

Pink Mountain and Graham Caribou Populations Assessment 2021-2022

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BC Ministry of Land, Water and Resource Stewardship
Caribou Recovery Program
July 2022



Suggested citation: Watt, K. and Pelletier, A. 2022. Pink Mountain and Graham Caribou Populations Assessment 2021-2022. *BC Ministry of Lands, Water and Resource Stewardship, p21, Fort St. John, BC, Canada.*

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Introduction

The Pink Mountain and Graham woodland caribou populations (*Rangifer tarandus caribou*) belong to the Northern Mountain Designatable Unit (DU7; Committee on the Status of Endangered Wildlife in Canada, 2014). In total, 25 caribou populations belong to DU7, and they are federally designated as “Special Concern” and “Blue-Listed” provincially (Anderson, 2020). Federal recovery and management plans have identified population monitoring for Northern Mountain caribou populations as a high priority (Environment Canada, 2012).

The Graham and Pink Mountain caribou populations were monitored sporadically from the 1960s to the late 1980s. Survey efforts during that time were inconsistent and lacked statistical rigor to provide strong population estimates. From the early 2000s to 2020s, the objective of most surveys was to determine calf recruitment (Pelletier & Watt, 2022). Within the last 5 years, there has been a push to monitor these populations more consistently to gain a better understanding of demographic trends and provide accurate population estimates.

Both the Pink Mountain and Graham caribou ranges are located within the Northeast Region (7B) of BC. The Northeast Region is on Treaty 8 territory, where caribou have an invaluable cultural importance for local Indigenous communities. As a response to declining caribou populations, several First Nations have implemented voluntary moratoriums on caribou hunting until populations recover (Government of Canada, 2020).

Concerns about the loss of traditional hunting opportunities brought forward by Blueberry River First Nation led to the implementation of a 3-year provincial wolf reduction program within the Pink Mountain caribou range in the winter of 2018-2019 (Bridger, 2021b). At the time, Graham caribou were used as a control so that their growth rate could be compared with neighbouring Central Mountain populations (DU8) that had been under wolf control since the winter of 2014-2015. After 5 years of continuous decline, wolf control was implemented in the Graham range in the winter of 2019-2020 (Bridger, 2021a). Recently, the wolf control program in both Pink Mountain and Graham was extended to the winter of 2025-2026. To assess the effects of this management tool on these populations, a monitoring schedule was implemented where mark-resight surveys are conducted every 4 to 5 years, and recruitment surveys in all other years.

The goal of this report is to summarize the last two years of caribou surveys for the Pink Mountain and Graham populations to assess the effect of wolf control on demographic and recruitment metrics. Mark-resight surveys were conducted in March 2021 and recruitment surveys in March 2022 in both ranges.

Study Area

The Pink Mountain caribou range is bordered south by the Halfway River and north by the Muskwa River, and encompasses a 9,511 km² surface area (Fig. 1). The majority of the range is composed of mountainous terrain, although the eastern portion includes large tracks of low elevation coniferous forests that extend 30 km eastward of Highway 97, up to the junction of Buckinghorse River and Medana Creek. Protected areas within the range include the southern portion of the Northern Rocky Mountains Provincial Park, Redfern-Keily Provincial Park, Prophet River Hot Springs Park, Buckinghorse-Wayside Park, Pink Mountain Park, Sikanni Chief River Ecological Reserve, and Sikanni Falls Protected Area.

The Graham caribou range is bordered south by the Peace River, extending westward to Williston Lake and then northward along the Ospika River (Fig. 3). From the WAC Bennet Dam, the range limit reaches the Halfway River, which also delineates its northernmost boundary. The range encompasses a 9,681 km² surface area, which includes high elevation alpine mountains (~1800m alt.) north of the Chowade River as well as south and west of the Graham River. The rest of the range is composed of subalpine mid-elevation parkland forests (~1500m alt.) and low elevation conifer forests (<1200m alt.). Protected areas within the range include the Graham Laurier Provincial Park and the Butler Ridge Park.

Methods

Mark-Resight Surveys

Mark-resight surveys allow to estimate a population's size based on the sightability of marked (or collared) animals. Mark-resight surveys were conducted from March 8th to 11th 2021 in the Graham and Pink Mountain caribou ranges. Flights were conducted in Bell 206 helicopters with bubble windows, and survey conditions were good with excellent visibility, moderate winds and good snow cover. Each survey crew consisted of an experienced pilot, an experienced navigator in the front left seat, and two experienced or well-trained observers in the rear seats.

The survey methods followed the BC Resource Information Standards Committee guidelines (Resources Information Standards Committee (RISC, 2002). All high elevation habitat above the treeline was surveyed within each range. For the Graham range, an additional area east of the Williston Reservoir, outside of the range boundary, was also surveyed. For this report, only the caribou located within the Graham range boundary were analyzed (the count of the East Williston caribou can be found in Appendix A).

Each survey area was flown by contouring lines between the treeline and ridgetops. The program GIS Pro (installed on an iPad with GPS capability) was used to navigate the mountain complexes. All caribou observed (either opportunistically or tracked via telemetry) were counted and classified as cows, bulls, unknown adults, or calves. Pictures of large groups were taken with a Canon Mark 6 camera affixed with a 70-300 mm lens to minimize disturbance and confirm field classification. Locations of caribou were marked with a handheld Garmin GPS unit, and flight tracks were recorded with both the handheld GPS unit and the GPS enabled iPad.

The following data were used to derive a population estimate with the Petersen method (Krebs, 2017):

- The number of marked animals (or number of active collars available, M); in this report, only active GPS collars are considered available marked animals, as the location and status of VHF collars cannot be confirmed prior to the survey)
- The number of recaptured animals (or number of collars located opportunistically, R)
- The total number of animals located opportunistically (or number of animals located without the aid of telemetry, C)

The Petersen method only requires one capture event and one relocation event of some of the animals to calculate the population estimate (N). It is assumed that the proportion of recaptured animals (R/M) is the same as the proportion of animals observed opportunistically (C/N). With this method, the population estimate is calculated as follows:

$$N = (C * M) / R$$

However, the above equation often leads to overestimations, especially in small populations. The modification below corrects this bias, preventing overestimation when (M + C) > N, or if there are at least seven recaptures of marked animals (R > 7). It calculates the population estimate as follows:

$$N = \frac{(C + 1) * (M + 1)}{R + 1} - 1$$

The Petersen corrected equation is the one used in this report to calculate the 2021 population estimates for the Graham and Pink Mountain populations.

It is important to note that the Petersen equation (corrected or uncorrected) is generally applied without distinction to the entire survey area, despite obvious differences in sightability levels depending on habitat type. This could lead to overestimations if a high number of collars tracked via telemetry ends up providing a low proportion of the animal count. One solution that could be used to resolve this would be to stratify the survey area into high, medium and low sightability potential areas, and then:

- i) apply the Petersen equation for survey areas with a high sightability potential (such as high alpine areas) and provide a population estimate for these areas; and
- ii) add all animal counted in areas with low and medium sightability to the high sightability area estimate calculated in i).

This would provide a blended population estimate, but could lead to underestimations when the number of animals observed in medium and low sightability areas is low.

Recruitment Surveys

Recruitment surveys provide a minimum count of caribou and cannot be used to estimate population size. Crew fly directly to collars to classify all caribou encountered by age and sex. The population metrics obtained include:

- i) the percentage of calves within the population;
- ii) the calf to cow ratio; and
- iii) the bull to cow ratio,

which can also be collected during mark-resight surveys.

The variance of these population metrics can be calculated in R 4.2.0 (RStudio Team, 2019) by applying a bootstrap estimator with 10,000 iterations (Davison & Hinkley, 1997) using the package *boot* (Canty & Ripley, 2022).

In 2022, late winter aerial recruitment surveys in the Pink Mountain and Graham ranges were conducted on March 16th and 17th in a Bell 206. Survey conditions were moderate with patchy snow cover and high winds, and crew were composed similarly as for mark-resight surveys. To maximize the number of animal observations, active collars were directly flown to, and GPS collars offline for less than 3 months and VHF collars were scanned for. Any offline GPS or VHF collar heard during the survey was tracked.

Survival Rate

The survival of adult females can provide information on population trends when it is combined with recruitment metrics. To calculate adult female survival (S), cows are affixed with GPS or VHF collars. These collars send different signals when an animal is fully stationary for a set period of time (assumed dead) than when it is moving. For the Pink and Graham populations, VHF collars were monitored by quarterly fixed-wing status flights where the collars' signals were located and assessed. GPS collars were monitored on by regularly checking movement patterns online. Mortality signals received via email were also investigated to confirm fate and determine cause of death.

In this report, the adult female survival rate was calculated yearly, from April 1st to March 31st based on a staggered entry design (Pollock et al., 1989; Skalski, 2005). In this design, survival rate is based on the number of animals alive at the start of the period, the number of animals that die during that period, and the number of animals whose status becomes unknown during that period. Animals of unknown status are censored from the date they go offline for GPS, or when they cannot be located via VHF, and provide partial survival information throughout the period (DeCesare et al., 2016).

Population growth for the Pink Mountain and Graham populations was estimated using the female specific recruitment-mortality (RM) method (DeCesare et al., 2012; Hatter & Bergerud, 1991). This equation avoids overestimations in lambda (λ) that result from not accounting for juvenile adult age ratios.

This adjusted RM equation is:

$$\lambda = S / (1 - Rrm)$$

Where:

$$Rrm = \frac{\text{number of female calves}}{\text{number of females of all age classes}}$$

When $\lambda > 1$, the population is growing, while it is declining when $\lambda < 1$. The population growth rate (r) is derived from λ , as follows:

$$r = \lambda - 1$$

Results

Pink Mountain

2021 Mark-Resight Survey

The Pink Mountain mark-resight survey (Fig. 1) required 53.8 hours of flight time which included 42.3 hours of search time. A total of 377 caribou in 59 groups were detected during the survey. This included 225 cows, 83 bulls, 8 unknown adults and 61 calves. The mean group size was 6.9 (95% CI 5.3-8.5). The calf:cow ratio was 0.27 (CI 95% 0.20-0.35), with calves representing 16.2% (CI 95% 12.6-19.9%) of the population and the bull:cow ratio was 0.37 bull (95% CI 0.25-0.55).

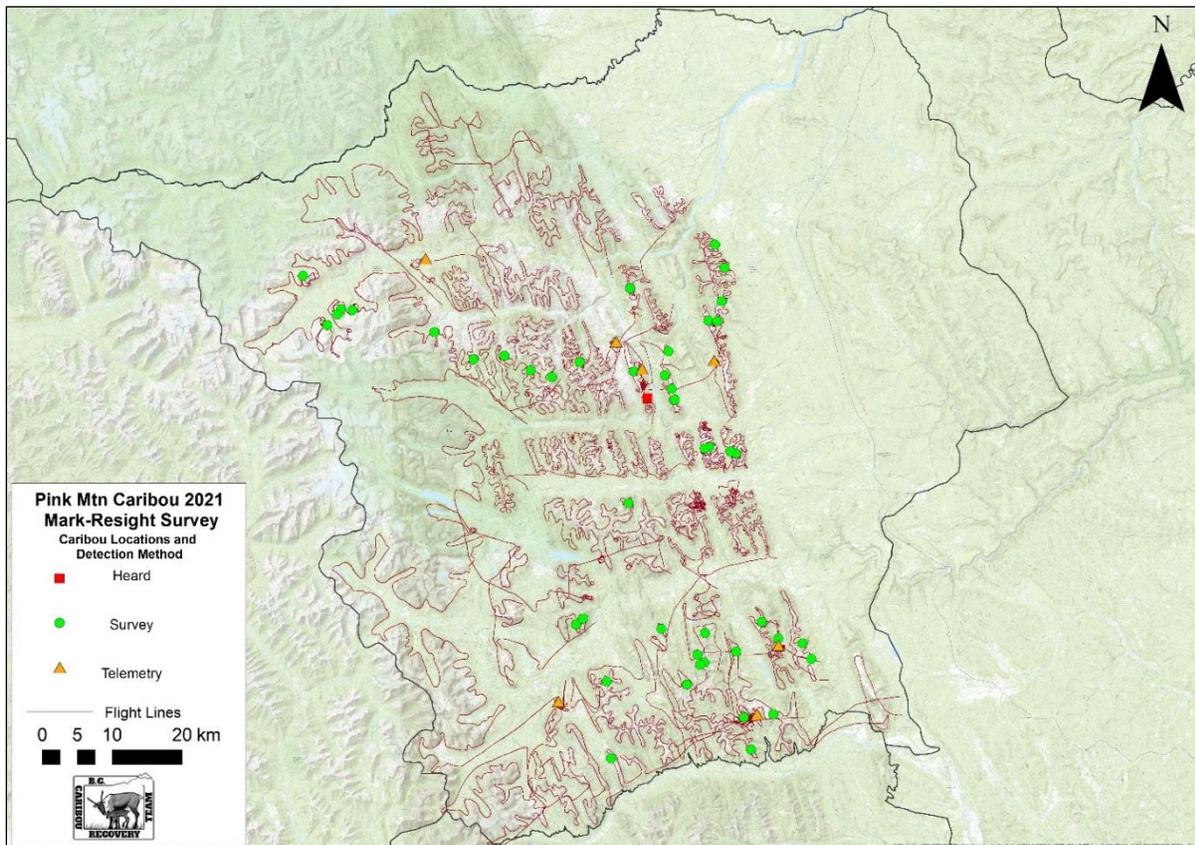


Figure 1. Caribou locations and flight tracks from the 2021 Pink Mountain mark-resight survey.

Prior to the start of the 2021 mark resight survey, there were 19 active GPS collars available, 6 offline GPS, and 7 VHF of unknown status. In total, 363 animals (incl. 12 active GPS and 2 VHF) were found without telemetry, 14 animals (incl. 6 active GPS and 1 offline GPS) were tracked, and one active collar was only heard, indicating a sightability of 63% (12/19). Offline GPS and VHF collars were tracked in order to determine minimum number of known caribou alive.

Applying the Petersen corrected equation on the counts from the active GPS collars provides a population estimate of 559 animals (95% CI 340-946), which is most likely an overestimate as the 32% of active collars that were successfully tracked only provided 3.2% of the animal count. A blended population estimate for the same survey would yield an estimate of 481 animals (475 estimated in high density areas, 95% CI 289-804, plus six animals observed in medium and low density areas). We are currently using the corrected Petersen estimate as the official population estimate, although the blended estimate might be more realistic.

From April 1st 2020 to March 31st 2021, Pink Mountain caribou survival was calculated based on collared females. At the beginning of the sampling period there were 30 collared females. No collared caribou died during the sampling period, 2 collars went offline and were censored, and 3 new collars were deployed. Adult female survival was calculated at $S = 1$, and combined with the recruitment data, provided a λ of 1.135, which represents a 13.5% growth rate for 2020-2021.

2022 Recruitment Survey

The Pink Mountain 2022 recruitment survey (Fig. 2) required 12.4 hours of flight time which included 9 hours of search time.

A total of 241 caribou were detected in 25 groups (mean group size 9.6, 95% CI 6.6-13.1). There were 21 active collars detected during the survey. Of these, 18 were seen including a VHF collar, and 3 were heard active but not located, and therefore not counted. An additional two VHF collars were located but were not included in the Petersen equation. (Fig. 2). There were 153 cows, 32 bulls, 29 unknown adults and 27 calves counted. Based on the sampled population the calf:cow ratio was 0.18 (95% CI 0.1-0.25), 11.2% (95% CI 6.9%-15.0%) of the population were calves, and the bull:cow ratio was 0.21 (95% CI 0.12-0.31).

Survival from April 1st 2021st to March 31st 2022 was calculated similarly as for 2020-2021. At the beginning of the sampling period there were 31 collared caribou, and 4 died during the sampling period. Another 13 collars went offline and were censored, and 7 new collars were deployed on in January and February 2022. The adult female survival was estimated to be $S = 0.86$ (95% CI 0.99-0.74), and combined with the recruitment data, provided a λ of 0.954, which represents a negative (-4.6%) growth rate.

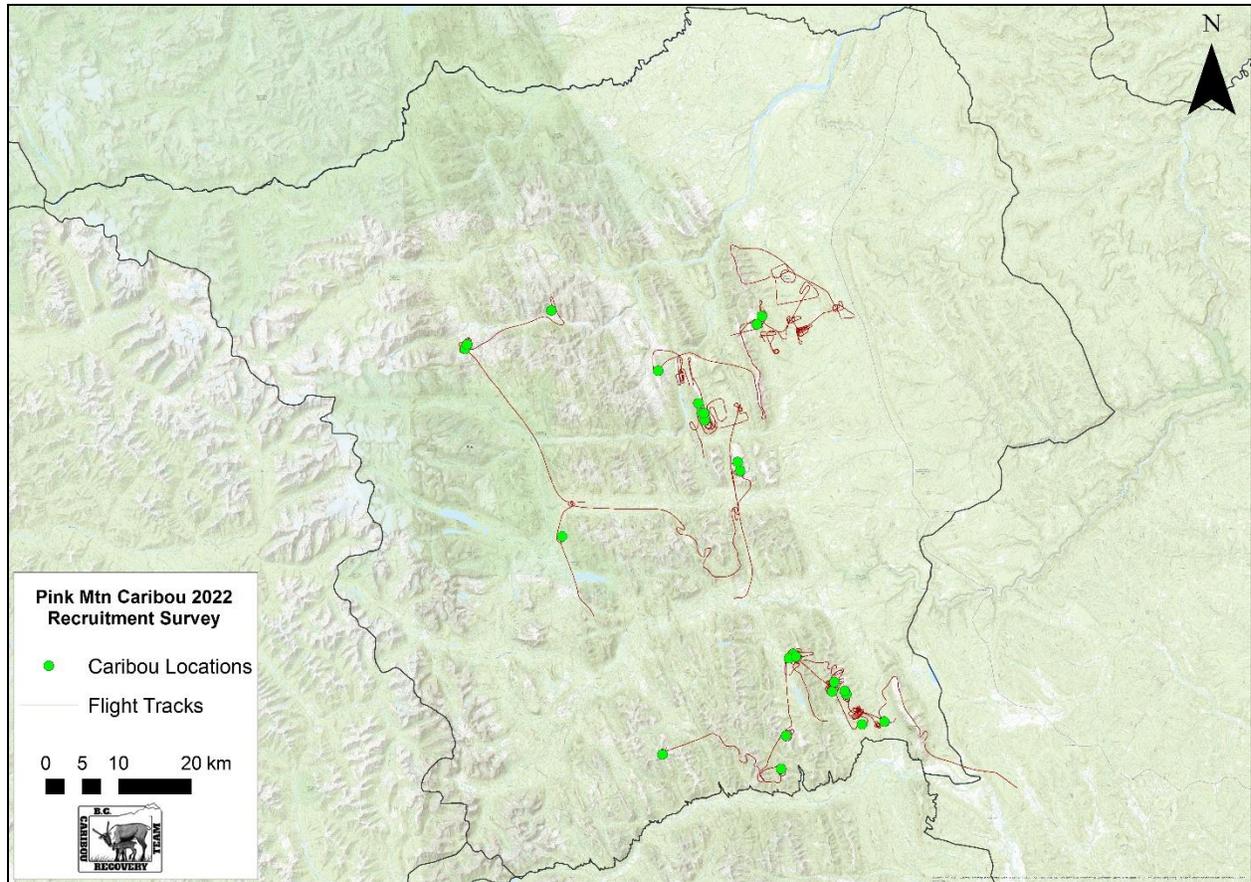


Figure 2. Caribou locations and flight tracks from the 2022 Pink Mountain recruitment survey.

Graham

2021 Mark-resight Survey

The Graham mark-resight survey required 55.3 hours of flight time which included 34.8 hours of search time (Fig. 3). Excluding East-Williston, 29 groups were observed (mean group size of 4.5, CI 95% 3.5-5.6). There were 131 caribou counted (53 cows, 41 bulls, 16 unknown adults and 21 calves), and 2 additional collared female caribou were heard in the trees but could not be visually located. Based on the age and sex classifications, the calf:cow ratio was 0.26 (CI 95% 0.22-0.58), there were 16% of calves (CI 95% 8.8-22.5%) in the population, and the bull:cow ratio was 0.77 (CI 95% 0.35-1.69).

Prior to the start of the survey, there were 8 active GPS collars available in the Graham range, and 14 VHF collars of unknown location and status. The VHF collars were scanned for when but not included in the sightability analysis. Of the 8 active GPS collars 4 were observed opportunistically, indicating a sightability of 50% (4/8). Of the 14 VHF collars, 9 were located, 2 were heard active but not located, and 3 were not heard.

Our survey count totaled 131 caribou, of which 109 were observed opportunistically, and 22 were detected by tracking collared animals. The Petersen corrected method provided a population estimate of 197 animals (95% CI 92-417), which is likely biased because the small sample size of available collars.

From April 1st 2020 to March 31st 2021, Graham caribou survival was calculated based on collared females. At the beginning of the sampling period, there were 19 collared caribou available for survival assessment. During the sampling period, 2 died, 6 collars went offline and were censored, and 7 new collars were deployed. The adult female survival was estimated at $S = 0.90$ (95% CI 1.0-0.76), and combined with the recruitment data, provided a λ of 1.08, which represents an 8.0% growth rate.

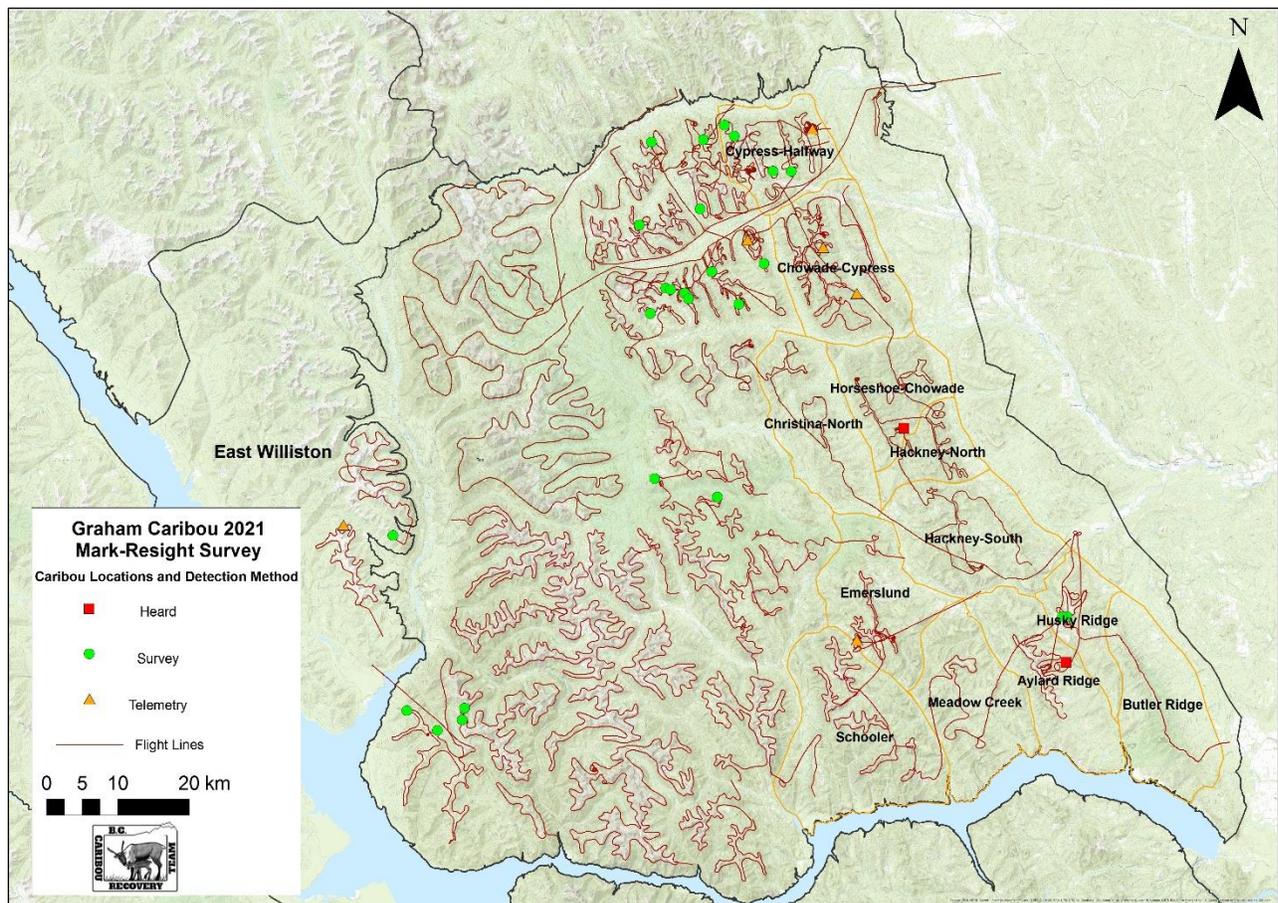


Figure 3. Caribou locations and flight tracks from the 2021 Graham mark-resight survey.

2022 Recruitment Survey

The Graham 2022 recruitment survey (Fig. 4) required 11.5 hours of flight time, which included 6.8 hours of search time.

A total of 74 caribou were detected in 12 groups (mean group size 6.3, CI 95% 4.3-8.5), with 15 active collars located during the survey. There were 34 cows, 14 bulls, 13 unknown adults and 13 calves counted. Based on the sampled population, the calf:cow ratio was 0.36 (CI 95% 0.30-0.49), calves represented 17.6% (CI 95% 12.8-22.2) of the population, and the bull:cow ratio was 0.38 (CI 95% 0.11-0.85).

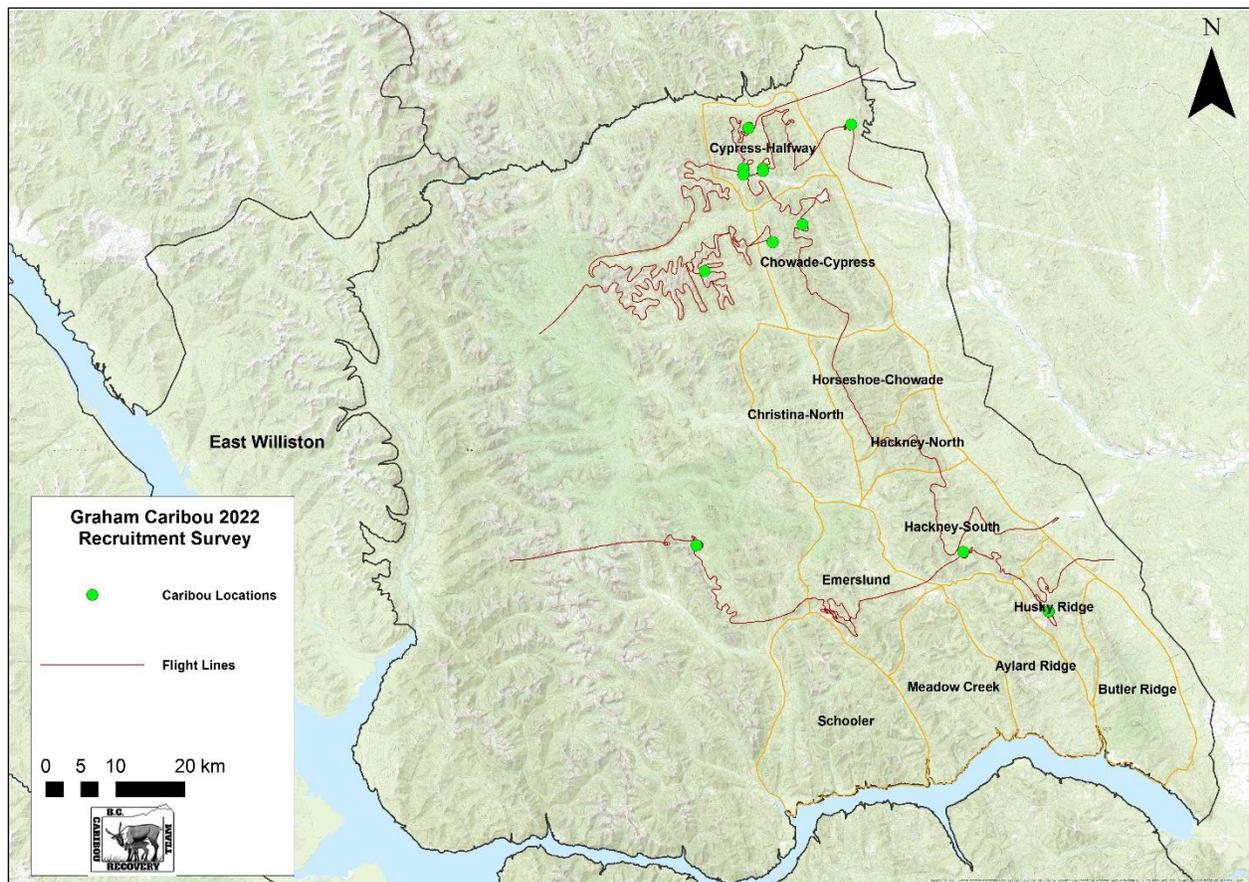


Figure 4. Caribou locations and flight tracks from the 2022 Graham recruitment survey.

Survival from April 1st 2021st to March 31st 2022 was calculated similarly as for 2020-2021. At the beginning of the sampling period, there were 17 collared females. No collared caribou died during the sampling period, 5 collars went offline and were censored, and 4 new collars were deployed. The adult female survival was estimated at $S = 1$ as no collared caribou died, and combined with the recruitment data, provided a λ of 1.18, which represents an 18.0% growth rate.

Discussion

The primary objective of the last two years of surveys for the Pink Mountain and Graham caribou populations was to assess their current status and determine the effect of wolf control on their respective growth rate. Wolf control was implemented in the Pink Mountain range in the winter of 2018-2019, and in the Graham range in the winter of 2019-2020.

Pink Mountain Population

Although there is a minimal amount of historical population data available for Pink Mountain, the existing information shows that the population experienced a precipitous decline from the late 1960s to present. In 1968 and 1969 caribou surveys resulted in counts of 1018 and 2675 respectively, while a survey in 1978 only counted 203 caribou (Bergerud, 1978). Poor survey conditions in 1978 likely led to the low number of caribou counted, but could also be indicative of a steep decline (Bergerud, 1978). Local outfitters conducted wolf reduction efforts in the area from the late 1970s through the early 1980s. The BC Government also reduced wolves from 1984 to 1987, with wolf densities estimated at 39/1,000 km² in 1984, and 22/1,000 km² by 1990 (Bergerud & Elliott, 1998).

From 1990 to 2015, Pink Mountain caribou were monitored infrequently. Incidental observations gathered during a 2012 Stone sheep survey in WMU 7-42 provided a count of 165 caribou, composed of 13% of calves and with a calf:cow ratio of 0.18. Both of these metrics are considered below what is needed for a self-sustaining population, as the recruitment targets for a population to be stable are: i) 15-16% of calves in the population; and ii) a calf:cow ratio of 0.26 or above (Bergerud, 1992; DeCesare et al., 2012).

The mark-resight survey conducted in 2021 was the first of its kind within the Pink Mountain Range and resulted in a Peterson corrected estimate of 559 (95% CI 340-946). The confidence interval is large due to high number of collars that had to be tracked via telemetry

Recruitment surveys were conducted for three consecutive years (2016 to 2018) in the Pink Mountain range prior to the implementation of wolf control. These surveys consistently indicated that calf recruitment was below self-sustaining levels (Table 1). Population metrics over the last two year indicate a stable to decreasing population. The 2021 population survey found a calf:cow ratio of 0.27, and 16.2% calves, with an adult female survival rate of 1. These metrics were at or above the minimum targets for a self-sustaining population, and the growth rate was 13.5%. It is important to note, however, that the survival rate of 1 is unlikely to apply to the entire population. As such, the growth rate calculated in 2020-2021 was most likely an overestimate.

For the 2022 recruitment survey, the calf recruitment metrics were well below the desired minimum targets as the calf:cow ratio was 0.18 and calves only made up 11.2% of the population. The lower survival rate observed in 2022 compared to 2021, associated with a low calf recruitment, led to a negative growth rate for 2021-2022, indicating a potential decline (Table 1). The upcoming surveys and survival monitoring will help determine whether the low calf recruitment detected during the 2022 survey was a one-year anomaly, and whether the population is actually declining.

Table 1. Population metrics for Pink Mountain caribou, 2014-2022.

Year	Calf %	Calf:cow ratio	Survival Rate*	Lambda (DeCesare)	Growth Rate (r)	Wolf Density (per 1000 km ²)**
2014-2015	NA	NA	NA	NA	NA	NA
2015-2016	8.7%	0.15	NA	NA	NA	12.9
2016-2017	9.9%	0.17	0.95	1.033	3.3%	12.9
2017-2018	15.6%	0.23	0.84	0.937	-6.3%	12.9
2018-2019	NA	NA	0.80	NA	NA	12.9
2019-2020	NA	NA	0.80	NA	NA	2.6
2020-2021	16.2%	0.27	1.00	1.135	13.5%	1.7
2021-2022	12.7%	0.21	0.86	0.954	-4.6%	1.7
Average pre-wolf control (2014-2019)	11.4%	0.18	0.86	0.985	-1.5%	12.9
Average with wolf control (2019-2022)	14.5%	0.24	0.89	1.015	1.5%	2.0

*Survival is calculated from April 1st to March 31st for each year, and recruitment statistics are gathered during late winter surveys.

**Wolf density is based on the estimated density at the end of the winter. Wolf density from 2015-2016 to 2018-2019 was based on the number of wolves encountered at the beginning of wolf control in 2018-2019.

Unfortunately, the CoVid pandemic and weather constraints prevented to conduct surveys at the beginning of the wolf control program in the Pink Mountain range. This led to a lack of baseline data (2018-2019) for that population, and an absence of recruitment information for the first year where wolf control should have had a demographic effect (2019-2020). The preliminary results of wolf control indicate that caribou recruitment metrics and female survival have increased slightly (-1.5% growth pre-wolf control and 1.5 % growth after wolf control) after wolf control was implemented during the winter of 2018-2019 (Table 1). After each winter of wolf control, wolf densities ranged from 1.7 to 2.6 wolves per 1000 km², which is below the 3 wolves/1000 km² target that Environment Canada suggests to effectively minimize predation risk for caribou (Environment Canada, 2014). Wolf control within other ranges in the province have led to an increase in growth rates (Bridger, 2019; Serrouya et al., 2019). To gain a better understanding of the effects of wolf control on the Pink Mountain population, annual surveys should continue as scheduled.

Graham Population

The Graham population experienced a substantial decline since the 1960s, when caribou numbers were estimated at about 2000 (Harper, 1988). It is speculated that a major population crash caused by harsh winter conditions and predation occurred in the early 1970s (Harper, 1988). A mark-resight survey conducted in 1989 counted 589 caribou and provided a population estimate of 1761; this estimate should be interpreted with caution, however, as only 3 out of 9 collars were found opportunistically (Backmeyer, 1990).

There were no mark-resight surveys conducted during the 1990s, but results from 2002 to 2021 confirm that there has been a large decline in the population since the 589 minimum count of 1989 (Table 2).

The 2021 mark-resight survey estimated a population of 197 using the Petersen corrected method and covered a much larger survey area than from 2002 to 2016 as previous mark-resight surveys concentrated on mountain blocks on the eastern site of the range, as seen in blocks highlighted in orange in Fig. 3 and 4 (Culling & Culling, 2009).

Table 2. Graham caribou mark-resight surveys from 2002 to 2021.

Year	# of collars located opportunistically & tracked	# of animals counted	Population Estimate (95% CI)	References
2002	6 & 9	113	282 (177-609)	(Culling & Culling, 2005)
2003	3 & 7	67	107 (61-348)*	(Culling & Culling, 2005)
2009	3 & 17	190	708 (311-1558)**	(Culling & Culling, 2009)
2015	20 & 16	215	347 (207-660)	(Culling & Culling, 2015)
2016	11 & 10	181	230 (116-447)	(Culling & Culling, 2016)
2021	4 & 4	131	197 (92-417)	(Pelletier & Watt, 2022)

* The population estimate from the 2003 survey may be unreliable due to the low number of collars and low number of caribou encountered.

** The population estimate from the 2009 survey may be unreliable due to poor survey conditions and low number of collars detected while on survey.

The past 2 years of monitoring of the Graham population have indicated that the population is stable to increasing, as calf recruitment metrics were all above target and adult female survival was high (Table 3). During the 2022 survey, many of the caribou were detected in the trees which led to 13 unclassified adults. This suggests that for this specific survey, the percentage of calves in the population is a better metric to measure recruitment than the calf:cow ratio.

Since wolf control was implemented in the winter of the 2019-2020, calf recruitment, adult survival and growth rate have all increased compared to 2014-2020, during which the population was mostly declining annually (Table 3). This shows that wolf control is having its desired effect on the Graham population as the recent data indicate a positive growth rate. Since wolf control has only been occurring for three years, the population should continue to be monitored to determine the long-term effect of wolf control.

Table 3. Population metrics for Graham caribou, 2014-2022.

Year	Calf %	Calf:cow ratio	Survival Rate*	Lambda (DeCesare)	Growth Rate (r)	Wolf Density (per 1000km ²)**
2014-2015	12.6%	0.21	NA	NA	NA	NA
2015-2016	11.6%	0.17	0.96	1.047	4.7%	NA
2016-2017	15.1%	0.20	0.77	0.846	NA	4.5
2017-2018	NA	NA	0.65	NA	-6.3%	4.5
2018-2019	14.5%	0.28	0.73	0.835	-16.5%	4.5
2019-2020	11.0%	0.30	0.86	0.993	-0.7%	4.5
2020-2021	16.0%	0.40	0.90	1.080	8.0%	2.7
2021-2022	17.6%	0.36	1.00	1.180	18.0%	1.2
Average pre-wolf control (2014-2020)	13.0%	0.23	0.8	0.930	-7%	4.5
Average with wolf control (2020-2022)	16.8%	0.38	0.95	1.130	13%	1.95

*Survival is calculated from April 1st to March 31st for each year, and recruitment statistics are gathered during late winter surveys.

**Wolf density is based on the estimated density at the end of the winter. Wolf density from 2015-2016 to 2018-2019 was based on the number of wolves encountered at the beginning of wolf control in 2018-2019.

Recommendations

The demographic data presented in this report show that the Pink Mountain caribou population has only shown a slightly positive-growth rate (1.5%) since wolf control was implemented, while the Graham population has shown a high growth rate under wolf control (13.0%). Surveys within the coming years should help us gain a better understanding of the impact of wolf control on these two populations, which is currently recognized as a short-term solution to help increase caribou growth rate.

To allow for accurate mark-resight and recruitment surveys and to determine adult female survival and growth rates, a minimum number of collared individuals needs to be maintained in a population. Collared individuals within the Pink Mountain population should be maintained at approximately 30, and at 15-20 in Graham. Further, a full understanding of demographic trends for these populations will require that mark-resight surveys be conducted every 4 to 5 years, and recruitment surveys in all other years.

Consistency in survey implementation is another important item: surveys in the Graham and Pink populations have often been conducted differently (collar distribution, survey area covered, number of collars available), which has led to difficulty when comparing demographic trends and recruitment data at the population level. This is particularly limiting, as growth rates calculated annually, or over multiple years can define the management and recovery actions chosen for specific populations. The BC Provincial Caribou Recovery Team is currently moving towards Integrated Population Models to assess caribou populations' trends, as they allow to correct for various sources of observation error, to account

for fluctuations in age structure and sex-ratios, to incorporate survival data, and to differentiate the effects of different management tools (Lee et al., 2015; Schaub & Abadi, 2011).

Finally, the lack of habitat use and movement data in the low elevation area of the Pink Mountain range east of Highway 97 is also an important knowledge gap that needs to be filled. Because of the low sightability in this area, population estimates do not incorporate animals staying at low elevation in the winter. A remote camera project was implemented in 2022 in the southeastern corner of the Pink Mountain range in collaboration with Blueberry River First Nation to gain a better understanding of caribou presence and habitat use at low elevation. The results of this project should be incorporated for the management of low elevation habitat within the range. This project could also be expanded to other low elevation areas where it is difficult to deploy collars, so that more accurate population information can be gathered.

Acknowledgements

Funding for the 2021-2022 monitoring was provided by the Province of British Columbia and the Peace Northern Caribou Plan Offsetting Fund. We would like to thank Bailey Helicopter pilots Tom Halbert, Ken Knight, and Shane Drader for safe flights and excellent piloting skills. We would also like to thank BC Government staff Scott Schilds, Kristen Peck, Chris Lewis, Michael Huck, Katie Connah, Dominica Harrison, Kerry Harvey, Joelle Ward as well as external observers Anita Michalak (University of Calgary), Margaret Hughes (University of Calgary), and Sejer Meyhoff for their diligent work as observers. Many thanks to the reviewers of the papers Aaron Reid, and Scott Schilds.

References

- Anderson, B. (2020). *Northern Mountain Caribou Strategy*. BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development.
- Backmeyer, R. (1990). *Graham River caribou study progress report* (p. 14).
- Bergerud, A. T. (1978). *Status and management of caribou in British Columbia*.
- Bergerud, A. T. (1992). Rareness as an Antipredator Strategy to Reduce Predation Risk for Moose and Caribou. In D. R. McCullough, R. H. Barrett, D. R. McCullough, & R. H. Barrett (Eds.), *Wildlife 2001: Populations* (pp. 1008–1021). http://link.springer.com/10.1007/978-94-011-2868-1_77
- Bergerud, A. T., & Elliott, J. P. (1998). Wolf predation in a multiple-ungulate system in northern British Columbia. *Canadian Journal of Zoology*, 76(8), 1551–1569. <https://doi.org/10.1139/z98-083>
- Bridger, M. (2019). *South Peace caribou recovery following 5 years of experimental wolf reduction* (p. 29).
- Bridger, M. (2021a). *Wolf Reduction to Support Graham Caribou Recovery – 2-Year Assessment*.
- Bridger, M. (2021b). *Wolf Reduction to Support Pink Mountain Caribou Recovery – 3-Year Assessment* (p. 13). Ministry of Forests, Lands, Natural Resources, and Rural Development.
- Canty, A., & Ripley, B. (2022). *boot: Bootstrap R (S-Plus) Functions* (R package version 1.3-28) [R].
- Committee on the Status of Endangered Wildlife in Canada. (2014). *COSEWIC assessment and status report on the caribou, Rangifer tarandus: Northern mountain population, central mountain population, southern mountain population, in Canada*.
- Culling, D., & Culling, B. (2005). *Seasonal habitat use and movements of Graham caribou 2001 to 2003* (p. 96).
- Culling, D., & Culling, B. (2009). *Graham caribou herd 2009 late winter inventory* (p. 19).
- Culling, D., & Culling, B. (2015). *Graham caribou herd 2015 late winter inventory* (p. 36).
- Culling, D., & Culling, B. (2016). *Graham caribou herd 2016 late winter inventory*.
- Davison, A. C., & Hinkley, D. V. (1997). *Bootstrap Methods and Their Application* (Vol. 1). Cambridge University Press. <http://dx.doi.org/10.1017/CBO9780511802843>

DeCesare, N. J., Hebblewhite, M., Bradley, M., Smith, K. G., Hervieux, D., & Neufeld, L. (2012). Estimating ungulate recruitment and growth rates using age ratios. *The Journal of Wildlife Management*, 76(1), 144–153. <https://doi.org/10.1002/jwmg.244>

DeCesare, N. J., Hebblewhite, M., Lukacs, P. M., & Hervieux, D. (2016). Evaluating sources of censoring and truncation in telemetry-based survival data: Telemetry-based survival monitoring. *The Journal of Wildlife Management*, 80(1), 138–148. <https://doi.org/10.1002/jwmg.991>

Environment Canada. (2012). *Management plan for the northern mountain population of woodland caribou (Rangifer tarandus caribou) in Canada*. Environment Canada.

Environment Canada. (2014). *Recovery strategy for the woodland caribou, southern mountain population (Rangifer tarandus caribou) in Canada*. Environment Canada. <https://central.bac-lac.gc.ca/.item?id=En3-4-187-2014-eng&op=pdf&app=Library>

Government of Canada. (2020). Background on Section 11 and partnership agreements for the Southern Mountain Caribou. *Environment and Climate Change Canada*. <https://www.canada.ca/en/environment-climate-change/news/2020/02/background-on-section-11-and-partnership-agreements-for-the-southern-mountain-caribou.html>

Harper, F. (1988). *Regional wildlife plan for the Peace subregion*.

Hatter, I. W., & Bergerud, W. A. (1991). Moose recruitment adult mortality and rate of change.pdf. *Alces: A Journal Devoted to the Biology and Management of Moose*, 27, 65–73.

Krebs, C. J. (2017). *Chapter 2, Estimating Abundance and Density: Mark-Recapture Techniques* (p. 58).

Lee, A. M., Bjørkvoll, E. M., Hansen, B. B., Albon, S. D., Stien, A., Sæther, B.-E., Engen, S., Veiberg, V., Loe, L. E., & Grøtan, V. (2015). An integrated population model for a long-lived ungulate: More efficient data use with Bayesian methods. *Oikos*, 124(6), 806–816. <https://doi.org/10.1111/oik.01924>

Pelletier, A., & Watt, K. (2022). *Survey history and status of Northern Mountain Caribou populations in the Northeast region of BC* (p. 39). MBC Ministry of Forests, Lands, Natural Resource Operations and Rural Development/Ministry of Forests, Lands a.

Pollock, K. H., Winterstein, S. R., Bunck, C. M., & Curtis, P. D. (1989). Survival analysis in telemetry studies: The staggered entry design. *The Journal of Wildlife Management*, 53(1), 7. <https://doi.org/10.2307/3801296>

Resources Information Standards Committee (RISC). (2002). *Aerial-based inventory methods for selected ungulates: Bison, mountain goat, mountain sheep, moose, elk, deer and caribou : Version 2.0*. B.C. Ministry of Forests, Lands, and Natural Resource Operations and Ministry of Environment.

https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/unga_ml20_final.pdf

RStudio Team. (2019). *RStudio: Integrated Development Environment for R* (1.2.5001) [Computer software]. RStudio, Inc. <http://www.rstudio.com/>

Schaub, M., & Abadi, F. (2011). Integrated population models: A novel analysis framework for deeper insights into population dynamics. *Journal of Ornithology*, *152*(S1), 227–237.
<https://doi.org/10.1007/s10336-010-0632-7>

Serrouya, R., Seip, D. R., Hervieux, D., McLellan, B. N., McNay, R. S., Steenweg, R., Heard, D. C., Hebblewhite, M., Gillingham, M., & Boutin, S. (2019). Saving endangered species using adaptive management. *Proceedings of the National Academy of Sciences*, *116*(13), 6181–6186.
<https://doi.org/10.1073/pnas.1816923116>

Skalski, J. (2005). Estimating population sex ratios. In *Wildlife Demography: Analysis of sex, age and count data*.

Appendix A

2021 East Williston Caribou Observations

Group #	Cows	Bulls	Unknown Adults	Calves	Total
1	4	0	0	2	6
2	4	2	0	1	7
Sum	8	2	0	3	13

Calf:cow ratio: 0.38

Calf %: 23.1%

Bull:cow ratio: 0.25