is the survival estimate over time t, $r(T_j)$ represents the number of animals at risk of dying in the interval (T_{j-1}, T_j) and $d(T_j)$ represents the number of animals that died during that same interval, for $j=1, \ldots, n_0$ (White and Garrot, 1990). This method for estimating survival makes no assumptions about the hazard function, and animals can be added or removed from the population at risk at any time (White and Garrot, 1990). This is especially useful in telemetry studies where entry of radio-collars into the study is staggered, and collar failure occasionally occurs.

Geometric Mean Regression, or central trend line analysis, was performed to determine the regression equations for the relationship between adult mortality and calf recruitment within the Wells Gray North and Quesnel Lake Study Areas. This method of regression is useful when there is no clear causal relationship between the variables, yet a correlation appears to exist (Krebs, 1989; Ricker, 1984 and 1973). Tests of significance used for comparison of the two study areas' regression equations, were t-tests of the correlation coefficients and an F-test for homogeneity of slope (Sokal and Rohlf, 1995). The relationship between adult mortality and calf recruitment was also analyzed using second degree polynomial regression, as it does not assume a pre-determined relationship between mortality and recruitment.

It should be noted that over the years statistical methods have been adjusted to reflect changing standards and to provide the most useful results for management. Some minor errors have occurred in previous progress reports and have subsequently been corrected; where numbers or values differ from previous reports, the estimates found in this report should be considered the most reliable. Methods utilized in this report reflect our current understanding of the most appropriate techniques for data analysis.

Results

During the 2001 March survey a total of 154 caribou were observed within the Wells Gray North caribou sub-population (Junction, Stevenson and Horsefly census blocks), including 127 adults and 27 calves (Table 2). The percentage calves was 17.53. Five of the seven collared animals in these three census blocks were observed. Correcting for sightability, using the JHE, provides an estimate of 215 caribou with 95% confidence limits of 164 to 435 animals.

A total of 88 caribou, 71 adults and 17 calves, were observed within the subunit of the Wells Gray North sub-population known as the Quesnel Lake Study Area. The percentage calves was 19.32. Two of four collared animals in the study area were

observed resulting in an estimate of 175 caribou with 95% confidence limits of 99 to 813 animals.

Thirty-five caribou were observed from the Barkerville sub-population: 26 adults and 9 calves, giving a calf recruitment of 25.71. All of the three collared caribou in this block were observed during the survey. An estimate of 35 caribou with 95% confidence limits of 35 to 65 animals, when corrected for sightability was calculated.

In the portion of the Northern Cariboo Mountains Sub-population known as the Bowron Census Block a total of 23 caribou, 1 calf and 22 adults, were observed. The observed percentage calves was 4.35. There were no collared caribou in this block.

Table 2. Summary of the 2001 caribou census results for the Quesnel Highland and Cariboo Mountains survey area.

Provincial sub-population	Area Surveyed	Total Classified	Adults	Calves	% Calves
N. Cariboo Mtns.	**Bowron Block**	**23**	**22**	**1**	**4.35**
Barkerville	**Barkerville Block**	**35**	**26**	**9**	**25.71**
Wells Gray North	**Stevenson Block**	61	47	14	22.95
Wells Gray North	**Junction Block**	61	53	8	13.11
Wells Gray North	**Horsefly Block**	32	27	5	15.63
Wells Gray North	**Total**	**154**	**127**	**27**	**17.53**
Wells Gray North	**Quesnel Lake Study Area**	88	71	17	19.32

Survey Costs

Helicopter rental for the 2001 March surveys totalled 43.0 hours of helicopter time, approximately $30,281.09. Cost and time estimates include ferrying to and from each census area; additional flight hours, as compared to previous years, were accumulated during the investigation of mountain goat sightings. Staff time to undertake surveys and prepare the summary report was approximately 25 person days.

Discussion

Sub-Population Trends

Completed surveys undertaken over the past nine years observed between 148 and 249 caribou within the Wells Gray North sub-population (Table 3). Initially, caribou were found to be most plentiful in the Quesnel Highland Ecosection, as the majority of animals were observed within the Stevenson and Horsefly census blocks from 1992 to 1995. A shift in this trend began in 1996, when greater numbers of animals were observed in the Junction block (85), closely followed by the Stevenson (75) census block. Between 1997 and 2001 numbers found in these two census blocks remained fairly consistent. In 2001, an equivalent number of 61 animals were observed in the Junction and Stevenson blocks.

Table 3. Summary of observed caribou by census block for the Quesnel Highland and Cariboo Mountains Survey area (1992 - 2001).

Provincial Sub-Population	Block Surveyed	Number Of Caribou Observed By Year (uncorrected)									
		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
N. Cariboo Mtns.	**Bowron**	**32**	**3**	**N/S[a]**	**11**	**N/S[a]**	**58**	**N/S[a]**	**23**	**31**	**23**
Barkerville	**Barkerville**	**27**	**16**	**39**	**12**	**15**	**50**	**26**	**20**	**38**	**35**
Wells Gray North	**Stevenson**	73	96	69	86	75	68	70	67	61	61
Wells Gray North	**Junction**	35	24	68	63	85	65	65	47	64	61
Wells Gray North	**Horsefly**	66[b]	96	112	94	71	72	49	37	23	32
Wells Gray North	**Total**	**174**	**216**	**249**	**243**	**231**	**205**	**184**	**151**	**148**	**154**
Wells Gray North	**Quesnel Lake Study Area**	92	98	75	102	125	84	76	75	79	88

[a] Bowron census block not surveyed (N/S)

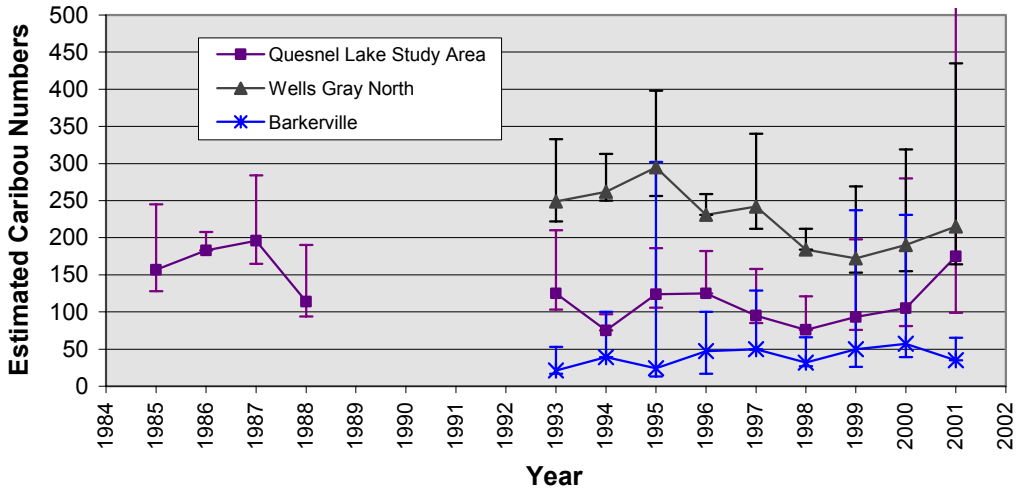
[b] Incomplete survey

Based on previous estimates of the Wells Gray North area (corrected for yearly sightability using the Joint Hypergeometric Estimator; Appendix 13) from 1993 to 2001 the population fluctuated first up (1993-1995 λ=1.088), and then down (1996-1999 λ=0.9063) with a slight overall decline (1993-2001 λ=0.9818) (Figure 3). The population trend using uncorrected counts (Figure 4) suggests a slightly lower finite rate of increase between 1993 and 1995 (λ = 1.061); population growth rates were lower, and showed greater decline, when calculations involved the uncorrected counts. The majority of the observed decline has occurred within the Horsefly census block, which has dropped from a record high count of 112 animals in 1994 to a record low count of 23

caribou in 2000 (Table 3). The trend, based on estimates of the Horsefly block (corrected for sightability) from 1993 to 2001, shows an initial finite rate of increase (1993-1995 λ=1.104) then a significant decline (1996-2000 λ=0.7544), resulting in an overall negative population growth rate (1993-2001 λ=0.8527). The population estimate for Wells Gray North (Junction, Stevenson and Horsefly blocks) of 215 animals in an area of 5,540km^2 provides a 2001 density estimate of 0.039 caribou/km^2 (Figure 5).

The 2001 survey of the Quesnel Lake Study Area resulted in a count of 88 caribou, a corrected estimate of 175 animals, and 95% confidence interval of 99 to 813 estimated caribou (Appendix 13). Utilising this population estimate and an area estimate of 2150 km^2 provides a 2001 density of 0.081 caribou/km^2 (Figure 5). This is substantially higher than previous years, which ranged from 0.035 caribou/km^2 in 1998 to 0.049 caribou/km^2 in 2000. This may be attributed to the relatively small sample size and poor sightability factor obtained in 2001, when only two of four potential collars were visually located; observed numbers of animals did not vary as significantly (1997-2001 range: 79 to 88 observed caribou) as the corrected estimates for this same time frame. Average density, using population estimates obtained in recent years, 1997 through 2000 was 0.043 caribou/km^2.

When survey results for the Quesnel Lake study area were corrected (with yearly sightability correction factors) slightly different trends were obtained. Numbers in this area (corrected for sightability) appeared to decline in the late 1980's (1986-1988: λ= 0.7893) with some recovery in the early 1990's (Figure 3). Corrected estimates suggested that the caribou population was stable (λ= 1.00) between 1993 and 1996, and did not show any positive growth, merely the maintenance of the population level. In the late 1990's, the population appeared to increase (1997-2000: λ= 1.0339) based on corrected estimates, however observed caribou numbers for the same period suggest a slight decline (λ= 0.9798). The corrected estimate for 2001 was not included in the growth rate analysis as it was not considered very reliable due to a low collar sightability factor that may have skewed the results. Uncorrected survey results also showed a stable population (1993-95: λ= 1.0202) following the population decline observed between 1986 and 1992 (λ= 0.8917), as reported by Seip (1992). Based on the number of animals observed during late winter flights, the population declined from 183 animals in 1986 to an observed low of 76 in 1990. With the exception of 1994 there was positive growth in subsequent years with a high of 125 observed animals in 1996 (observed numbers 1990 to 1996: λ = 1.0865), at which point numbers appeared to decline once again. The low numbers observed within the Quesnel Lake Study Area during the 1994 survey were likely a result of animals shifting out of the area rather than a major population decline (see Figure 6). The latest decline appears to have bottomed out in 1999 at 75 observed caribou with a slight increase observed over the past two years. However, the overall decrease in observed animals since 1996 (1996-2001: λ= 0.8917) is likely the result of lower calf recruitment in recent years.



*Quesnel Lake Study Area 2001 confidence interval (99-813) extends beyond y-axis scale

Figure 3. The estimated number of caribou and 95% confidence limits using collared animals to correct for sightability within the Quesnel Lake Study Area from 1985 to 2001 (incomplete survey in 1985; 1985-1988 data from Seip, 1992), and within the Wells Gray North and Barkerville sub-populations from 1993 to 2001.

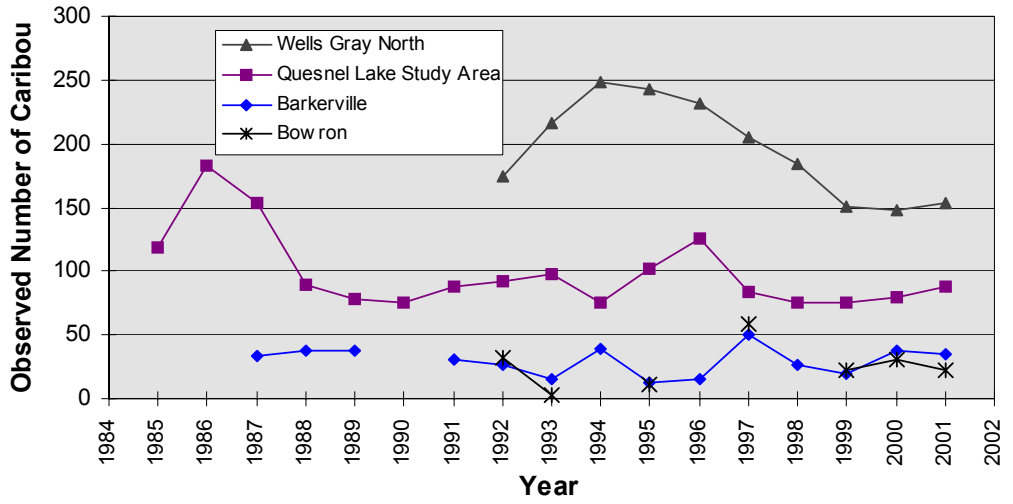


Figure 4. The total number of caribou observed within the Wells Gray North sub-population, the Quesnel Lake Study Area (1985-1988 data from Seip, 1992) and the Barkerville census block/sub-population, 1985-2001. Incomplete surveys of the Quesnel Lake Study Area occurred in 1985 and 1989 and totals for Wells Gray North include an incomplete survey of the Horsefly census block in 1992.

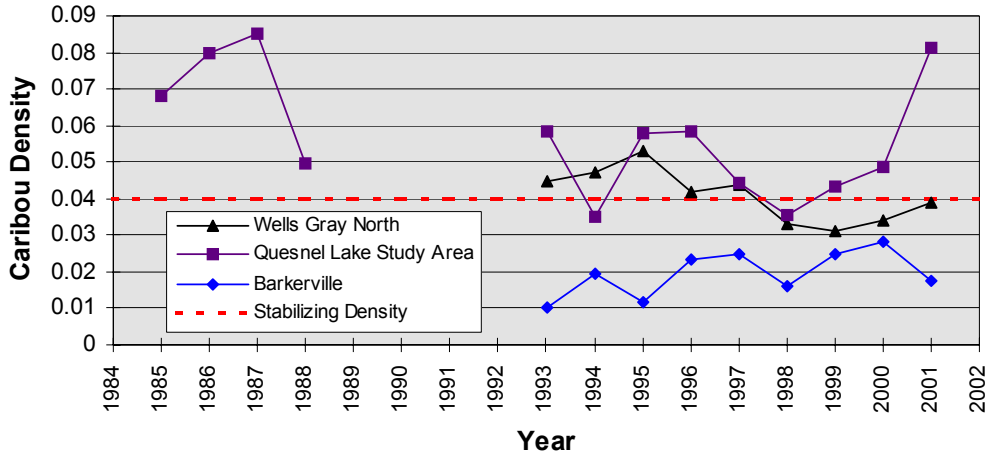


Figure 5. Caribou density for Wells Gray North (1993-2001), the Quesnel Lake Study Area[1] (1985-2001, incomplete data for 1989-1992) and Barkerville (1993-2001), using estimated numbers of animals (corrected for yearly sightability). Also included is the stabilizing density of 0.04 caribou/km^2 from Seip and Cichowski (1996).

During 14 surveys between 1987 and 2001 a range of 12 to 50 caribou have been observed within the Barkerville census block/sub-population. When corrected for sightability, the population estimate for this census year was 35 caribou with 95% confidence limits of 35 to 65 animals. Based on corrected estimates from 1993 to 2001, caribou numbers in this area appear to be increasing slightly (λ =1.066). Caribou density for this sub-population/census block has been consistently lower than the Wells Gray sub-population ranging from 0.01 to 0.028 caribou/km^2 in 1993 and 2000, respectively. For the 2001 census, the estimated density for the Barkerville sub-population was 0.017 caribou/km^2. The lack of a high stratum (open sub-alpine forest) throughout the Barkerville census block reduced the expected sightability for this area when compared to other census blocks.

Between 3 and 58 caribou were observed during the six years when the Bowron census block was surveyed. Caribou within this census block represent only a small portion of the North Cariboo Mountains sub-population. As caribou are suspected of moving frequently in and out of this census block from the north and east, lack of collared caribou made it difficult to obtain accurate population estimates for the area. Changes in caribou distribution between years may be one explanation for the large fluctuations in animal numbers between surveys. In 1999 the portion of the range of the North Cariboo

[1] Quesnel Lake Study Area 2001 density estimate has been skewed high due to the survey's poor sightability factor of 50% and the low number of marked animals available (n=4), which resulted in an inconsistent population estimate with wide confidence intervals.

Mountains sub-population located north of Bowron Lake Provincial Park was surveyed: 235 caribou were observed (Watt, 1999) bringing the total number of animals observed to 258 for that sub-population. In March 2001, Seip surveyed the area north-east of the Bowron Census block and found 24 caribou (20 adults and 4 calves) in the upper reaches of the Goat River watershed; during the previous year's survey Seip observed only four caribou in the upper Goat River (Seip, 2001 and 2000). The increased numbers were probably indicative of a year to year change in winter distribution. As is the case with the headwaters of Betty Wendle Creek and Cariboo River, Seip (2000) suggests much of the terrain immediately east of the Bowron Census block is too rugged to provide suitable winter habitat for mountain caribou.

The large variation in observed numbers of animals within individual census blocks, between years, suggests that the annual winter distribution of caribou is dynamic. This is supported by the observed movements of radio collared caribou between inventory blocks (Figure 6). In addition, annual differences in observed numbers also appear to be influenced by variation in sightability between years. For example, in some years there were fewer animals in the alpine and more in the adjacent forest, resulting in fewer caribou being observed.

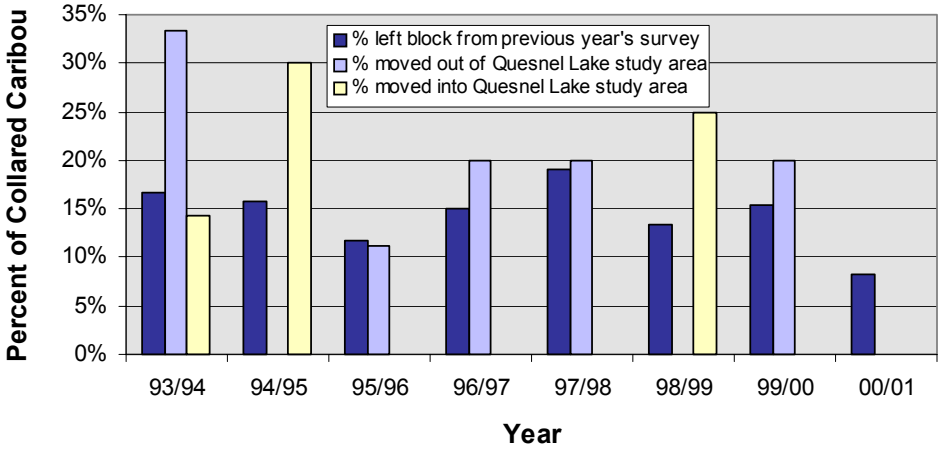


Figure 6. Caribou movement in and out of the Quesnel Lake Study Area (QLSA) and to and from individual Census blocks between years from 1993 to 2001 (based on animal locations during subsequent March surveys). Percent movement in and out of the QLSA is based on total number of marked animals at the beginning and end of each yearly cycle.

Bergerud (1992) suggests that for woodland caribou populations that space out within available habitat to avoid predation, the stabilizing density is 0.064 animals per square kilometre. Seip and Cichowski (1996) further refined this estimate by suggesting that for woodland caribou populations within British Columbia that space out within available sub-alpine and alpine habitats to avoid predation, the stabilizing density is about 0.04

animals per square kilometre. Seip (1992) reported that the density of caribou within the Quesnel Lake Study Area declined from approximately 0.1 to 0.04 caribou per square kilometre between 1986 and 1989. The initial decline would have been towards the stabilizing density suggested by Seip and Cichowski (1996). Since 1991, it appears that the Wells Gray North sub-population has fluctuated slightly around this hypothesised stabilizing density; since 1998 the estimated density has been below the stabilizing density, reaching a low of 0.031 caribou/km^2 in 1999 (Figure 5).

Production and Calf Recruitment Trends

Caribou were tested for pregnancy at the time of their initial capture and collaring; blood samples were taken and progesterone concentration levels analyzed. A threshold value of 1.5 ng progesterone / mL serum or plasma was used to classify caribou as pregnant or not pregnant (Russell et al, 1998). Seasonal variations in progesterone levels have been characterized for *Rangifer* and were taken into consideration during the analysis; all the collared caribou were captured during the winter months of February and March, at which time marked differences in progesterone concentrations exist between pregnant and non-pregnant animals. Blood samples from 41 of the 43 caribou captured were tested: 37 adults were classified as pregnant, with progesterone concentration levels ranging from 2.2 ng/mL to 10.2 ng/mL. For the adult collared caribou tested, a pregnancy rate of 92.5% was observed. Three adults were classified as not pregnant, all with progesterone concentrations of 0.1 ng/mL; one suspected yearling was captured and found to have a concentration of 0.4 ng/mL.

The Wells Gray North sub-population calf recruitment rates have fluctuated drastically in the past ten years. In the 1992 survey, calf recruitment was observed at 10.9 percent calves (n=174). Calf recruitment subsequently increased, remaining fairly high from 1993 to 1995 at an average of 16.5 percent calves (n=708), dropped quite drastically from 1996 to 1998, averaging only 9.8 percent calves (n=620), and rose again in 1999 to 15.2 percent calves (n=151). In 2001, calf recruitment was observed to be 17.5 percent calves (n=154), the highest recorded value over the last ten years; this was much higher than the 12.8 percent calves (n=148) recorded in the 2000 survey.

Late winter surveys undertaken in the Quesnel Lake Study Area during the mid to late 1980's generally found low to moderate calf survival (Figure 7), whereas surveys undertaken from 1991 to 1995 observed moderate to high calf survival (Table 4). The Quesnel Lake Study Area averaged 8.5 percent calves (n=698) from 1985 to 1990 and 16.2 percent calves (n=455) from 1991 to 1995. Over the next three years calf recruitment rates again declined, averaging 10.6 percent calves; the 2000 survey resulted in an average of 10.1 percent calves. A record high recruitment rate of 19.3 percent calves was observed in 2001, greater than the 1999 value of 17.3 percent calves.

The Quesnel Lake Study Area's 1991-1995 recruitment values (16.2% calves or 19.4 calves/100 adults) were only slightly lower than the estimated fourteen-year average of

21.3 calves/100 adults for the Revelstoke area (McLellan et al. 1994). The recruitment values were also similar to those of adjacent Wells Gray Park (a portion of both the Wells Gray North and South sub-populations were surveyed) where the three year average from 1987 to 1989 was 17.7 calves/100 adults (Seip 1990) and, more recently, 21.8 calves/100 adults in 1995 (Scheer 1995).

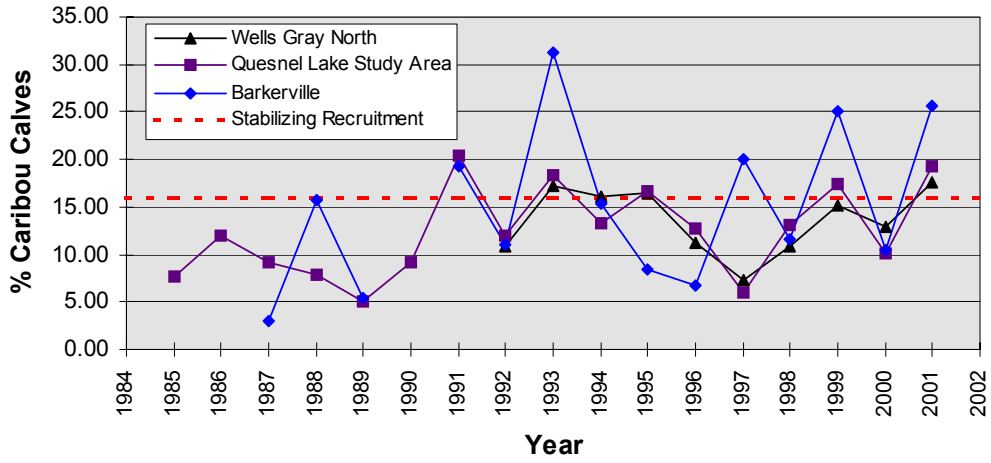


Figure 7. Summary of the observed number of % caribou calves for the Wells Gray North sub-population, Quesnel Lake Study Area (1985-1988 data from Seip, 1992) and Barkerville sub-population/census block; 1985-2001 (1988 sample for the Quesnel Lake Study Area includes two animals from outside the study area). For comparison, Bergerud's (1992) stabilizing recruitment of 16% calves is shown from 1985-2001.

Although less than half the census area population occupies the Quesnel Lake Study Area, it appears that this area provides an estimate of calf recruitment that is fairly consistent with that obtained for the Wells Gray North sub-population (Figure 7). On the other hand, the Barkerville census area calf recruitment statistics do not appear consistent with those in the adjacent Wells Gray North sub-population, with calf recruitment numbers constantly fluctuating, often differing by more than 15% from 1 year to the next. This may be partly due to the small sample sizes in some years in this area.

Table 4. Summary of observed percent caribou calves for the Quesnel Highland and Cariboo Mountains survey area, 1992 to 2001.

Provincial Sub-Population	Block Surveyed	Percent Calves									
		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Barkerville	**Barkerville**	**11.1**	**31.3**	**15.4**	**8.3**	**6.7**	**20.0**	**11.5**	**25**	**10.5**	**25.7**
N. Cariboo Mtns.	**Bowron**	**18.9**	**0**	**N/S[a]**	**9.1**	**N/S[a]**	**12.1**	**N/S[a]**	**13.0**	**19.4**	**4.4**
Wells Gray North	**Stevenson**	9.6	15.6	11.6	17.4	10.7	10.3	15.7	20.9	13.1	23.0
Wells Gray North	**Junction**	11.4	16.7	19.1	15.9	15.3	4.6	7.7	10.6	12.5	13.1
Wells Gray North	**Horsefly**	12.1[b]	18.8	17.0	16.0	7.0	6.9	8.2	10.8	13.0	15.6
Wells Gray North	**Total**	**10.9**	**17.1**	**16.1**	**16.5**	**11.3**	**7.3**	**10.9**	**15.2**	**12.8**	**17.5**
Wells Gray North	**Quesnel Lake Study Area**	12.0	18.4	13.3	16.7	12.8	6.0	13.2	17.3	10.1	19.3

[a] Bowron census block not surveyed (N/S)
[b] Incomplete survey of Horsefly block in 1992

Comment: Bowron census block not surveyed (N/S)

Comment: Bowron census block not surveyed (N/S)

Bergerud (1992) suggests that for caribou populations that space out to avoid predation, the required stabilizing recruitment of the population to balance natural mortality of adults is 15-16% calves (Figure 7). Within the Quesnel Lake Study Area the population declined in the mid to late 1980's with low recruitment (<16%) and then subsequently stabilized in the early 1990's with levels of moderate recruitment (about 16%). As such, the recruitment statistics from this area would appear to support Bergerud's premise that population trends can be inferred from the percentage calves. From 1996 to 1998, and again in 2000, calf recruitment numbers dropped below the hypothesized stabilizing recruitment value of 16 percent (Table 4).

Calf ratios should be reviewed cautiously as it is difficult at times to differentiate yearlings from calves, especially when there are no calves within the group being classified. This bias could result in reported recruitment rates being higher than the true values for the population.

Mortality of Radio-Collared Caribou

Most radio-collared caribou mortalities occurred in summer and early to mid-winter. There were 26 radio-collared caribou mortalities between February 1993 and March 2001; three deaths occurred in the Barkerville sub-population and 23 in the Wells Gray North sub-population. The latter comprised of nine caribou mortalities in the Stevenson and Junction areas, eleven mortalities in the Horsefly area, and three mortalities outside of the WGN survey area in Wells Gray Park (Figure 8). The three mortalities in Wells Gray Park were caribou originally collared within the Horsefly census block; these caribou were frequently observed to range east of the Horsefly census boundary.

Deaths were classified into six categories: accidental, malnutrition, predation, undetermined with possible predation, undetermined/other and not recovered. The accidental classification included caribou mortalities resulting from naturally occurring incidents such as birthing, falls, or avalanches. The undetermined categories were utilized when evidence at the mortality site was insufficient to draw concrete conclusions upon; the 'other' classification included mortalities in which predation appeared not to be a factor but disease may have contributed to the death. Sites were visited as soon as possible after a collar transmitted a mortality signal however, when there was a delay of collar retrieval, death classification was conservative. Two collar deaths in October and November were not retrieved due to lengthy delays preventing access to the sites; subsequently, they were classified as 'not recovered'. One caribou in the Horsefly area died as a result of complications associated with the project and was excluded from the mortality analysis.

Deaths attributed to malnutrition were based on analysis of femur bone-marrow fat content; ten of the twenty-four investigated caribou mortalities were analyzed. Two caribou deaths were linked to malnutrition, with only 19.3% and 12.0% bone-marrow fat content. Of the remaining caribou sampled, five had percent fat in the 80^{th} percentile ranging from 82.3% to 89.7%, two were in the 70^{th} percentile with 72.4% and 73.0% fat, and one had 45.0% fat content at the time of death.

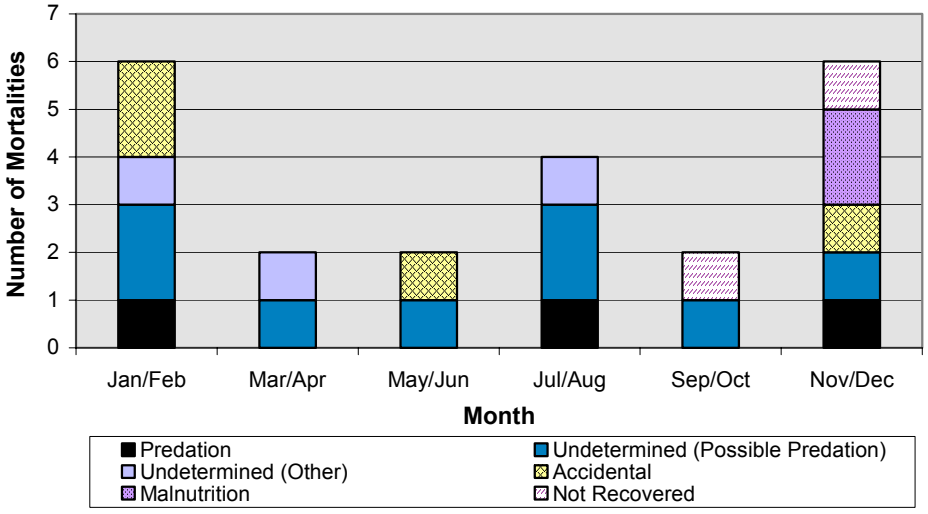


Figure 8. Monthly distribution and cause of radio-collared caribou mortalities within the Wells Gray North sub-population, 1993 to 2001.

The monthly distribution of radio-collared caribou mortalities for the Wells Gray North sub-population was dissimilar to the distribution observed by Seip (1992) in the Quesnel Lake Study Area during the mid 1980's (Figure 9). In the 1990's caribou mortalities appeared to be spread more evenly throughout the year, with most deaths occurring between November and February and in the summer months of July and August. In contrast, the majority of radio-collared deaths in the mid 1980's took place between May and December, with the greatest number occurring during July and August.

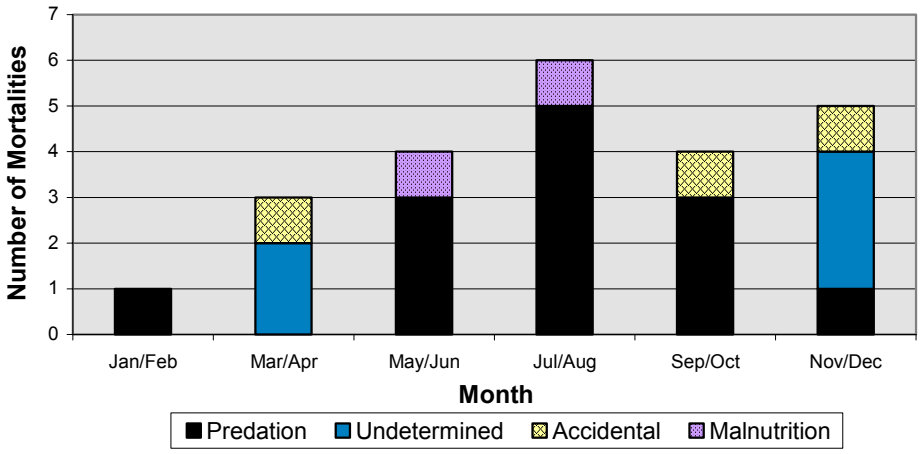


Figure 9. Monthly distribution and cause of radio-collared caribou mortalities within the Quesnel Lake Study Area, 1984 to 1989 (data from Seip, 1992).

The average elevation of the radio-collared caribou mortalities in the Wells Gray North sub-population was 1447m (SD=367m). Caribou that died due to predation or undetermined/possible predation factors were found at an average elevation of 1556m and 1521m (SD = 370m and 364m), respectively. Young and Freeman (*in prep*, 2001) observed radio-collared caribou at an average elevation of 1644m from June to September, 1571m in October and 1441m in November; average elevation climbed throughout the winter months, peaked in March at 1729m, and dropped in spring to 1502m. Collared wolves in the same study were relocated the majority of time in the 750-1000m elevation band; however, wolves were found to partially use similar elevation bands as caribou throughout the entire year.

A difference in the average elevation of mortality occurrences was observed between the two decades; deaths due to predation were recorded at elevations approximately 160m higher in the 1990's as compared to the 1980's. In the Quesnel Lake Study Area in the mid 1980's, average elevation of mortalities was 1287m ± 365m (Seip, 1992). Seip observed average elevation of caribou mortalities attributed to predation (1265m, SD = 400m) to be lower than the average elevation of radio-collared caribou relocations, suggesting that caribou were more vulnerable to predation when they occupied lower elevations. The decline in caribou numbers in the mid 1980's was attributed to wolf predation, which generally appeared to increase during the summer months (Seip, 1992). Similar monthly elevation use by caribou was observed between the mid 1980's and the 1990's. Average elevation of caribou relocations in the mid 1980's was 1629m during the summer and fall months, 1619m in October, and 1488m in November. As observed in the 1990's, average elevation increased throughout the winter with a March high of 1765m, before dropping to the yearly spring low of 1463m.

Adult Mortality and Calf Recruitment Relationship

Natural mortality of adults and yearlings (based on natural mortality of collared animals from April 1st to March 31st of each year) varied from 18 to 33 percent from 1984 to 1989 (Seip, unpublished data) for the Quesnel Lake Study Area and from 0 to 33 percent from 1993 to 2001 for the Wells Gray North sub-population. In the mid to late 1980's the caribou population in the Quesnel Lake Study Area declined as a result of both low calf recruitment and high adult mortality (Figure 10). Higher calf recruitment and lower adult mortality were evident in 1994 and 1995, with an observed corresponding population increase, before again beginning to decline from 1996 to 2000. In 2001 calf recruitment was 17.5 percent calves.

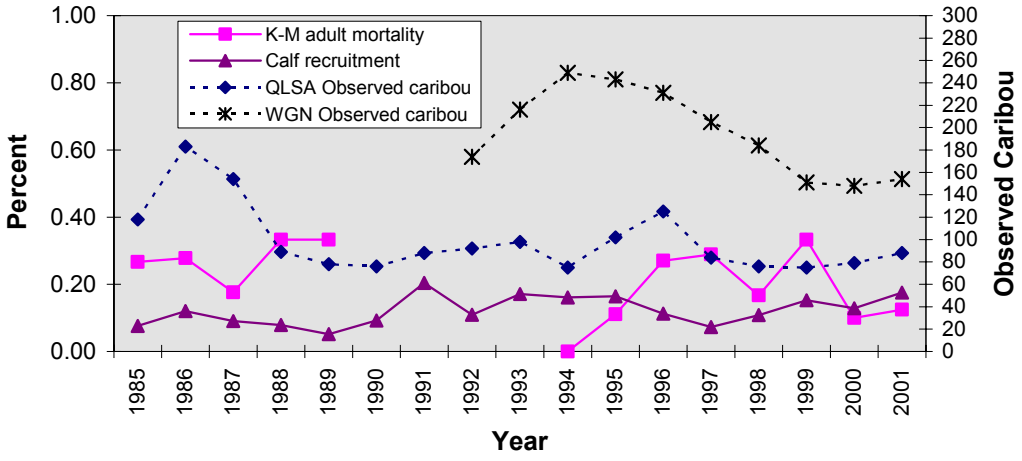


Figure 10. Kaplan-Meier annual adult mortality[1] and calf recruitment rates[2] (1985-1991 data from the Quesnel Lake Study Area; 1992-2001 data from Wells Gray North sub-population) compared to total numbers of observed caribou within the Quesnel Lake Study Area[1] (1985-1988 data from Seip 1992, and Seip unpubl. Data).

Data from Quesnel Lake Study Area for the period 1984-1989 was combined with the Wells Gray North 1993-2001 dataset for the calculation of the Kaplan Meier mortality estimates in order to increase sample size. This was done under the assumption that the survival trend in the Quesnel Lake Study Area was representative of the survival trend in the Wells Gray North sub-population as caribou within the latter area are of a relatively closed population.

Second-degree polynomial regression analysis was performed, as it does not assume a pre-determined relationship between adult mortality and calf recruitment; the intercept was fixed at 0.333 as this was the highest adult mortality rate observed (Figure 11). There appears to be a negative, curvilinear relationship between adult mortality rate and calf recruitment rate ($R^2 = 0.4027$). Adult mortality changes little at low calf recruitment. Note that stabilizing recruitment (where recruitment = adult mortality) was about 15%, supporting Bergerud's (1992) prediction of a stabilizing calf recruitment that balances the natural mortality of adults. There is a possibility that the data may be autocorrellated, however the strength of the data comes from the fact that stabilizing recruitment is about 15%.

[1] measured from April 1st to March 31st of each year
[2] calculated from March surveys

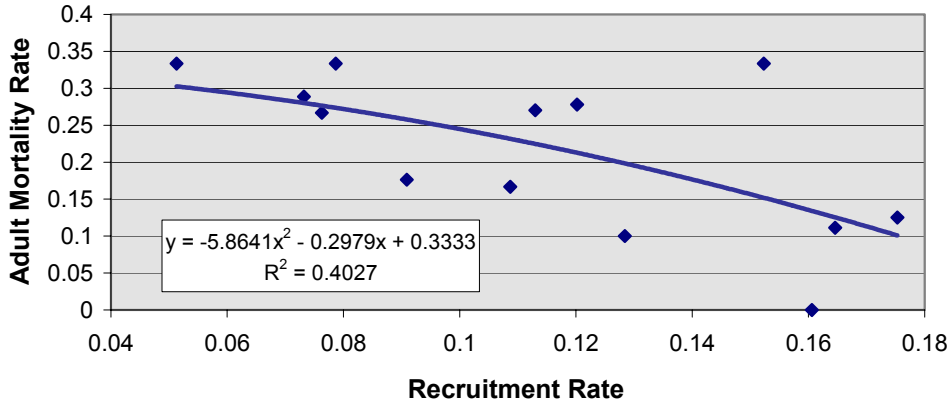


Figure 11. Relationship between annual caribou calf recruitment and natural adult mortality (data from the Quesnel Lake Study Area from 1984-1989 and Wells Gray North sub-population from 1993-2001) represented by 2nd degree polynomial regression.

To determine whether it was reasonable to infer that survival trends in the Quesnel Lake Study Area were representative of the survival trend in Wells Gray North, a comparison of the Quesnel Lake Study Area and the Wells Gray North datasets was analyzed. Since the assumptions of parametric regression were not met, linear regression was not appropriate; adult mortality rate did not depend on recruitment rate, thus there was no clear dependent or independent variable or causal relationship between recruitment and adult mortality. A better description of this relationship would be given by the central trend line, also known as the functional regression or the geometric mean regression (GMR) (Krebs, 1989). Central trend lines were found to be useful in describing the relationship between adult mortality and calf recruitment because both variables had measurement errors.

Individual study area datasets were evaluated to determine relationships between adult mortality and calf recruitment. A significant negative regression relationship was found between adult mortality and calf recruitment for the combined dataset of Quesnel Lake Study Area 1984-1989 and Wells Gray North 1993-2001 ($p < 0.02$). This was also true for the Quesnel Lake Study Area 1984-1989/1993-2001 dataset ($p < 0.01$). No significant relationship was detected for Wells Gray North 1993-2001 ($0.1 < p$) or Quesnel Lake Study Area 1984-1989 ($0.4 < p$); this could possibly be due to small sample size with respect to number of years analyzed.

Analysis for the Quesnel Lake Study Area 1993-2001 dataset was performed and no significant relationship between adult mortality and calf recruitment was detected ($0.2<p$). However, data for this time period was deemed unreliable due to Kaplan Meier survival rates being equal to 1.00 for five of the eight monitored years. Only four collar mortalities occurred within the Quesnel Lake Study Area during this time period, two in 1996, one in 1997, and one in 1998; thus, calculated mortality rates of zero for the

remaining years were not considered realistic population parameters. Small sample size with respect to number of years analyzed and small numbers of collared caribou inhabiting the area likely contributed to the these ambiguous results.

During the period April 1, 2000 to March 31, 2001 monthly monitoring of the radio-collared caribou ceased after May 2000. A reconnaissance flight in preparation for the caribou population inventory was completed in March 2001, at which point a collar mortality and a collar failure were recorded.

The 2001 Kaplan Meier adult mortality calculations for Wells Gray North and Quesnel Lake Study Area were done based on conservative estimations of the months that the failure and mortality occurred; the Quesnel Lake Study Area was affected only by the collar failure. Since continuous monitoring was not done, cross-boundary movement into and out of the Quesnel Lake Study Area was not recorded. One of the main advantages of the Kaplan Meier product limit estimator was that animals could be added to or removed from the population at risk at any time without affecting survivorship. Recruitment or censoring of animals affected the width of the confidence intervals, such that confidence intervals became wider as the number of animals at risk of mortality decreased. Thus, the Quesnel Lake Study Area 2001 Kaplan Meier survival estimator was used with the knowledge that the associated confidence intervals were not representative of the potential animal cross-boundary movement that may have occurred during the year.

We chose to compare the regression relationship for the combined Quesnel Lake Study Area 1984-1989/Wells Gray North 1993-2001 with that of the Quesnel Lake Study Area 1984-2001. The relationship between adult mortality and calf recruitment had tested significant for both sets of data. When the central trend line equations were compared no significant difference in slopes was detected ($0.25 < p$), thereby suggesting that survival trends in the Quesnel Lake Study Area may mirror those in the Wells Gray North Area (Figure 12). The robustness of the Geometric Mean Regression allows for extrapolation, when used with caution, and provides a useful description of the population's central trend in situations where the population or the sample, or both, are not binormal. Given the relatively small number of pair-wise years of data from both Wells Gray North and Quesnel Lake Study Area, any extrapolation made regarding population trends for the combined dataset should be utilized with caution.

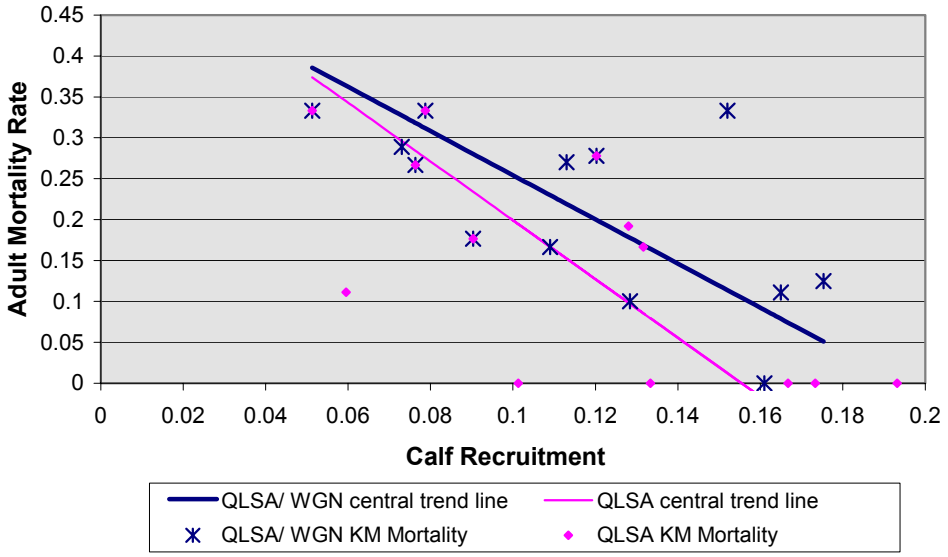


Figure 12. Kaplan-Meier annual adult mortality rates and Geometric Mean Regression lines for the relationship between caribou calf recruitment and natural adult mortality (data shown is from the Quesnel Lake Study Area 1984-1989/1993-2001 and the combined Quesnel Lake Study Area 1984-1989/Wells Gray North sub-population 1993-2001).

Sightability Correction Factors and Population Trend

From 1993 to 2001 the proportion of radio collared caribou known to be within the overall census area that were seen during the surveys averaged 84.2% (123/146) and ranged from 69 to 95 percent between individual years. This compares closely to the results obtained for the Quesnel Lake Study Area (Seip 1992) where from 1985 to 1988 the average was 84% (41/49) and ranged from 75 to 100 percent between years. In adjacent Wells Gray Park (including portions of both Wells Gray North and South sub-populations) between 1987 and 1989, Seip (1990) observed an average 78% (52/67) of collared caribou with a range of 67 to 87 percent between years. Combining data from all years and areas indicates an average sightability correction factor of 82.4% (216/262).

Similar population trends are observed within the Quesnel Lake Study Area whether the average sightability correction factor (82.5%), annual sightability correction factor (Samuel et al, 1987), or the actual numbers observed were used for each year (Figure 14). Between 1986 and 1988 there appears to have been a major population decline, followed by population stabilization with slight positive growth until 1996. From 1997 to 1999 the population appears to have again declined with possible stabilization in the last two years.

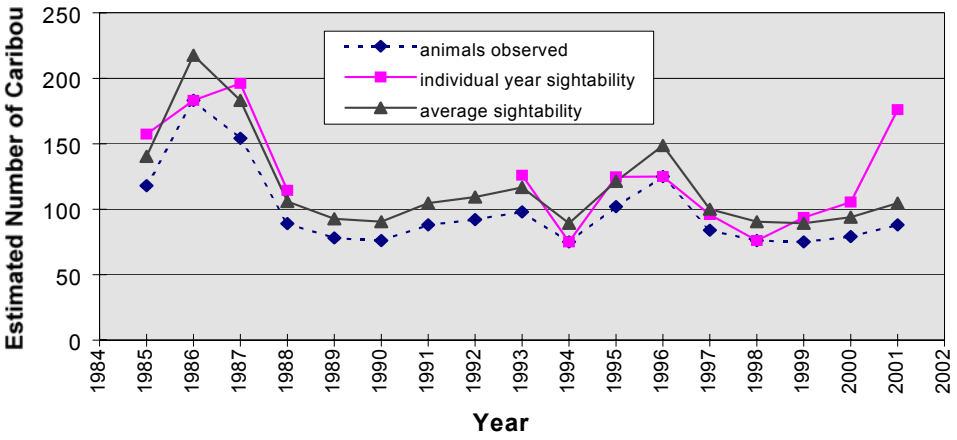


Figure 13. Comparison of animals observed, individual year sightability and overall average sightability for caribou in the Quesnel Lake Study Area; (individual year sightability only calculated for years in which functioning collars were present; 1985-1988 data from Seip, 1992).

Conclusions

- During the late winter surveys of 2001 a total of 154 caribou were observed within the Wells Gray North sub-population; including 127 adults and 27 calves. The observed percentage calves was 17.53. Five of the seven collared caribou in this area were observed. Correcting for sightability, the late winter population estimate was 215 animals.

- Thirty-five caribou were observed in the Barkerville sub-population: 26 adults and 9 calves resulting in an observed percentage calves of 25.71. All three collared animals were observed, resulting in an estimated 35 caribou.

- Of the total 212 caribou observed during the 2001 March surveys, 88 animals were located within the Quesnel Lake Study Area of which 71 were adults and 17 were calves. Within this subunit the observed percentage calves was 19.32. Two of the four collared caribou in the Quesnel Lake Study Area were observed resulting in the late winter population estimate of 175 animals.

- Low recruitment from 1996 to 1998, and again in 2000, may be partially responsible for the apparent population decline in the last few years within the Wells Gray North caribou sub-population.

- Population trend and recruitment statistics suggest caribou numbers within the Quesnel Lake Study Area stabilized subsequent to the observed decline in the mid to late 1980's. An increase in recruitment was noted between 1993 and 1995, however since then, population trends have suggested further decline with stabilization over the last two years.

- The presence of a significant negative relationship between adult mortality and calf recruitment was established for the Quesnel Lake and Wells Gray North Study Areas; thereby demonstrating that recruitment and survival trends in the Quesnel Lake Study Area may mirror those in Wells Gray North.

Recommendations

- Due to the large home range of some caribou it would be advantageous to plan future surveys with adjoining administrative regions.

- Continued monitoring of mountain caribou population trends and calf recruitment rates within the Quesnel Highland and Cariboo Mountains is recommended in conjunction with implementation of the mountain caribou strategy and recovery efforts for the species.

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APPENDICES

Appendix 1. March 2001, Quesnel Highland caribou census.

Appendix 2. March 2000, Quesnel Highland caribou census.

Appendix 3. March 1999, Quesnel Highland caribou census.

Appendix 4. March 1998, Quesnel Highland caribou census.

Appendix 5. March 1997, Quesnel Highland caribou census.

Appendix 6. March 1996, Quesnel Highland caribou census.

Appendix 7. March 1995, Quesnel Highland caribou census.

Appendix 8. March 1994, Quesnel Highland caribou census.

Appendix 9. March 1993, Quesnel Highland caribou census.

Appendix 10. March 1992, Quesnel Highland caribou census.

Appendix 11. Summary of caribou surveys for the Quesnel Lake Study Area prior to 1992.

Appendix 12. Summary of caribou surveys for the Barkerville census block/sub-population prior to 1992.

Appendix 13. Summary of observed caribou numbers and calculated caribou sub-population estimates with 95% confidence intervals for late winter, 1985-2001. Population estimates derived from the joint hypergeometric estimator.