Provincial Caribou Recovery Program
Herd Planning Disclaimer

The following herd plans are a result of Phase One planning and are an incomplete product. Additionally, the documents are 'living' reports and will be updated regularly as Phase Two progresses.

Phase Two planning is currently underway for some herds however still at its early stages of development; many plans reflect this as they are in different stages along their scheduled project continuum.

One of the cornerstone guiding principles to the Caribou Recovery Program (the Program) is to use consistent, fact-based approaches for all woodland caribou herds in the province. The Program has refined and adopted a new format to herd planning that will effectively:

- ❖ Provide a consistent approach to managing all woodland caribou herds in BC
- ❖ Recognize the unique circumstances of each herd
- ❖ Build from current (legacy) caribou management plans
- ❖ Consider First Nations' and stakeholder interests and ideas
- ❖ Be included in larger regional plans

Completed herd plans will describe the status of each herd, and the threats faced by that particular herd. The plans will take note of previous actions, and actions that are planned to take place in the future. As we implement the herd plans, the Program will carefully monitor to which extent and magnitude the caribou respond, and modify its actions as accordingly. Herd plans will help us document our decisions and discuss issues with First Nations and with stakeholders.

Phase One consisted of:

- ✓ Status of herd or sub-population
- ✓ Identified threats
- ✓ Literature
- ✓ Previous work completed

Phase Two will consist of input from:

- Engagement with Indigenous communities
- Provincial Caribou Science Team
- Stakeholders
- Decision-support tools

WOODLAND CARIBOU PLAN

Pink Mountain
Subpopulation

Northern Mountain Population

BRITISH COLUMBIA

Recommended Citation:

Photo credit: Doug Heard

EXECUTIVE SUMMARY

TABLE OF CONTENTS

1 BACKGROUND

1.1 INTRODUCTION TO THE PROGRAM

2 POPULATION DESCRIPTION

Pink Mountain caribou are a subpopulation of northern mountain (NM) caribou, an ecotype of woodland caribou that is listed as *Special Concern* by the *Committee on the Status of Endangered Wildlife in Canada* (COSEWIC 2014). NM caribou currently occur in 45 subpopulations that are distributed across the northwestern section of British Columbia, the southwestern part of the Northwest Territories and the southern two-thirds of the Yukon Territory with one Yukon subpopulation being trans-boundary with Alaska (COSEWIC 2014). Within COSEWIC's (2011) Designatable Units classification system, which reflects evolutionary and ecological distinctions among caribou groups, NM caribou are considered part of Designatable Unit 7. In British Columbia, mountain-living caribou are classified into "northern" and "southern mountain" ecotypes, which reflect differences in feeding ecology during winter (Stevenson and Hatler 1985). The northern ecotype, which includes all NM caribou subpopulations, occurs in mountainous areas receiving relatively low annual snowfall and primarily forages on terrestrial lichens within mature conifer forests or wind-swept alpine slopes (Seip and McLellan 2008). The southern mountain ecotype, in contrast, inhabits the interior, deep-snow mountains and forages on arboreal lichens during winter as terrestrial foods are generally unavailable. Within British Columbia, NM caribou are currently *Blue-listed* with a conservation status of S2/S3 due to sustained declines in some subpopulations, uncertainty in the population trend of others, and high threats from predation and anthropogenic disturbance (BC Conservation Data Centre 2017).

2.1 DISTRIBUTION

The Pink Mountain subpopulation is situated within the Northern Rocky Mountains in the northeastern portion of the province (Fig. 1). The subpopulation's range falls within the Northern Boreal Mountains ecoprovince and is typified by rugged alpine areas (Boreal Altai Fescue Alpine biogeoclimatic zone) and lower elevation forests (Spruce-Willow-Birch and Boreal White and Black Spruce zones; McNay 2011). The range is bounded to the north by the Prophet River, which forms the boundary with the Muskwa caribou range, and to the south by the Sikanni Chief River, which separates the Pink Mountain range from the Graham caribou range. To the west, the range is separated from the Finlay caribou range by the height of the Northern Rockies. Its eastern border is formed by the boreal forests of the Taiga and Boreal Plains ecoprovinces. Approximately 68% of the 9,583 km^2 range lies within the Muskwa-Kechika Management Area. The range encompasses Redfern-Keily Provincial Park, Pink Mountain Provincial Park, Sikanni Chief Ecological Reserve, Sikanni Chief Falls Protected Area, Prophet River Hot Springs and portions of Northern Rocky Mountains Provincial Park.

2.2 HABITAT AND BEHAVIOUR

NM caribou undergo seasonal range shifts in response to snowfall conditions affecting forage availability (Bergerud 1978, Heard and Vagt 1998). These shifts vary among subpopulations, being affected by such factors as topography, predation risk, and snow characteristics (Seip and McLellan 2008). In general, Pink Mountain caribou occur at higher elevations in late spring, summer and fall then move into lower elevation conifer forests during the winter and early spring (Gustine and Parker 2008).

Considerable variation, however, exists among individuals and among seasons. For example, in late winter, many caribou use wind-swept alpine ridges to access exposed terrestrial lichens, particularly during high snowfall years, whereas other individuals remain below treeline in the conifer forests of the eastern foothills (Wood 1996, Gustine and Parker 2008). Differing spatial strategies are also found during calving, which generally occurs from mid-May to mid-June, with many females using high elevation sites above treeline while others calve in subalpine conifer forests prior to moving to higher elevation summer ranges (Gustine and Parker 2008). Similar to the grouping behaviour of other woodland caribou, the average group size of NM caribou is highest during the rut (late September to early October) and smallest during calving (Bergerud et al. 1984, Bergerud and Page 1987).

Analyses of radio-collar data from 48 female caribou monitored between 2001 – 2004 revealed three general calving areas within the Pink Mountain range: Western High Country, North Prophet and the Foothills (Parker and Gustine 2007). The Western High Country area is characterized by high elevation (1,400 – 3,000 m), rugged mountainous terrain with little vegetative cover. The North Prophet area is at slightly lower elevation (1,200 – 2,400 m) and also characterized by rugged, high elevation mountainous terrain with little forest cover. The Foothills area (1,000 – 2,100 m elev.) is comprised of forested lower elevation mountains and valleys.

2.3 Population Size and Trend

Over the past four decades, the Pink Mountain subpopulation has had only a few punctuated periods when population size was estimated (Table 1). Bergerud (1978) reported that this subpopulation was first censused in 1968, which yielded a minimum count of 1018 caribou. The next year, another survey counted 2675 caribou, which represents the highest number recorded. Eight years later, the population appeared to undergo a significant decline as surveys in 1976 and 1978 counted only 186 and 195 caribou, respectively (Bergerud 1978). Note that Bergerud (1978) considered the distribution of Pink Mountain caribou to extend north to the Muskwa River so the area considered for these early surveys may be larger than the present-day Pink Mountain range. The Pink Mountain subpopulation was not surveyed again until the mid-1990s when minimum counts (1993: n = 626; 1994: n = 264; 1995: n = 825) were recorded from fixed-wing aircraft flying along transects between the Prophet and Halfway Rivers (Duncan 2009). Based on these counts, Heard and Vagt (1998) estimated the population size to be ~ 1300 animals in 1996. In 2007, incidental observations of caribou during a Stone's sheep (*Ovis dalli stonei*) survey recorded 226 animals. The most recent surveys, conducted in 2016 and 2017, yielded similar results with 252 and 323 caribou recorded, respectively, during March flights to estimate juvenile recruitment (BC Ministry of Forests, Lands, and Natural Resource Operations, *unpublished data*).

Juvenile recruitment and adult female survival, two demographic parameters with high influence on caribou population dynamics (DeCesare et al. 2012), have also been estimated intermittently over the past four decades (Table 2). In 1976 and 1978, Bergerud (1978) estimated that calves made up 16% of the population in late winter, estimates that slightly exceeded values associated with population stability (15%; Bergerud 1996). From 1993 – 1995, calf percentages ranged from 9 – 14% (Duncan 2009).

Recent surveys in 2016 and 2017 have recorded lower calf percentages (9-10%), which suggests a gradually declining population if concurrent female survival is lower than ~ 92%.

Estimates of adult female survival have been less frequent than juvenile recruitment. Using the juvenile recruitment data shown in Table 2, Duncan (2009) derived annual estimates of adult female survival using Bergerud's (1978) regression equation ($y = 13.8 – 0.3856x$ where x is calf recruitment). The resulting estimates varied between 90 and 92% (years estimated: 1976, 1978, 1993-1995, 2000).

In hunted populations of ungulates such as the Pink Mountain subpopulation, harvest indices such as catch-per-unit-effort and hunter success rate can give an indication of population trend. Using data from Wildlife Management Unit (WMU) 7-42, harvest indices estimated between 1976 and 2016 suggest that the population peaked in the 1990s then declined during the early 2000s (Fig. 2; see also Duncan 2009). For the last decade, harvest indices have shown a slightly increasing trend, perhaps suggesting a stable or increasing population though this inference showed be viewed cautiously given the low rates of juvenile recruitment in recent years and should be corroborated by repeated reliable estimates of population size.

In general, discerning population trend for the Pink Mountain subpopulation is difficult due to limited monitoring and potential confounds when comparing the above estimates of population size. These confounds include differences in survey design, the area surveyed and the response metric (e.g. minimum count versus sightability corrected estimates). Because of these deficiencies, COSEWIC (2014) has listed the population trend for this subpopulation as unknown.

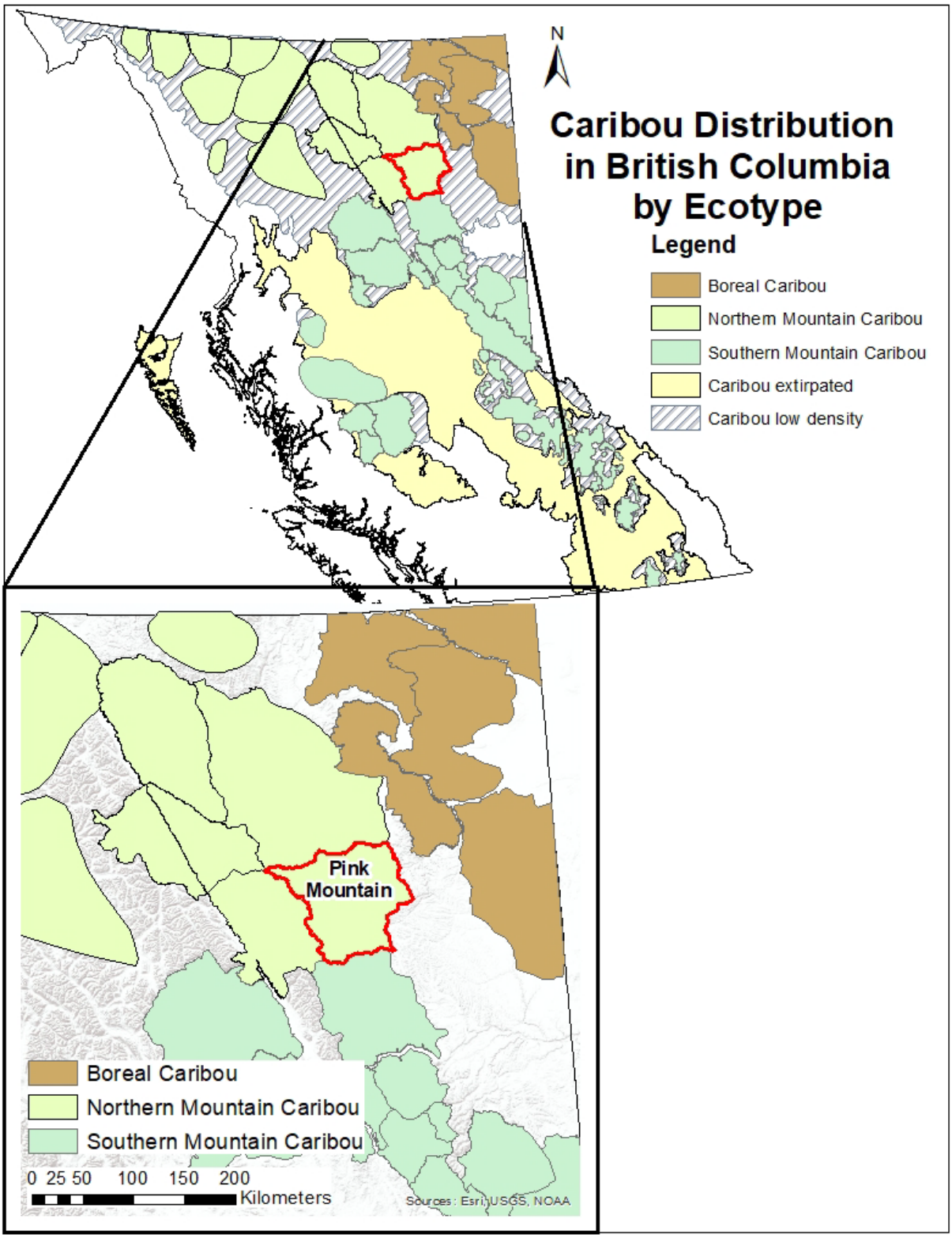

Figure 1: The geographical location of the Pink Mountain subpopulation of northern mountain caribou. The 9,583 km^2 range (inset: red outline) is situated within the Northern Rocky Mountains of northeastern British Columbia.

Table 1: Estimates of population size by year for the Pink Mountain subpopulation of northern mountain caribou in northeastern British Columbia.

Year	Estimate	Method	Survey Timing	Reference
1968	1018[1]	minimum count	winter	Bergerud 1978
1969	2675[1]	minimum count	winter	Bergerud 1978
1976	186[1]	minimum count	winter	Bergerud 1978
1978	195 (342)[1,2]	minimum count (estimate)	winter	Bergerud 1978
1993	626[3]	minimum count	winter	Duncan 2009 (BC MFLNRO, *unpublished data*)
1994	264[3]	minimum count	winter	Duncan 2009 (BC MFLNRO, *unpublished data*)
1995	825[4]	minimum count	winter	Duncan 2009 (BC MFLNRO, *unpublished data*)
1996	1300	estimate	NA	Heard and Vagt 1998
2000	850	estimate	NA	COSEWIC 2002
2007	226[5]	minimum count	winter	Duncan 2009 (BC MFLNRO, *unpublished data*)
2016	252[6]	minimum count	winter	BC MFLNRO, *unpublished data*
2017	323[6]	minimum count	winter	BC MFLNRO, *unpublished data*

[1] Survey area may have been larger than the current range boundaries for the Pink Mountain subpopulation
[2] Estimate was based on probable decline derived from estimates of caribou productivity, juvenile recruitment and harvest
[3] Minimum counts from fixed wing aircraft along transects between the Prophet and Halfway Rivers
[4] Minimum counts from fixed wing aircraft along transects and tracking radio-collared individuals
[5] Incidental observations of caribou conducted during an aerial survey to census Stone's sheep
[6] Minimum counts during March recruitment surveys where aircraft flew to radio-collared individuals

Table 2: Estimates of juvenile recruitment in the Pink Mountain subpopulation of northern mountain caribou in northeastern British Columbia. Juvenile recruitment can be expressed as the number of calves per 100 females or as the percentage of calves in the population, both estimated when calves are ~ 9 months old. Ratios exceeding 28.9 calves:100 females or calf percentages exceeding 15% are generally associated with stable or increasing populations (Bergerud 1996, Environment Canada 2008).

Year	% Calves	Survey Timing	Reference
1976	16	March	Bergerud 1978
1978	16	March	Bergerud 1978
1993	9	March	Duncan 2009 (BC MFLNRO, *unpublished data*)
1994	14	March	Duncan 2009 (BC MFLNRO, *unpublished data*)
1995	14	March	Duncan 2009 (BC MFLNRO, *unpublished data*)
2000	10	March	Duncan 2009 (BC MFLNRO, *unpublished data*)
2016	9	winter	BC MFLNRO, *unpublished data*
2017	10	March	BC MFLNRO, *unpublished data*

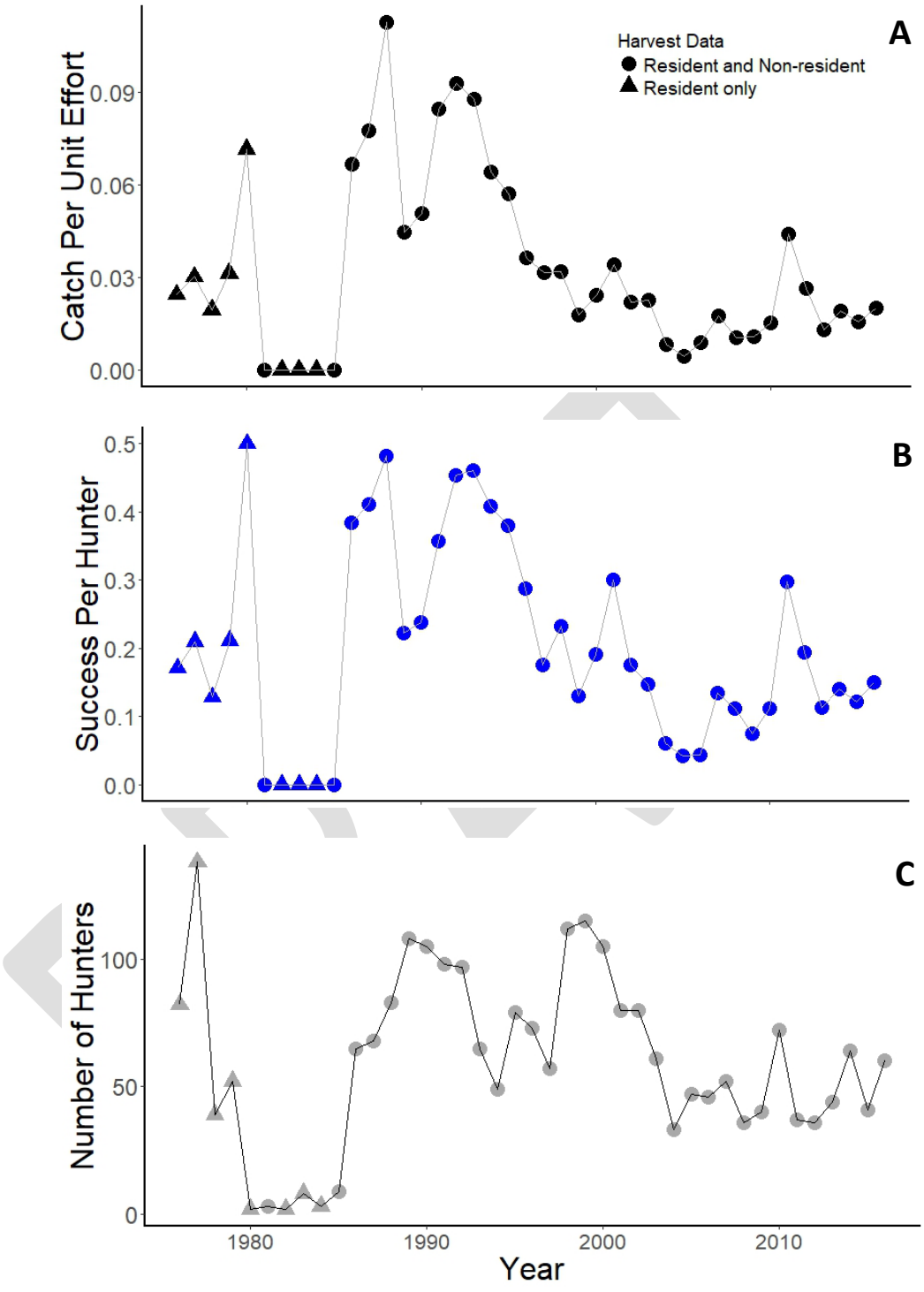

Figure 2: Harvest indices for the Pink Mountain subpopulation of northern mountain caribou in northeastern British Columbia from 1976 to 2016. Catch per unit effort (A) is the total kills divided by the total number of hunter-days. Success per hunter (B) is the total kills divided the total number of hunters. The total number of hunters (C) represents both resident and non-resident hunters.

3 THREATS AND LIMITING FACTORS

Populations of NM caribou face a variety of threats and limiting factors that may compromise their stability now and in the future. Current declines in many woodland caribou populations have been ultimately attributed to direct and indirect effects of human activities and climate change (Vors and Boyce 2009, Festa-Bianchet et al. 2011, Environment Canada 2014). These effects have resulted in lowered rates of adult female survival and/or juvenile recruitment, two demographic rates that have high influence on caribou population dynamics (DeCesare et al. 2012). For most populations, effects of human activities and climate change have led to unsustainable rates of predation (McLoughlin et al. 2003, Wittmer et al. 2005*b*, Apps et al. 2013). Compared to other ungulates, caribou are particularly vulnerable to increasing predation because they have low reproductive rates (Bergerud 2000). To reduce predation risk, caribou generally occur at low densities and have evolved to live in low productivity habitats that spatially separates them from other ungulates and their generalist predators (Bergerud 1992). Effects from human activities and climate change likely compromise this spacing strategy by changing the abundance and spatial distribution of these other ungulates and predators, increasing the likelihood of caribou-predator encounters and consequently increasing predation rates (Festa-Bianchet et al. 2011).

The federal *Management Plan* for NM caribou (Environment Canada 2012*a*) and the recent status report by COSEWIC (2014) identified a number of threats potentially affecting NM caribou subpopulations and their habitat. These threats included: predation, industrial activities, roads and other linear features, recreational activities, natural disturbances (e.g. fire), hunting, climate change and parasites and diseases. This section discusses these threats – and others – and the order of discussion does not reflect their relative importance to a specific subpopulation. Note that while threats are discussed individually, they are not mutually exclusive as they may interact and their effects on caribou population dynamics are likely cumulative (Sorensen et al. 2008, Johnson et al. 2015). Overall, the NM caribou population was recently assigned a threat impact rating of High by COSWEIC (2014).

3.1 PREDATION

Woodland caribou populations are naturally limited by predation, which results in caribou occurring at relatively low but stable densities within their range (Fuller and Keith 1981, Bergerud 1996, Bergerud and Elliott 1998). Because caribou have low rates of reproduction, their populations are sensitive to changes in predation rates. Indeed, increasing predation is the primary proximate cause of population decline in most woodland caribou herds (McLoughlin et al. 2003, Wittmer et al. 2005*b*, Apps et al. 2013). Increasing predation in these populations has been ultimately linked to human-mediated landscape disturbance and climate change, both of which alter the abundances and distributions of predators and alternate prey (Seip 1992, Latham et al. 2011*b*, Apps et al. 2013, DeMars and Boutin 2018). Hypothesized mechanisms relating increased predation to landscape alteration and climate change are detailed under *Section 3.3 Human Activities* and *Section 3.6 Climate Change*.

The effect of predation on the population dynamics of Pink Mountain caribou is not well understood although predation was found to be a major limiting factor for the adjacent Muskwa subpopulation (Bergerud and Elliott 1998). Bergerud (1978) suggested that overharvest and high predation on calves were primary factors in suspected population declines in Pink Mountain caribou during the 1970s. Support for this hypothesis relied on correlating subjective assessments of predator abundances with caribou abundance. Gustine et al. (2006) found predation to be the dominant cause of mortality in calves < 60 days old (17 out of 19 mortalities over 2 calving seasons), which is similar to other caribou ranges (Adams et al. 1995, Pinard et al. 2012), but the magnitude of predation effects on Pink Mountain population dynamics was not quantified. The dominant predators of calves were wolverine, wolves, and bears.

Predation effects on adult female survival, the other key demographic factor influencing caribou population dynamics (DeCesare et al. 2012), are also generally unknown as the few studies to date using radio-collared animals in the Pink Mountain subpopulation were not focused on assessing adult survival; therefore, mortality site investigations were not conducted to determine causes of mortality. Evidence from other woodland caribou populations, however, suggests that predation is the dominant cause of mortality in adult animals (Bergerud 1996).

3.2 FOOD LIMITATION

Spatiotemporal changes in the quality and quantity of food resources can influence the dynamics of caribou populations by directly affecting survival and reproductive rates (Parker et al. 2009). Woodland caribou are generally associated with old-growth habitats and food limitation may occur if such habitats are converted to early seral habitats (i.e. younger forest), which are avoided because of increased predation risk (Fortin et al. 2013, Serrouya et al. 2017*b*). Such avoidance behaviours may also result in caribou restricting their annual movements, leading to over-grazing of seasonal areas (Heard and Zimmerman 2017). Climate change may further affect food availability and quality; for example, an increase in rain-on-snow events may limit forage availability by increasing the probability of icing (Hansen et al. 2011).

For mountain-dwelling caribou in British Columbia, evidence to date suggests that food limitation is not a primary factor in recent declines in many populations (Wittmer et al. 2005*b*, McLellan et al. 2012). Such evidence, however, does not preclude any food limitation effect. For example, risk-sensitive foraging in highly altered landscapes may increase predation risk for caribou if such behaviour causes them to become more predictable in time and space or more clumped in their distribution (Fortin et al. 2013, DeMars et al. 2016). Food limitations may also result in smaller calves, which could have increased predation risk (Adams et al. 1995). Determining the magnitude of such food limitation effects, however, is difficult in a high predation environment because predation may occur before effects on body condition become evident (Cook and Cook 2015, Boutin and Merrill 2016).

For inferences specific to the Pink Mountain subpopulation, there have been two studies undertaken since 2000 that specifically assessed the nutritional status of mountain-dwelling caribou within and

adjacent to the Pink Mountain range. In the winters of 2001-2002 and 2002-2003, Parker and Gustine (2007) assessed nutritional status by estimating rump fat on captured animals (n = 38; see also Gustine et al. 2007), quantifying pregnancy rates and evaluating body mass of newborn calves. Their findings suggested that, at the time, Pink Mountain caribou were not nutritionally limited as all indices had values similar to other caribou populations considered to be robust. More recently, rump fat assessments were made on adult females captured during the winter of 2014-2015 in neighboring ranges (e.g. Graham; Cook and Cook 2015). Results of this study suggested that the nutritional condition of mountain-dwelling caribou was lower than caribou found further east on the boreal plains. The degree to which these lower nutritional scores affect caribou population dynamics, however, is not yet fully understood.

3.3 HUMAN ACTIVITIES

Human activities within and adjacent to caribou range are believed to be a primary driver of current declines in many populations of woodland caribou (Wittmer et al. 2007, Environment Canada 2008, Sorensen et al. 2008, Johnson et al. 2015) . Such activities can impact caribou populations through multiple mechanisms including direct habitat loss, displacement from preferred habitats (Seip et al. 2007) and indirectly increasing predation (Apps et al. 2013, DeMars and Boutin 2018). This section focuses on impacts associated with industrial activities, recreational activities and other activities such as agriculture and roads.

3.3.1 INDUSTRIAL

Industrial activities include forestry, mining, oil & gas development and clean energy.

3.3.1.1 FORESTRY

Woodland caribou are an old-growth forest dependent species (Bergerud 2000) and are therefore affected by forestry practices. Logging of old-growth forests can result in direct habitat loss and an increase in the extent of early seral (or young) forest, which can increase the abundance and alter the distribution of other ungulates (e.g. moose) and their predators, potentially leading to increased caribou predation (Serrouya et al. 2011, 2015). Cutblocks can further increase predation risk for caribou if behavioural avoidance of these areas causes caribou to become more clumped in their distribution (Schaefer and Mahoney 2007, Fortin et al. 2013).

Forestry impacts within the Pink Mountain caribou range are minimal. Using cutblock GIS data up to 2015, the few cutblocks < 20 years old that occur within the range are situated in its northeast corner and comprise < 0.05% of the range's area. The intensity of cutblocks, however, does increase outside of the range boundary, particularly to the southeast.

3.3.1.2 MINING

Impacts from mining primarily relate to direct habitat loss. The effective amount of habitat loss, however, can extend well beyond its physical footprint due to behavioural avoidance of areas surrounding mine infrastructure (Polfus et al. 2011, Johnson et al. 2015). As noted previously, impacts

that limit the spatial distribution of caribou can potentially lead to increased predation risk (Fortin et al. 2013, DeMars et al. 2016). Related infrastructure such as roads may further increase predation risk by increasing predator hunting efficiency and facilitating predator movement into caribou habitat (Latham et al. 2011*a*, DeMars and Boutin 2018).

There are currently no impacts from mining within the Pink Mountain caribou range.

3.3.1.3 Oil and Gas

Landscape alteration from oil and gas exploration and extraction can affect caribou populations through direct habitat loss and by indirectly increasing predation. As with other industrial impacts, avoidance behaviours by caribou can increase the effective extent of habitat loss (Dyer et al. 2001, Vistnes and Nellemann 2008) and limit the spatial distribution of caribou, potentially increasing predation risk (Fortin et al. 2013, DeMars et al. 2016). Oil and gas impacts may further increase predation risk by facilitating the expansion of alternate prey (e.g. white-tailed deer) into caribou range (Dawe and Boutin 2016). Linear features associated with oil and gas development may also increase predation risk by enhancing predator hunting efficiency and facilitating predator movement into caribou range (Dickie et al. 2017, DeMars and Boutin 2018; see also *Section 3.3.3.3 Linear Features* below).

Impacts from oil and gas exploration and extraction constitute the most ubiquitous form of human disturbance in northeastern British Columbia, including within the Pink Mountain caribou range (Thiessen 2009, DeMars and Boutin 2018). Such disturbances include polygonal features such as well sites and camps as well as linear disturbances such as seismic lines, pipe lines and roads. For the former, GIS data available from the BC Oil and Gas Commission up to 2016 suggests that there are > 300 active, completed or abandoned wells within the Pink Mountain range. The vast majority of these wells occur in the eastern third of the range. Linear features are the most widespread form of disturbance and their impacts are further discussed in *Section 3.3.3.3 Linear Features* below.

3.3.1.4 Clean Energy

Infrastructure related to clean energy production (e.g. hydroelectric facilities, wind power) can impact caribou populations through mechanisms similar to other industrial developments. Caribou may avoid such infrastructure with the degree of avoidance dependent on the degree of human activity (Mahoney and Schaefer 2002, Colman et al. 2013). Such avoidance can alter seasonal migration patterns (Mahoney and Schaefer 2002), which can result in negative demographic impacts (Bolger et al. 2008). Power lines associated with energy development can also increase predation risk for caribou because these features create relatively permanent early seral habitat that is favorable to other ungulates (e.g. moose, white-tailed deer) and provide movement corridors for predators (Latham et al. 2011*a*, Dickie et al. 2017*b*).

There are currently no wind power developments within the Pink Mountain caribou range; however, Aeolis Wind has identified the ridge top of Pink Mountain itself as a potential site for a wind power development (http://aeoliswind.ca/chapter-links/pink-mountain/). There are no other clean energy projects within the Pink Mountain range.

3.3.1.5 Other

There are currently no other major forms of industrial development within the Pink Mountain caribou range.

3.3.2 Recreation

Recreational activities conducted within caribou range can impact caribou populations by displacing individuals into sub-optimal habitats (Seip et al. 2007), increasing stress levels (Freeman 2008) and / or facilitating predator movement into caribou habitat (Whittington et al. 2011). This section considers impacts related to snowmobiling and backcountry skiing as well as other activities such as hiking and mountain biking.

3.3.2.1 Snowmobile

Among winter recreational activities, snowmobiling appears to have the highest impact on caribou, in part because the preferred areas for this activity often overlap with the preferred winter habitat of caribou (Simpson and Terry 2000). Snowmobiling has been shown to displace caribou from preferred areas and the intensity of displacement – both in space and time – can depend on the intensity of snowmobile use (Simpson and Terry 2000, Seip et al. 2007). Snowmobiling may further induce physiological stress, potentially affecting individual fitness and population dynamics (Freeman 2008). Compacted trails from snowmobiles may also facilitate movement of predators into winter habitats of caribou, thereby increasing predation risk (Droghini and Boutin 2017).

Because of the remoteness of the Pink Mountain range, snowmobile use is relatively light compared to other ranges of mountain-dwelling caribou further south in the province. The area with the highest snowmobile use is the Redfern Lake trail, which accesses Redfern-Keily Provincial Park from the Alaska Highway. This access trail appears to traverse areas used by Pink Mountain caribou during the winter (BC MFLNRO, *unpublished data*); however, it is unknown the degree to which snowmobile use of this trail impacts space use by caribou.

3.3.2.2 Heli-ski / Cat-ski

Heli- and cat-skiing can have similar mechanistic effects on caribou populations as snowmobiling though the degree of impacts is considered to be lower, primarily because skiing generally occurs on slopes steeper than those preferred by caribou (Simpson and Terry 2000). Also, best management practices such as skiing at least 500-m away from observed caribou may reduce caribou-skier encounters (Huebel 2012) although the lack of compliance with these practices remains an issue (L. DeGroot, *personal communication*).

There are no heli-skiing or cat-skiing companies operating within the Pink Mountain range.

3.3.2.3 Summer Recreation

Recreational activities in the snow-free seasons can also impact caribou populations. Trails associated with off-road vehicles, hiking, mountain biking and horseback riding may facilitate predator movements into summer habitats used by caribou, potentially increasing predation risk (Whittington et al. 2011).

Human presence on hiking trails may also induce physiological stress, though this response may attenuate if humans are not perceived as a predation threat (Lesmerises et al. 2017).

All of these activities occur within the Pink Mountain range though their intensity is likely low due to the remoteness of this range and the small number of developed trails. The main developed trails are those accessing and within Redfern-Keily Provincial Park.

3.3.2.4 Other

In many ranges of mountain-dwelling caribou, backcountry skiing (i.e. ski touring) has become an increasingly popular activity. Simpson and Terry (2000) rated this activity's threat to caribou as low because of its non-motorized nature. Because of the range's remoteness, ski touring impacts within the Pink Mountain are likely minimal.

3.3.3 Other

This section considers other forms of human activity potentially impacting caribou populations, including agriculture, major highways linear features and hunting.

3.3.3.1 Agriculture

Agriculture can impact caribou populations through a number of mechanisms. First, conversion of forested areas to agriculture can result in direct habitat loss and avoidance behaviours by caribou may increase the extent of loss beyond the physical footprint (Vistnes and Nellemann 2008). Second, agricultural areas are generally favourable to alternate prey (e.g. deer and elk), potentially increasing their populations and those of predators, which ultimately may increase predation rates of caribou. Third, agriculture could increase the likelihood of disease and parasite transmission among domesticated animals, alternate prey and caribou although such links have not been established within British Columbia caribou herds (Vors and Boyce 2009, Martin et al. 2011).

Agricultural impacts within the Pink Mountain caribou range are minimal, being restricted to a few small areas along the range's southeastern boundary immediately adjacent to Pink Mountain.

3.3.3.2 Major Highway Corridors

Major highways can constitute a direct source of mortality (i.e. road kill) for caribou and may further alter or impede caribou movements (Leblond et al. 2013). Although road kill of caribou is generally rare, it can become an increasingly important mortality source for small populations (Kinley and Apps 2001). With respect to movement impacts, the relative permeability of highways to caribou movement is inversely related to traffic volumes (Leblond et al. 2013) and, as such, major highways with high traffic may lead to population fragmentation (Apps and McLellan 2006).

The only major highway impacting the Pink Mountain subpopulation is the Alaska Highway, which travels in a north-south direction through the foothills located in the eastern part of the range. Estimates of seasonal space use from recently radio-collared individuals suggest that this highway transects a portion of the range that sees year-round use by Pink Mountain caribou with the highest use occurring in the winter and early spring (BC MFLNRO, *unpublished data*). Bergerud (1978) suggested that high

hunting pressure along the Alaska Highway contributed to the population decline observed during the 1970s.

3.3.3.3 Linear Features

Industrial activities within forested systems are often accompanied by the creation of linear features such as roads, railways, power lines, pipe lines and seismic lines. Such features are thought to increase predation of caribou by increasing predator hunting efficiency (McKenzie et al. 2012, Dickie et al. 2017*b*) and facilitating predator movement into caribou range (Whittington et al. 2011, DeMars and Boutin 2018). Linear features may further contribute to caribou-predator spatial overlap if such features facilitate the movement of alternate prey into caribou range (Dawe and Boutin 2016, Fisher et al. 2017). With natural resource exploration increasing in NM caribou ranges, the creation of new linear features is becoming an increasingly important management concern as such features may result in increased harvest by allowing easier human access to caribou habitat (Seip and McLellan 2008, Hegel and Russell 2013).

Linear features are the most ubiquitous form of human-caused disturbance within the Pink Mountain range (Fig. 3). The vast majority of these features are situated in the foothills of the eastern portion of the range. The high density of linear features within this area likely constitutes an increased predation risk for Pink Mountain caribou, particularly during the winter and early spring when these lower elevation areas see higher use. Note that the age, width and state of regeneration on linear features within the Pink Mountain range are largely unknown and that these attributes likely play a significant role in determining predator use of – and movement efficiency on – a given linear feature (Dickie et al. 2017*a*).

3.3.3.4 Hunting

Historical records indicate that NM caribou have long been hunted by First Nations in BC (Spalding 2000). Pink Mountain caribou also have a long history of being hunted following Euro-American settlement of the region. Guided hunting has occurred within the Pink Mountain range at least since the 1940s (Spalding 2000) and Bergerud (1978) suggested that overharvest was likely a key factor in declines of caribou numbers during the 1970s. Currently, licensed hunting for caribou is still allowed within WMUs 7-42 and 7-57, which collectively comprise ~ 80% of the Pink Mountain range. Harvest is restricted to 5-point bulls with a bag limit of one. Within British Columbia, all licensed harvest of caribou has been tracked since 1976 by compulsory inspection or hunter surveys. For a review of harvest statistics within the Pink Mountain range, see *Section 2.3 Population Size and Trend* and Figure 2 above.

3.3.3.5 Poaching

The impact of illegal hunting (i.e. poaching) is unknown but is likely small (Environment Canada 2014).

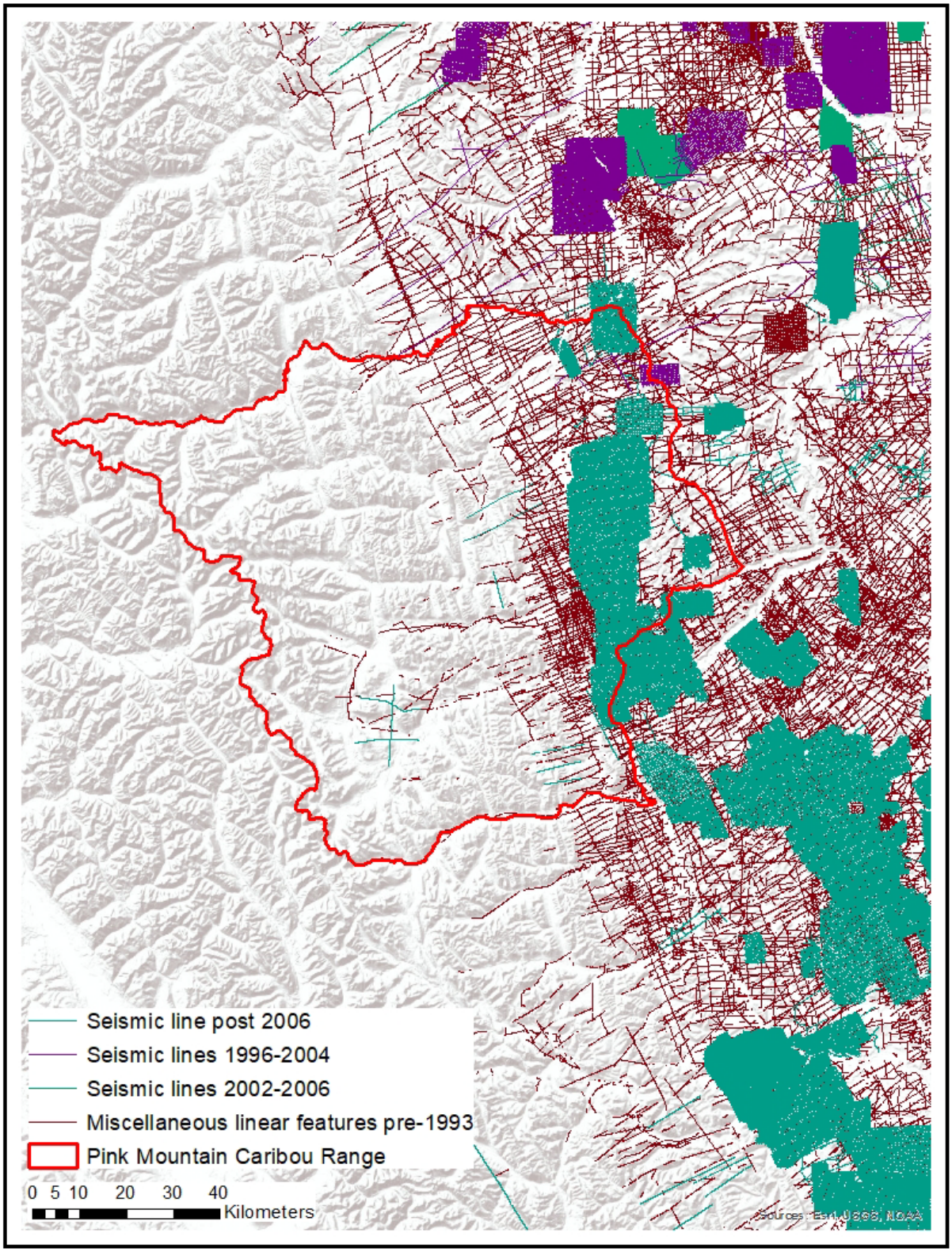

Figure 3: The distribution of seismic lines within the range of the Pink Mountain subpopulation of northern mountain caribou.

3.4 Natural Disturbance

Caribou populations are subject to impacts from a number of natural disturbances. Being dependent on old-growth forests, caribou are impacted by forest fires. Areas burned by fire may be avoided for up to 50 years (Dalerum et al. 2007) and the early seral habitat created post-fire may facilitate population increases in predators and alternate prey. Although caribou are likely adapted to the natural forest fire regime within and adjacent to their ranges, effects of forest fire may act cumulatively with human-mediated disturbances to negatively impact caribou demography (Sorensen et al. 2008). Caribou may also be affected by insect or disease outbreaks that affect forest stand condition. For example, mountain pine beetle outbreaks can highly impact old-growth pine stands, affecting lichen availability (Cichowski and Haeussler 2015, Apps and Dodd 2017) – a primary forage resource for caribou – and increasing the likelihood of fire (Lynch et al. 2006). For mountain-dwelling caribou, avalanches constitute another type of natural disturbance that can potentially impact demography, though under normal conditions their importance as a mortality should be small unless population sizes are small (Seip and Cichowski 1996, Hebblewhite et al. 2010).

Within the boreal forests of northeastern British Columbia, the median return interval for forest fires is ~ 100 years (Johnstone et al. 2010). Using forest fire data available to 2015, the extent of areas burned < 50 years ago constitutes ~ 4% of the Pink Mountain range. Within this time frame, the largest fire occurred in 2007 (5068 ha burned) and was situated in the northeastern part of the range.

The Pink Mountain range has also been affected by the mountain pine beetle epidemic with the majority of damage occurring in the lower elevation foothills situated in the eastern third of the range (https://www.for.gov.bc.ca/hre/bcmpb/year13.htm). The potential impact of beetle-damaged forests on the demography and space use of Pink Mountain caribou, however, is currently unknown.

3.5 Parasites and Diseases

Caribou can be impacted by a range of native and introduced diseases and parasites (Bergerud et al. 2008, Schwantje et al. 2014). Disease and parasite outbreaks can limit caribou populations by affecting survival and reproductive rates (Klein 1991, Albon et al. 2002) and effects of disease and parasites may interact with other limiting factors such as predation and nutrition. Threats from disease and parasites are predicted to increase with climate change (see *Section 3.6* below), particularly if spatial overlap between caribou and other ungulate species increases (Bradley et al. 2005, Kutz et al. 2005, Dobson 2009). For example, increasing expansion of white-tailed deer into caribou range may increase the prevalence of meningeal worm in caribou, a parasite that is highly pathogenic to caribou and whose usual host is white-tailed deer (Anderson 1972).

Impacts from parasites and disease on the population dynamics of Pink Mountain caribou are not well studied. In nearby ranges of boreal caribou, a three-year study documented a number of potential disease and pathogenic threats to these subpopulations, including the pathogenic bacterium *Erysipelothrix rhusiopathiae*, the protozoan parasite *Neospora caninum*, and high winter tick (*Dermacentor albipictus*) loads (Schwantje et al. 2014). Winter tick in particular was identified as an

emerging threat to caribou in the region as moderate to severe infestations were observed in all ranges, although its prevalence in NM caribou has not been explicitly assessed. In the federal *Management Plan* for NM caribou, determining the role of disease and parasites in limiting caribou populations was identified as a priority for future research (Environment Canada 2012*a*).

3.6 Climate Change

Climate change can potentially exert numerous effects on caribou population dynamics. Warmer winters may impact forage availability by increasing icing events and / or causing poor snow conditions that limit the ability of SM caribou to access arboreal lichens (Kinley et al. 2007, Hansen et al. 2011). A warming climate may also change the abundances and distribution of alternate prey and their generalist predators, potentially increasing rates of caribou predation (Latham et al. 2011*b*, Dawe and Boutin 2016). Climate change may alter the spatial and temporal distribution of insects, diseases and parasites, potentially affecting individual fitness and population dynamics (Bradley et al. 2005). Changes to the natural disturbance regime (e.g. fire interval, fire intensity, avalanche frequency) may further impact caribou through mechanisms outlined in *Section 3.4*.

Impacts of climate change on the Pink Mountain range have not been well studied. The negative impacts of the northward expansion white-tailed deer have been documented in ranges of boreal caribou (Latham et al. 2011*b*, Dawe and Boutin 2016) but whether white-tailed deer have impacted NM caribou ranges is unclear. Recent analyses using demographic data from boreal caribou subpopulations in northeast British Columbia have suggested that woodland caribou may be impacted from effects of climate change other than those related to alterations in predator-prey communities. Specifically, juvenile recruitment was negatively affected by increasing mean winter temperatures while adult female survival was positively associated with the timing of spring (i.e., later onset of spring growing conditions equated to increased survival; DeMars et al. 2017). Collectively, these relationships suggest that warmer winter temperatures and lowered snowfall may have a negative effect on caribou population dynamics. It is unknown whether the Pink Mountain subpopulation has been specifically impacted by these predicted effects of climate change.

3.7 Small Population Size Effects

Caribou subpopulations that are small and isolated may be subject to negative demographic effects that can occur as a result of their small size (Caughley 1994). Such effects include inbreeding depression, genetic isolation from population fragmentation (Serrouya et al. 2012), demographic stochasticity (e.g. all offspring produced are of one sex), environmental stochasticity (e.g. the population is extirpated by a random natural disturbance such as an avalanche; Hebblewhite et al. 2010), and Allee effects (e.g. lowered demographic performance with decreasing population size; Courchamp et al. 1999). For group-living ungulates such as caribou, McLellan et al. (2010) documented a predation-mediated Allee effect where the predation rate may increase with declining population size because group size declines at a faster rate than the number of groups in the population and the number of groups dictates the rate of caribou-predator encounters.

Currently, potential effects from small population size are likely to be minimal in the Pink Mountain subpopulation as recent demographic data suggests a minimum population size of > 300 animals (see *Section 2.3*).

4 MANAGEMENT HISTORY

Many subpopulations of NM caribou have a limited history of active management, which in part may be due to the remoteness of their ranges and a lack of baseline information. In its initial assessment of NM caribou, COSEWIC (2002) suggested that most subpopulations were stable because their habitat was remote and relatively intact. Only two subpopulations were thought to be at risk with the primary threats being altered predator-prey dynamics and increased human access. Twelve years later, a reassessment of NM caribou found two subpopulations to be increasing, seven were stable, nine were decreasing, and the statuses of the remaining 27 subpopulations were unknown due to data deficiencies (COSEWIC 2014). For subpopulations within British Columbia, one subpopulation was thought to be stable, seven were decreasing and the population trends for the remaining 15 were uncertain.

In 2012, the federal *Management Plan* for NM caribou was developed to prevent further population declines and avoid their potential listing as threatened or endangered. The *Plan* recommended a series of management actions to address the uncertainties surrounding the status of many subpopulations and to outline recovery measures for those in decline (Environment Canada 2012*a*). These actions were similar to those recommended for recovering Boreal and Southern Mountain caribou (Environment Canada 2012*b*, 2014), and broadly included the following key components:

i. Managing and protecting of sufficient habitat for caribou to carry out life history processes and reduce predation risk thereby ensuring long-term population persistence. Habitat protection generally has included access management.

ii. Managing the populations of other ungulate species.

iii. Managing of predator populations.

As a fourth key component, the *Management Plan* also recommended that NM caribou be managed for a sustainable harvest, which is unique to this population as Boreal and Southern Mountain caribou are no longer hunted.

This section reviews management actions undertaken for the Pink Mountain subpopulation under five broad categories: habitat management, recreation and access management, predator management, alternate prey management, and population reinforcement. For a review of this subpopulation's harvest history and management, see Sections *2.3 Population Size and Trend* and 3.3.3.4 *Hunting*.

4.1 HABITAT

Protecting and restoring sufficient habitat for caribou to carry out essential life processes and reduce predation risk is fundamental to achieving self-sustaining populations (Environment Canada 2014, Ray et al. 2015). NM caribou require large tracts of undisturbed habitat and have evolved to inhabit alpine

areas and old-growth forests, which separates them – both in terms of elevation and horizontal space – from other ungulates and their generalist predators (Bergerud et al. 1984, Bergerud and Page 1987, Seip 1992). In winter, NM caribou use mature forests and wind-swept alpine areas to access lichen (Johnson et al. 2004). Summer ranges are typified by alpine birch-sedge meadows (Oosenbrug and Theberge 1980, Denryter et al. 2017). Spatial requirements for NM caribou also extend beyond seasonal areas of high use (i.e. habitat cores) and can include "matrix" habitat, areas of relatively low use that may be used during migration (Environment Canada 2012*a*).

The 2012 federal *Management Plan* for NM caribou suggests that effective habitat management for each subpopulation requires delineating and protecting habitats with high influence on population dynamics (e.g. calving areas, rutting ranges, winter ranges, movement corridors). Because natural and anthropogenic disturbances are known to negatively impact habitat quality (Wittmer et al. 2007, Sorensen et al. 2008), active restoration may be required for those subpopulations residing in highly disturbed landscapes.

4.1.1 PROTECTION

Approximately 68% of the Pink Mountain caribou range lies within the Muskwa-Kechika Management Area, which is managed to maintain wilderness values. Provincial Parks and Protected Areas within the Muskwa-Kechika Management Area, which encompass 20% of the range's area, provide even stronger protections as no industrial development is permitted in these areas. The range also contains zones designated as Ungulate Winter Range (6% of range area) and Wildlife Habitat Areas (15% of range area) where logging is prohibited or severely restricted.

4.1.2 ENHANCEMENT AND RESTORATION

There has been no management actions to enhance or restore caribou habitat within the Pink Mountain range.

4.2 RECREATION AND ACCESS MANAGEMENT

The Pink Mountain caribou range is generally remote and see much lower recreational activity than caribou ranges situated in mountainous areas of southern British Columbia. Approximately 68% of the range ranges is encompassed by the Muskwa-Kechika Management Area, which restricts motorized access to specific routes (http://www.muskwa-kechika.com/management-area/access-management).

4.2.1 SNOWMOBILE

Snowmobile use within the Pink Mountain range is low compared to ranges of mountain-dwelling caribou located further south in the province (Simpson and Terry 2000, BC Ministry of Environment 2003). Within the Muskwa-Kechika Management Area, snowmobiling is restricted to designated routes. The most popular area for snowmobiling within the Pink Mountain range is the Redfern Lake trail, which accesses Redfern-Keily Provincial Park from the Alaska Highway. Outside of the Muskwa-Kechika Management Area, there are no restrictions on snowmobile activity.

4.2.2 HELI-SKI / CAT-SKI

There are no heli- or cat-ski companies operating within the Pink Mountain and thus it is not subjected to impacts from these activities.

4.2.3 SUMMER RECREATION

Due to its remoteness, the Pink Mountain range sees relatively light summer recreational use. Within the Muskwa-Kechika Management Area, motorized vehicles are restricted to a few specified access routes and some trails have weight restrictions (< 500 kg). There are no restrictions on off-road vehicle use on those parts of the range outside of the Muskwa-Kechika Management Area. Other activities in the range include backpacking, horseback riding and guide outfitting, all of which occur at a low intensity and consequently there are no restrictions on these types of recreation.

4.2.4 OTHER

There are no other restrictions on recreational activities within the Pink Mountain caribou range.

4.3 PREDATORS

Actions aimed at managing predators may include liberalizing hunting and trapping quotas (Cluff and Murray 1995), diversionary feeding (Lewis et al. 2017), managing alternate prey (Serrouya et al. 2017*c*), and lethal control (Hervieux et al. 2014). Note that actions such as lethal control are controversial (Boertje et al. 2010, Lute and Attari 2017) and are generally considered short-term strategies used to sustain small and rapidly declining populations until the effects of habitat restoration and protection are realized (Wittmer et al. 2010, Hervieux et al. 2014).

4.3.1 WOLF MANAGEMENT

Within British Columbia, active management of wolves began in the early 1900s with the introduction of a bounty program, which lasted until 1955 (BC Ministry of Forests, Lands and Natural Resource Operations 2014). Predator control programs were also initiated during the 1940s and the combined effect of these initiatives resulted in wolf populations declining to their lowest estimated numbers provincially in the late 1950s. The suppression of wolf numbers resulted in population peaks of caribou in northeastern British Columbia during the 1960s (Bergerud 1978, Spalding 2000) though the specific effects of wolf control on the Pink Mountain subpopulation is unknown.

In the late-1970s and 1980s, wolf removals were conducted in northeastern British Columbia to evaluate demographic effects on ungulate populations. Although no wolves were removed in the Pink Mountain range, 505 wolves were removed in the neighboring Muskwa range (Bergerud and Elliott 1998). It is unclear what effect these removals had on wolf populations and predator-prey dynamics within the Pink Mountain range.

There has been no other management actions directed at wolves in the context of caribou conservation within the Pink Mountain range. Currently, there is an eight month general hunting season for wolves with a bag limit of three in WMUs within and adjacent to the Pink Mountain range. In 2016, removal of the bag limit was being considered (https://www2.gov.bc.ca/assets/gov/sports-recreation-arts-and-

culture/outdoor-recreation/fishing-and-hunting/hunting/regulations/2016-2018/hunting-trapping-synopsis-2016-2018-region7b.pdf).

4.3.2 Cougar Management

Being situated at the northern edge of cougar distribution within western North America, the Pink Mountain range likely has a low density of cougars, though their population has not been explicitly enumerated. To date, cougar predation of Pink Mountain caribou has not been documented and consequently cougars have not been subject to management actions in the context of caribou conservation. The 2017 bag limit for cougars in WMUs within and adjacent to the Pink Mountain range is one.

4.3.3 Other

Within the context of caribou conservation, there have been no other management actions directed at other predators (e.g. bears or wolverine) within the Pink Mountain range.

4.4 Alternate Prey

Declines in many populations of woodland caribou have been attributed to apparent competition, an indirect interaction between two or more prey species and a shared predator (Holt 1977, DeCesare et al. 2010, Hebblewhite 2017). In this process, increased abundances of other ungulate species – stemming from an increase in favourable habitat following landscape alteration – has led to higher populations of predators, resulting in unsustainable predation of caribou. Because of these linkages, recommended strategies for recovering caribou populations includes reducing the abundances of primary prey (Wittmer et al. 2013, Serrouya et al. 2015, Boutin and Merrill 2016).

4.4.1 Moose Management

Only three of the five WMUs overlapping the Pink Mountain caribou range have been surveyed within the last five years to inventory moose. In 2012-2013, moose were surveyed in portions of WMUs 7-48 and 7-49 (7% of MU area) as part of a project to estimate moose densities in ranges of boreal caribou (McNay et al. 2013). The estimated density within the portion situated within WMUs 7-48 and 7-49 was 0.12 moose / km^2. WMU 7-49 received another survey in 2016, yielding a density of 0.14 moose / km^2 (Patterson and Smith 2016). The third WMU, 7-42, was surveyed in 2014-2015 and estimated a density of 0.26 moose / km^2 (Poole and DeMars 2015). For the other two WMUs overlapping the Pink Mountain range, Poole and DeMars (2015) estimated moose densities based on habitat capability modelling, deriving estimates of 0.15 moose / km^2 for WMU 7-57 and 0.67 moose / km^2 for WMU 7-58. For perspective, Bergerud (1996) has suggested that caribou populations will decline when moose densities exceed 0.2 – 0.3 / km^2.

To date, there has been no active management of moose in the context of caribou conservation within the Pink Mountain range. Licensed hunting for moose is restricted to bulls with a bag limit of one. The impact of First Nations hunting on moose populations is unknown.

4.4.2 Deer Management

White-tailed deer and mule deer are present within the Pink Mountain caribou range. Mule deer are more abundant (Thiessen 2008) although the northern distribution and abundance of white-tailed are likely increasing (Latham et al. 2011*b*, Dawe and Boutin 2016). A general hunting season is open for mule deer bucks (four points or larger) and white-tailed deer bucks in WMUs 7-42, 7-49, 7-57 and 7-58. The bag limit for each species is one. To date, there have been no management actions targeted toward deer in the context of caribou conservation in the Pink Mountain caribou range.

4.4.3 Other

Elk (*Cervus elaphus*) and Stone's sheep (*Ovis dalli stonei*) are also present within the Pink Mountain caribou range. For elk, there is a general hunting season in WMUs 7-42, 7-49, 7-57 and 7-58 for bulls (seasonal size restrictions apply) while WMU 7-57 also has an open season for females. For Stone's sheep, there is a general hunting season for full curl rams in WMUs 7-42 and 7-57. The bag limit for each species is one. Neither species has been subject to management actions in the context of caribou conservation.

4.5 Population Reinforcement

To bolster small populations, management actions may include population reinforcement. Such measures include maternal penning, captive breeding, and translocation. Population reinforcement techniques are generally considered to be highly invasive, logistically difficult and expensive (Hayek et al. 2016).

4.5.1 Maternal Penning

Maternal penning is a captive-rearing technique where wild female caribou are captured in late-winter and confined to a predator-proof pen within their range to give birth (Hayek et al. 2016). Females and calves are retained in the pen for at least four weeks post-parturition. The main objective of maternal penning is to increase calf survival during the neonate period when predation rates are generally highest (Adams et al. 1995, Pinard et al. 2012). To effectively improve caribou population dynamics, the success of maternal penning depends on the proportion of the female population penned, the survival of penned females and calves post-release, and the survival of wild females and calves.

Maternal penning has not been used within the Pink Mountain caribou range.

4.5.2 Captive Breeding

Captive breeding is defined by Hayek et al. (2016) as "keeping and selectively breeding caribou in captivity, usually at an ex-situ facility, over a relatively long period of time with the purpose of releasing individuals back into the wild". To date, captive breeding of caribou has not been implemented as a management tool for conserving wild caribou populations.

There have been no captive breeding efforts undertaken for the Pink Mountain subpopulation.

4.5.3 TRANSLOCATION

Translocation refers to the movement of individuals from one population (or subpopulation) to another (Hayek et al. 2016). Numerous translocation efforts for caribou have taken place across South America and are reviewed in Bergerud and Mercer (1989) and Hayek et al. (2016).

There have been no translocations of other caribou into the Pink Mountain subpopulation.

4.5.4 OTHER

There have been no other forms of population reinforcement implemented for the Pink Mountain subpopulation.

4.6 STEWARDSHIP/OUTREACH

[NO IDEA WHAT TO PUT HERE....]

4.7 RESEARCH

Most subpopulations of NM caribou are relatively little studied, perhaps because they are a lower management priority due to being less threatened than populations of boreal and southern mountain caribou (Environment Canada 2012*a*). Within British Columbia, the first research efforts aimed at evaluating NM caribou ecology and behaviour began in the late 1970s with Bergerud's (1978) surveys of various subpopulations to estimate size, juvenile recruitment and population trend. Since then, numerous studies have been conducted within NM caribou ranges, with research focusing on predator-prey dynamics (Bergerud and Elliot 1986, Bergerud and Elliott 1998, Gustine et al. 2006), estimating vital rates (Parker and Gustine 2007, McNay et al. 2014), spatial behaviours (Bergerud et al. 1984, Bergerud and Page 1987), habitat selection (Gustine and Parker 2008, Polfus et al. 2014), responses to disturbance impacts (Polfus et al. 2011), pregnancy rates (McNay et al. 2014), diet (Denryter et al. 2017) and nutritional condition (Parker and Gustine 2007). While these studies have collectively informed the broad management strategies outlined in the federal *Management Plan* for NM caribou, further herd-specific research will likely be necessary to develop effective strategies for individual subpopulations (Environment Canada 2012*a*).

There have been few studies conducted within the Pink Mountain range focusing on caribou ecology and behaviour. Bergerud (1978) reviewed early surveys of the Pink Mountain subpopulation conducted in the late-1960s and 1970s. Besides providing minimum counts, these surveys allowed Bergerud (1978) to speculate on the likely seasonal movements of Pink Mountain caribou and potential causes (overharvest and predation) of population decline during this period.

The most intensive study of the Pink Mountain subpopulation occurred from 2001 – 2004 when radio-collars were deployed on 48 adult females (all GPS collars) and 50 neonate calves (all VHF collars; Gustine et al. 2006, Parker and Gustine 2007, Gustine and Parker 2008). This study provided the first insights into seasonal space use, habitat selection, and demography of Pink Mountain caribou. With its focus on neonate survival, the study also provided novel insights into female calving behaviour and predator-prey dynamics during the calving season.

Recently, a new radio-collaring program has been initiated within the Pink Mountain range. Between March 2016 and February 2017, a total of 26 radio-collars have been deployed on adult females. Data from these animals will allow further assessment and refinement of seasonal movements, habitat selection and demography of Pink Mountain caribou.

4.8 MONITORING

Over the last 50 years, the Pink Mountain subpopulation has been infrequently surveyed to estimate population size and between these efforts has been primarily monitored by harvest statistics (Environment Canada 2012*a*). In the late-1960s, the Pink Mountain range was surveyed in two separate years to estimate the minimum number alive (Bergerud 1978). The range was surveyed again in 1976 and 1978 by Bergerud (19878). The range was not surveyed again until the 1990s when the provincial government conducted late-winter counts and estimated juvenile recruitment in 1993, 1994, 1995 and 2000 (Duncan 2009). In the early 2000s, radio-collars were deployed on female caribou and neonate calves to assess seasonal movement behaviours, habitat selection and survival rates (Gustine et al. 2006, Parker and Gustine 2007, Gustine and Parker 2008). During this period, however, surveys to estimate population size or trend were not conducted. Since 2000, the provincial government has conducted three late-winter surveys – in 2007, 2016 and 2017 – to record minimum population size and estimate recruitment. The latter two surveys have coincided with a new monitoring initiative for the Pink Mountain subpopulation, which has resulted in radio-collars being deployed on 26 females. Data from these animals should provide current demographic data that can be used to better monitor population trend and assist in future efforts to estimate population size.

5 IMPLICATIONS TO OTHER WILDLIFE

Management actions focused on conserving caribou will necessarily have impacts on other wildlife species. Caribou require landscapes where densities of other ungulates and predators are low; thus, management actions undertaken for caribou may result in population sizes of moose, deer, and wolf that are much lower than those currently experienced (Serrouya et al. 2015, 2017*c*). Reducing the populations of these species may occur from either direct management actions (e.g. lethal control) or through environmental changes (e.g. habitat restoration for caribou) that lowers the extent of suitable habitat.

Conserving caribou will likely benefit a myriad of other species co-occurring within old-growth forests. In this context, caribou may be considered an “umbrella” species (Bichet et al. 2016). Such species generally have large spatial requirements and are sensitive to environmental changes, both attributes associated with caribou. Meeting the habitat requirements of caribou will therefore result in the habitat needs of many other species also being met.

6 IMPLICATIONS TO OTHER VALUES

Enacting measures to conserve caribou will likely have impacts on social, political and economic values. Most woodland caribou populations occur in working landscapes managed for natural resource extraction. Conserving caribou in these landscapes will require limits on these activities, which will invoke socioeconomic costs (Schneider et al. 2011). Limiting recreational activities such as snowmobiling and skiing within caribou range will likely create further socioeconomic costs. To effectively mitigate these impacts while conserving caribou in multi-use landscapes, conservation planning will need to incorporate both economic costs and the biological needs of caribou in a spatially-explicit modelling framework (Schneider et al. 2011, 2012).

In many caribou ranges, reducing the current densities of other ungulate species will be fundamental to conserving caribou (Serrouya et al. 2015). Lowered populations of big-game species such as moose and white-tailed deer will result in reduced hunting opportunities. While incorporating hunters in the initial lowering of these populations can be advantageous and seen as a "win-win" (Serrouya et al. 2015), the long-term suppression of these populations will likely require support from the regional hunting community.

Caribou have evolved a life history strategy that is dependent on large landscapes of intact wilderness (Bergerud 2000). For many, such landscapes have inherent and intangible value. Intact wilderness also has economic benefits, including climate regulation, sedimentation control and nutrient cycling (Balmford et al. 2002).

Caribou conservation can also elicit ethical issues. For many small and rapidly declining populations, management actions may include direct control of predators and other ungulates (Hervieux et al. 2014). Such actions can elicit considerable controversy and, consequently, require substantial scientific support and justification for their implementation (Boertje et al. 2010).

7 PARTNERS / NEIGHBOURS

[LEAVING THIS FOR THE RELEVANT GOV FOLKS....]

Partners are bodies, currently existing or with strong future potential, that can assist in some aspect of management, such as expertise, financial contribution, in-kind support or moral support.

Neighbours are bodies within in the caribou subpopulation area that are currently not participating in caribou management that could be affected by caribou management, such as local governments, industry tenure holders, and recreation groups. These neighbours could potentially become future partners.

8 RECOMMENDED ACTIONS

In 2012, the federal *Management Plan* for NM caribou was released to outline objectives and strategies for recovering and managing subpopulations of NM caribou (Environment Canada 2012*a*). The primary

goal of the *Management Plan* was to facilitate cooperative management of NM caribou to prevent the population from becoming threatened or endangered. Inherent to the latter part of this goal is that subpopulations are maintained within their natural range of variability. To achieve this goal, the *Management Plan* outlined a number of objectives, including:

i. Evaluating and monitoring population size and trend
ii. Managing harvest for sustainable use
iii. Identifying and protecting demographically important habitats
iv. Understanding and managing predator-prey dynamics
v. Assessing health risks (e.g. parasites and disease) to caribou
vi. Evaluating disturbance impacts in a cumulative affects framework
vii. Foster multi-stakeholder stewardship and develop knowledge sharing programs

The relative importance and order of implementation of the above objectives will vary by subpopulation and will depend on such factors as current population size, population trend (stable, increasing or decreasing) and known threats. To assess progress toward management objectives, the *Management Plan* recommended that population size and trend, habitat conservation and the reduction of threats be used as performance measures.

Below, recommended management actions are outlined for the Pink Mountain subpopulation. Following the framework of the federal Management Plan, actions are grouped under three headings: Population Management, Habitat Management, and Communication and Involvement.

Recommended Actions for the Pink Mountain Subpopulation

1. *Population Management*

    - *Develop a consistent monitoring program to track population size and trend*

      The Pink Mountain subpopulation has been surveyed infrequently over the last 30 years and each survey has varied in design and search intensity, which confounds the comparison of estimates over time to evaluate trend. Going forward, population size should be estimated using a consistent survey design (see Wittmer et al. 2005*a* and Serrouya et al. 2014, 2017*a* for examples and discussion). In the absence of annual estimates of population size, trend can be monitored indirectly using Hatter and Bergerud's (1991) "R/M" equation, which estimates the population growth rate (λ) by relating annual adult female survival (S) to juvenile recruitment (R) ($\lambda = S / (1 - R)$; DeCesare et al. 2012*b*, Serrouya et al. 2017*a*). This indirect approach requires a sample of radio-collared females to estimate S and late-winter composition surveys to estimate R. An advantage to the indirect approach is that by maintaining a sample of radio-collared animals, information on mortality causes can also be collected, which can provide insights into mechanisms influencing population declines. If an indirect approach is used, period surveys (e.g. every five years) should be done, however, to validate trend estimates (Serrouya et al. 2017*a*).

    - *Manage harvest for sustainable use*

Current hunting regulations allow for a general season on 5-point bulls within the Pink Mountain range with no quota on the number of animals harvested. While harvest indices over the last decade have been relatively stable (see Section 2.3 *Population Size and Trend*), they are still lower than the peaks observed in the 1990s. Current harvest regulations should therefore be examined to assess whether harvest rates are limiting population growth.

- *Identify current limiting factors on the demography of Pink Mountain caribou*

  For the last decade, low rates of juvenile recruitment and low minimum counts (c.f. counts in the 1990s) suggest that the Pink Mountain subpopulation is in decline or limited at a relatively small population size. Understanding limiting factors should be given a high priority.

2. *Habitat Management*

   - *Identify and ensure protection of core habitat areas*

     Information on space use by Pink Mountain caribou has predominantly relied on GPS radio-collar data collected from 2001-2004 (Parker and Gustine 2007, Arnison 2016). These data were used to define Ungulate Winter Range and Wildlife Habitat Areas within the Pink Mountain range (Arnison 2016). The performance of these areas should be evaluated as new data from the recent (2016-2017) radio-collaring program becomes available.

   - *Maintain a spatial inventory of natural and anthropogenic disturbances within caribou range*

     Substantial evidence from boreal and southern mountain caribou populations demonstrates a negative relationship between caribou population growth rates and the amount of disturbance within caribou range (Environment Canada 2008, 2014). Analyses from these populations suggest that the spatial extent of buffered (500-m) disturbances should not exceed 35% of caribou range. While a substantial portion of the Pink Mountain range is under protection, industrial development is impacting the eastern part of the range.

3. *Communication and Involvement*

   - *Facilitate shared stewardship with all relevant stakeholders, including guide outfitters and First Nations*

     The Pink Mountain range has a long history of use by First Nations and incorporating traditional knowledge and perspectives should be integral to any management plan. The Pink Mountain range is also an important area for guided hunting and local outfitters should be consulted and included in management planning.

8.1 Short Term (Within 6-12 Months)

[BLANK FOR NOW]

8.2 Medium Term (Within 12-24 Months)

[BLANK FOR NOW]

8.3 Long Term (Within 24-48 Months)

[BLANK FOR NOW]

9 Literature Cited

Adams, L. G., F. J. Singer, and B. W. Dale. 1995. Caribou calf mortality in Denali National Park, Alaska. The Journal of Wildlife Management 59:584–594.

Albon, S. D., A. Stien, R. J. Irvine, R. Langvatn, E. Ropstad, and O. Halvorsen. 2002. The role of parasites in the dynamics of a reindeer population. Proceedings of the Royal Society of London B: Biological Sciences 269:1625–1632.

Anderson, R. C. 1972. The ecological relationships of meningeal worm and native cervids in North America. Journal of Wildlife Diseases 8:304–310.

Apps, C. D., and N. Dodd. 2017. Landscape response of woodland caribou to forest disturbances from beetles, logging and wildfire. BC Ministry of Forests, Lands and Natural Resource Operations, Williams Lake, BC.

Apps, C. D., and B. N. McLellan. 2006. Factors influencing the dispersion and fragmentation of endangered mountain caribou populations. Biological Conservation 130:84–97.

Apps, C. D., B. N. McLellan, T. A. Kinley, R. Serrouya, D. R. Seip, and H. U. Wittmer. 2013. Spatial factors related to mortality and population decline of endangered mountain caribou. The Journal of Wildlife Management 77:1409–1419.

Arnison, C. 2016. Pink Mountain northern caribou and Stone's sheep ungulate winter range (U-9-005) and wildlife habitat area (9-146 to 9-165 and 9-172 to 9-180) proposal rationale. BC Ministry of Forests, Lands and Natural Resource Operations, Fort St. John, BC.

Balmford, A., A. Bruner, P. Cooper, R. Costanza, S. Farber, R. E. Green, M. Jenkins, P. Jefferiss, V. Jessamy, J. Madden, K. Munro, N. Myers, S. Naeem, J. Paavola, M. Rayment, S. Rosendo, J. Roughgarden, K. Trumper, and R. K. Turner. 2002. Economic reasons for conserving wild nature. Science 297:950–953.

BC Conservation Data Centre. 2017. Conservation status report: Rangifer tarandus pop. 15. BC Ministry of Environment, Victoria, BC.

BC Ministry of Environment. 2003. Stone Mountain Provincial Park purpose statement and zoning plan. BC Ministry of Environment, Victoria, BC.

BC Ministry of Forests, Lands and Natural Resource Operations. 2014. Management plan for the grey wolf (*Canis lupus*) in British Columbia. BC Ministry of Forests, Lands and Natural Resource Operations, Victoria, BC.

Bergerud, A. T. 1978. The status and management of caribou in British Columbia. Fish and Wildlife Branch Report, BC Ministry of Environment, Victoria, BC.

Bergerud, A. T. 1992. Rareness as an antipredator strategy to reduce predation risk for moose and caribou. Page 1164 *in*. Wildlife 2001: Populations. Springer.
Bergerud, A. T. 1996. Evolving perspectives on caribou population dynamics, have we got it right yet? Rangifer 16:95–116.
Bergerud, A. T. 2000. Caribou. Pages 658–693 *in*. Ecology and management of large mammals in North America. Prentice Hall, New Jersey.
Bergerud, A. T., H. E. Butler, and D. R. Miller. 1984. Antipredator tactics of calving caribou: dispersion in mountains. Canadian Journal of Zoology 62:1566–1575.
Bergerud, A. T., and J. P. Elliot. 1986. Dynamics of caribou and wolves in northern British Columbia. Canadian Journal of Zoology 64:1515–1529.
Bergerud, A. T., and J. P. Elliott. 1998. Wolf predation in a multiple-ungulate system in northern British Columbia. Canadian Journal of Zoology 76:1551–1569.
Bergerud, A. T., S. N. Luttich, and L. Camps. 2008. The return of caribou to Ungava. McGill-Queen's University Press.
Bergerud, A. T., and W. E. Mercer. 1989. Caribou introductions in eastern North America. Wildlife Society Bulletin 17:111–120.
Bergerud, A. T., and R. E. Page. 1987. Displacement and dispersion of parturient caribou at calving as antipredator tactics. Canadian Journal of Zoology 65:1597–1606.
Bichet, O., A. Dupuch, C. Hébert, H. Le Borgne, and D. Fortin. 2016. Maintaining animal assemblages through single-species management: the case of threatened caribou in boreal forest. Ecological Applications 26:612–623.
Boertje, R. D., M. A. Keech, and T. F. Paragi. 2010. Science and values influencing predator control for Alaska moose management. The Journal of Wildlife Management 74:917–928.
Bolger, D. T., W. D. Newmark, T. A. Morrison, and D. F. Doak. 2008. The need for integrative approaches to understand and conserve migratory ungulates. Ecology Letters 11:63–77.
Boutin, S., and E. Merrill. 2016. A review of population-based management of southern mountain caribou in BC. Columbia Mountains Institute, Revelstoke, BC.
Bradley, M. J., S. J. Kutz, E. Jenkins, and T. M. O'Hara. 2005. The potential impact of climate change on infectious diseases of Arctic fauna. International Journal of Circumpolar Health 64:468–477.
Caughley, G. 1994. Directions in conservation biology. The Journal of Animal Ecology 63:215–244.
Cichowski, D., and S. Haeussler. 2015. The response of caribou terrestrial forage lichens to mountain pine beetles and forest harvesting in the East Ootsa and Entiako areas: annual report - 2012/2013 - year 11. Ministry of Forests, Lands, and Natural Resource Operations, Smithers, BC.
Cluff, H. D., and D. L. Murray. 1995. Review of wolf control methods in North America. Ecology and conservation of wolves in a changing world. CCI Press, Edmonton, AB.
Colman, J. E., S. Eftestøl, D. Tsegaye, K. Flydal, and A. Mysterud. 2013. Summer distribution of semi-domesticated reindeer relative to a new wind-power plant. European Journal of Wildlife Research 59:359–370.
Cook, J. G., and R. C. Cook. 2015. Nutritional condition of caribou in northern British Columbia, 2012-2015 and southern Northwest Territories, 2015. National Council for Air and Stream Improvement, La Grande, OR.
COSEWIC. 2002. COSEWIC assessment and update status report on the woodland caribou Rangifer tarandus caribou in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON.
COSEWIC. 2011. Designatable units for caribou (*Rangifer tarandus*) in Canada. Ottawa, ON.

COSEWIC. 2014. COSEWIC assessment and status report on the Caribou (*Rangifer tarandus*), Northern Mountain population, Central Mountain population, and Southern Mountain population in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON.

Courchamp, F., T. Clutton-Brock, and B. Grenfell. 1999. Inverse density dependence and the Allee effect. Trends in Ecology & Evolution 14:405–410.

Dalerum, F., S. Boutin, and J. S. Dunford. 2007. Wildfire effects on home range size and fidelity of boreal caribou in Alberta, Canada. Canadian Journal of Zoology 85:26–32.

Dawe, K. L., and S. Boutin. 2016. Climate change is the primary driver of white-tailed deer (*Odocoileus virginianus*) range expansion at the northern extent of its range; land use is secondary. Ecology and Evolution 6:6435–6451.

DeCesare, N. J., M. Hebblewhite, M. Bradley, K. G. Smith, D. Hervieux, and L. Neufeld. 2012. Estimating ungulate recruitment and growth rates using age ratios. The Journal of Wildlife Management 76:144–153.

DeCesare, N. J., M. Hebblewhite, H. S. Robinson, and M. Musiani. 2010. Endangered, apparently: the role of apparent competition in endangered species conservation. Animal Conservation 13:353–362.

DeMars, C. A., and S. Boutin. 2018. Nowhere to hide: Effects of linear features on predator-prey dynamics in a large mammal system. Journal of Animal Ecology 87:274–284.

DeMars, C. A., G. A. Breed, J. R. Potts, and S. Boutin. 2016. Spatial patterning of prey at reproduction to reduce predation risk: what drives dispersion from groups? The American Naturalist 187:678–687.

DeMars, C., R. Serrouya, S. Gilbert, A. Kelly, N. C. Larter, and S. Boutin. 2017. The influence of climate on the demography of woodland caribou. BC Oil and Gas Research and Innovation Society, Victoria, BC.

Denryter, K. A., R. C. Cook, J. G. Cook, and K. L. Parker. 2017. Straight from the caribou's (*Rangifer tarandus*) mouth: detailed observations of tame caribou reveal new insights into summer–autumn diets. Canadian Journal of Zoology 95:81–94.

Dickie, M., R. Serrouya, C. DeMars, J. Cranston, and S. Boutin. 2017*a*. Evaluating functional recovery of habitat for threatened woodland caribou. Ecosphere 8:e01936.

Dickie, M., R. Serrouya, R. S. McNay, and S. Boutin. 2017*b*. Faster and farther: wolf movement on linear features and implications for hunting behaviour. Journal of Applied Ecology 54:253–263.

Dobson, D. 2009. Climate variability, global change, immunity, and the dynamics of infectious diseases. Ecology 90:920–927.

Droghini, A., and S. Boutin. 2017. Snow conditions influence grey wolf (*Canis lupus*) travel paths: the effect of human-created linear features. Canadian Journal of Zoology.

Duncan, S. 2009. Northern mountain caribou population dynamics: Peace River region. University of Victoria, Victoria, BC.

Dyer, S. J., J. P. O'Neill, S. M. Wasel, and S. Boutin. 2001. Avoidance of industrial development by woodland caribou. Journal of Wildlife Management 65:531–542.

Environment Canada. 2008. Scientific review for the identification of critical habitat for woodland caribou (*Rangifer tarandus caribou*), boreal population, in Canada. Ottawa, ON.

Environment Canada. 2012*a*. Management plan for the northern mountain population of woodland caribou (*Rangifer tarandus caribou*) in Canada. Species at Risk Act Management Plan Series, Environment Canada, Ottawa, ON.

Environment Canada. 2012*b*. Recovery strategy for the woodland caribou *(Rangifer tarandus caribou*), boreal population, in Canada. Species at Risk Act Recovery Strategy, Environment Canada, Ottawa, ON.

Environment Canada. 2014. Recovery strategy for the woodland caribou, southern mountain population (*Rangifer tarandus caribou*) in Canada. Species at Risk Act Recovery Strategy Series, Environment Canada, Ottawa, ON.

Festa-Bianchet, M., J. C. Ray, S. Boutin, S. D. Côté, and A. Gunn. 2011. Conservation of caribou (*Rangifer tarandus*) in Canada: an uncertain future. Canadian Journal of Zoology 89:419–434.

Fisher, J. T., A. C. Burton, L. Nolan, M. Hiltz, and L. D. Roy. 2017. White-tailed deer distribution, density, and habitat selection in the northeast boreal forest. Alberta Innovates-Technology Futures, Vegreville, Alberta.

Fortin, D., P.-L. Buono, A. Fortin, N. Courbin, C. Tye Gingras, P. R. Moorcroft, R. Courtois, and C. Dussault. 2013. Movement responses of caribou to human-induced habitat edges lead to their aggregation near anthropogenic features. The American Naturalist 181:827–836.

Freeman, N. 2008. Motorized backcountry recreation and stress response in mountain caribou (*Rangifer tarandus caribou*). M.Sc. thesis, University of British Columbia, Vancouver, BC.

Fuller, T. K., and L. B. Keith. 1981. Woodland caribou population dynamics in northeastern Alberta. The Journal of Wildlife Management 197–213.

Gustine, D. D., and K. L. Parker. 2008. Variation in the seasonal selection of resources by woodland caribou in northern British Columbia. Canadian Journal of Zoology 86:812–825.

Gustine, D. D., K. L. Parker, and D. C. Heard. 2007. Using ultrasound measurements of rump fat to assess nutritional condition of woodland caribou in northern British Columbia, Canada. Rangifer 27:249–256.

Gustine, D. D., K. L. Parker, R. J. Lay, M. P. Gillingham, and D. C. Heard. 2006. Calf survival of woodland caribou in a multi-predator ecosystem. Wildlife Monographs 165:1–32.

Hansen, B. B., R. Aanes, I. Herfindal, J. Kohler, and B.-E. Sæther. 2011. Climate, icing, and wild arctic reindeer: past relationships and future prospects. Ecology 92:1917–1923.

Hatter, I. W., and W. A. Bergerud. 1991. Moose recruitment, adult mortality, and rate of change. Alces 27:65–73.

Hayek, T., M. R. Stanley Price, J. G. Ewen, N. Lloyd, A. Saxena, and A. Moehrenschlager. 2016. An exploration of conservation breeding and translocation tools to improve the conservation status of boreal caribou populations in western Canada. Centre for Conservation Research, Calgary Zoological Society, Calgary, AB.

Heard, D. C., and K. L. Vagt. 1998. Caribou in British Columbia: a 1996 status report. Rangifer 18:117–123.

Heard, D., and K. Zimmerman. 2017. Supplemental feeding of Kennedy Siding caribou, September 2016 to January 2017. Peace Northern Caribou Program, Vancouver, BC.

Hebblewhite, M. 2017. Billion dollar boreal woodland caribou and the biodiversity impacts of the global oil and gas industry. Biological Conservation 206:102–111.

Hebblewhite, M., C. White, and M. Musiani. 2010. Revisiting extinction in National Parks: Mountain caribou in Banff. Conservation Biology 24:341–344.

Hegel, T. M., and K. Russell. 2013. Status of northern mountain caribou (Rangifer tarandus caribou) in Yukon, Canada. Rangifer 33:59–70.

Hervieux, D., M. Hebblewhite, D. Stepnisky, M. Bacon, and S. Boutin. 2014. Managing wolves (*Canis lupus*) to recover threatened woodland caribou (*Rangifer tarandus caribou*) in Alberta. Canadian Journal of Zoology 92:1029–1037.

Holt, R. D. 1977. Predation, apparent competition, and the structure of prey communities. Theoretical Population Biology 12:197–229.

Huebel, K. 2012. Assessing the impact of heli-skiing on the behaviour and spatial distribution of mountain caribou (*Rangifer tarandus caribou*). M.Sc. thesis, Thompson Rivers University, Kamloops, BC.

Johnson, C. J., L. P. W. Ehlers, and D. R. Seip. 2015. Witnessing extinction – Cumulative impacts across landscapes and the future loss of an evolutionarily significant unit of woodland caribou in Canada. Biological Conservation 186:176–186.

Johnson, C. J., K. L. Parker, D. C. Heard, and D. S. Seip. 2004. Movements, foraging habits, and habitat use strategies of northern woodland caribou during winter: Implications for forest practices in British Columbia. Journal of Ecosystems and Management 5.

Johnstone, J. F., F. S. Chapin, T. N. Hollingsworth, M. C. Mack, V. Romanovsky, and M. Turetsky. 2010. Fire, climate change, and forest resilience in interior Alaska. Canadian Journal of Forest Research 40:1302–1312.

Kinley, T. A., and C. D. Apps. 2001. Mortality patterns in a subpopulation of endangered mountain caribou. Wildlife Society Bulletin 158–164.

Kinley, T. A., T. Goward, B. N. McLellan, and R. Serrouya. 2007. The influence of variable snowpacks on habitat use by mountain caribou. Rangifer 27:93–102.

Klein, D. R. 1991. Limiting factors in caribou population ecology. Rangifer 11:30–35.

Kutz, S. J., E. P. Hoberg, L. Polley, and E. J. Jenkins. 2005. Global warming is changing the dynamics of Arctic host-parasite systems. Proceedings of the Royal Society B: Biological Sciences 272:2571–2576.

Latham, A. D. M., M. C. Latham, M. S. Boyce, and S. Boutin. 2011*a*. Movement responses by wolves to industrial linear features and their effect on woodland caribou in northeastern Alberta. Ecological Applications 21:2854–2865.

Latham, A. D. M., M. C. Latham, N. A. McCutchen, and S. Boutin. 2011*b*. Invading white-tailed deer change wolf-caribou dynamics in northeastern Alberta. The Journal of Wildlife Management 75:204–212.

Leblond, M., C. Dussault, and J.-P. Ouellet. 2013. Avoidance of roads by large herbivores and its relation to disturbance intensity: Avoidance of roads and disturbance intensity. Journal of Zoology 289:32–40.

Lesmerises, F., C. J. Johnson, and M.-H. St-Laurent. 2017. Refuge or predation risk? Alternate ways to perceive hiker disturbance based on maternal state of female caribou. Ecology and Evolution 7:845–854.

Lewis, K. P., S. E. Gullage, D. A. Fifield, D. H. Jennings, and S. P. Mahoney. 2017. Manipulations of black bear and coyote affect caribou calf survival. The Journal of Wildlife Management 81:122–132.

Lute, M. L., and S. Z. Attari. 2017. Public preferences for species conservation: choosing between lethal control, habitat protection and no action. Environmental Conservation 44:139–147.

Lynch, H. J., R. A. Renkin, R. L. Crabtree, and P. R. Moorcroft. 2006. The influence of previous mountain pine beetle (*Dendroctonus ponderosae*) activity on the 1988 Yellowstone fires. Ecosystems 9:1318–1327.

Mahoney, S. P., and J. A. Schaefer. 2002. Hydroelectric development and the disruption of migration in caribou. Biological Conservation 107:147–153.

Martin, C., P.-P. Pastoret, B. Brochier, M.-F. Humblet, and C. Saegerman. 2011. A survey of the transmission of infectious diseases/infections between wild and domestic ungulates in Europe. Veterinary Research 42:70.

McKenzie, H. W., E. H. Merrill, R. J. Spiteri, and M. A. Lewis. 2012. How linear features alter predator movement and the functional response. Interface Focus 2:205–216.

McLellan, B. N., R. Serrouya, H. U. Wittmer, and S. Boutin. 2010. Predator-mediated Allee effects in multi-prey systems. Ecology 91:286–292.

McLellan, M. L., R. Serrouya, B. N. McLellan, K. Furk, D. C. Heard, and H. U. Wittmer. 2012. Implications of body condition on the unsustainable predation rates of endangered mountain caribou. Oecologia 169:853–860.

McLoughlin, P. D., E. Dzus, B. O. B. Wynes, and S. Boutin. 2003. Declines in populations of woodland caribou. The Journal of Wildlife Management 67:755–761.

McNay, R. S. 2011. Silviculture options for use in ranges designated for the conservation of northern caribou in British Columbia. Journal of Ecosystems and Management 12.

McNay, R. S., L. Giguere, and V. Brumovsky. 2014. Identification of designated areas for Liard Plateau woodland caribou (*Rangifer tarandus caribou*) in British Columbia. Wildlife Infometrics Inc. Report, Wildlife Infometrics Inc., Mackenzie, BC.

McNay, S., D. Webster, and G. Sutherland. 2013. Aerial moose survey in north east BC 2013. Research and Effectiveness Monitoring Board, Victoria, BC.

Oosenbrug, S. M., and J. B. Theberge. 1980. Altitudinal movements and summer habitat preferences of woodland caribou in the Kluane Ranges, Yukon Territory. Arctic 33:59–72.

Parker, K. L., P. S. Barboza, and M. P. Gillingham. 2009. Nutrition integrates environmental responses of ungulates. Functional Ecology 23:57–69.

Parker, K. L., and D. D. Gustine. 2007. Winter habitat selection and calving strategies of woodland caribou in the Besa-Prophet. University of Northern British Columbia, Prince George, BC.

Patterson, A., and V. Smith. 2016. Winter moose survey in Management Unit 7-49, 2016. Environmental Dynamics Inc., Prince George, BC.

Pinard, V., C. Dussault, J.-P. Ouellet, D. Fortin, and R. Courtois. 2012. Calving rate, calf survival rate, and habitat selection of forest-dwelling caribou in a highly managed landscape. The Journal of Wildlife Management 76:189–199.

Polfus, J. L., M. Hebblewhite, and K. Heinemeyer. 2011. Identifying indirect habitat loss and avoidance of human infrastructure by northern mountain woodland caribou. Biological Conservation 144:2637–2646.

Polfus, J. L., K. Heinemeyer, M. Hebblewhite, and Taku River Tlingit First Nation. 2014. Comparing traditional ecological knowledge and western science woodland caribou habitat models. The Journal of Wildlife Management 78:112–121.

Poole, K. G., and C. A. DeMars. 2015. Review of moose management in the Peace Region of British Columbia. BC Ministry of Forests, Lands and Natural Resource Operations, Fort St. John, BC.

Ray, J. C., D. B. Cichowski, M.-H. St-Laurent, C. J. Johnson, S. D. Petersen, and I. D. Thompson. 2015. Conservation status of caribou in the western mountains of Canada: Protections under the species at risk act, 2002-2014. Rangifer 35:49.

Schaefer, J. A., and S. P. Mahoney. 2007. Effects of progressive clearcut logging on Newfoundland caribou. Journal of Wildlife Management 71:1753–1757.

Schneider, R. R., G. Hauer, K. Dawe, W. Adamowicz, and S. Boutin. 2012. Selection of reserves for woodland caribou using an optimization approach. PLoS ONE 7:e31672.

Schneider, R. R., G. Hauer, D. Farr, W. L. Adamowicz, and S. Boutin. 2011. Achieving conservation when opportunity costs are high: optimizing reserve design in Alberta's oil sands region. PLoS ONE 6:e23254.

Schwantje, H., B. J. Macbeth, S. Kutz, and B. Elkin. 2014. British Columbia boreal caribou health program progress report: year 1 (November 1, 2013 - December 31, 2014). Science, Community and Environmental Knowledge fund, Victoria, BC.

Seip, D., and B. McLellan. 2008. Mountain caribou. Pages 240–255 *in*. Caribou and the north: A shared future. Dundurn Press, Toronto, ON.

Seip, D. R. 1992. Factors limiting woodland caribou populations and their interrelationships with wolves and moose in southeastern British Columbia. Canadian Journal of Zoology 70:1494–1503.

Seip, D. R., and D. B. Cichowski. 1996. Population ecology of caribou in British Columbia. Rangifer 16:73–80.

Seip, D. R., C. J. Johnson, and G. S. Watts. 2007. Displacement of mountain caribou from winter habitat by snowmobiles. Journal of Wildlife Management 71:1539–1544.

Serrouya, R., K. Furk, and C. Legebokow. 2014. Census of the Columbia North mountain caribou subpopulation, March 2014. BC Ministry of Forests, Lands and Natural Resource Operations.

Serrouya, R., S. Gilbert, R. S. McNay, B. N. McLellan, D. C. Heard, D. R. Seip, and S. Boutin. 2017*a*. Comparing population growth rates between census and recruitment-mortality models: Population Growth Rates. The Journal of Wildlife Management 81:297–305.

Serrouya, R., A. Kellner, G. Pavan, D. W. Lewis, C. A. DeMars, and B. N. McLellan. 2017*b*. Time vs. distance: Alternate metrics of animal resource selection provide opposing inference. Ecosphere 8.

Serrouya, R., B. N. McLellan, S. Boutin, D. R. Seip, and S. E. Nielsen. 2011. Developing a population target for an overabundant ungulate for ecosystem restoration: Restoring a predator-prey system. Journal of Applied Ecology 48:935–942.

Serrouya, R., B. N. McLellan, H. van Oort, G. Mowat, and S. Boutin. 2017*c*. Experimental moose reduction lowers wolf density and stops decline of endangered caribou. PeerJ 5:e3736.

Serrouya, R., D. Paetkau, B. N. McLellan, S. Boutin, M. Campbell, and D. A. Jenkins. 2012. Population size and major valleys explain microsatellite variation better than taxonomic units for caribou in western Canada. Molecular Ecology 21:2588–2601.

Serrouya, R., M. J. Wittmann, B. N. McLellan, H. U. Wittmer, and S. Boutin. 2015. Using predator-prey theory to predict outcomes of broadscale experiments to reduce apparent competition. The American Naturalist 185:665–679.

Simpson, K., and E. Terry. 2000. Impacts of backcountry recreation activities on mountain caribou: management concerns, interim management guidelines and research needs. BC Ministry of Environment, Lands, and Parks, Wildlife Branch, Victoria, B.C.

Sorensen, T., P. D. McLoughlin, D. Hervieux, E. Dzus, J. Nolan, B. Wynes, and S. Boutin. 2008. Determining sustainable levels of cumulative effects for boreal caribou. Journal of Wildlife Management 72:900–905.

Spalding, D. J. 2000. The early history of woodland caribou (*Rangifer tarandus caribou*) in British Columbia. Wildlife bulletin no. B-100, British Columbia, Ministry of Environment, Lands, and Parks, Wildlife Branch, Victoria, BC.

Stevenson, S. K., and D. F. Hatler. 1985. Woodland caribou and their habitat in southern and central British Columbia. Land management report no. 23, Information Services Branch, Ministry of Forests : Available from the Queen's Printer Publications, Victoria, B.C.

Thiessen, C. 2008. March 2007 Stone's sheep inventory Region 7B. BC Ministry of Environment, Fort St. John, BC.

Thiessen, C. 2009. Peace region boreal caribou monitoring: annual report 2008-09. British Columbia Ministry of Environment, Fort St. John, BC.

Vistnes, I., and C. Nellemann. 2008. The matter of spatial and temporal scales: a review of reindeer and caribou response to human activity. Polar Biology 31:399–407.

Vors, L. S., and M. S. Boyce. 2009. Global declines of caribou and reindeer. Global Change Biology 15:2626–2633.

Whittington, J., M. Hebblewhite, N. J. DeCesare, L. Neufeld, M. Bradley, J. Wilmshurst, and M. Musiani. 2011. Caribou encounters with wolves increase near roads and trails: a time-to-event approach. Journal of Applied Ecology 48:1535–1542.

Wittmer, H. U., R. N. M. Ahrens, and B. N. McLellan. 2010. Viability of mountain caribou in British Columbia, Canada: Effects of habitat change and population density. Biological Conservation 143:86–93.

Wittmer, H. U., B. N. McLellan, D. R. Seip, J. A. Young, T. A. Kinley, G. S. Watts, and D. Hamilton. 2005*a*. Population dynamics of the endangered mountain ecotype of woodland caribou (*Rangifer tarandus caribou*) in British Columbia, Canada. Canadian Journal of Zoology 83:407–418.

Wittmer, H. U., B. N. Mclellan, R. Serrouya, and C. D. Apps. 2007. Changes in landscape composition influence the decline of a threatened woodland caribou population. Journal of Animal Ecology 76:568–579.

Wittmer, H. U., R. Serrouya, L. M. Elbroch, and A. J. Marshall. 2013. Conservation strategies for species affected by apparent competition. Conservation Biology 27:254–260.

Wittmer, H. U., A. R. E. Sinclair, and B. N. McLellan. 2005*b*. The role of predation in the decline and extirpation of woodland caribou. Oecologia 144:257–267.

Wood, M. D. 1996. Seasonal habitat use and movements of woodland caribou in the Omineca Mountains, north central British Columbia, 1991-1993. Rangifer 365–378.