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

Rabbit
Subpopulation

Northern Mountain Population

BRITISH COLUMBIA

Recommended Citation:

Photo credit: Doug Heard

EXECUTIVE SUMMARY

TABLE OF CONTENTS

Executive Summary ii
1 Background 1
1.1 Introduction to the Program 1
2 Population Description 2
2.1 Distribution 2
2.2 Habitat and Behaviour 2
2.3 Population Size and Trend 2
3 Threats and Limiting Factors 9
3.1 Predation 9
3.2 Food Limitation 9
3.3 Human Activities 10
3.3.1 Industrial 11
3.3.1.1 Forestry 11
3.3.1.2 Mining 11
3.3.1.3 Oil and Gas 11
3.3.1.4 Clean Energy 12
3.3.1.5 Other 12
3.3.2 Recreation 12
3.3.2.1 Snowmobile 13
3.3.2.2 Heli-ski / Cat-ski 13
3.3.2.3 Summer Recreation 13
3.3.2.4 Other 13
3.3.3 Other 14
3.3.3.1 Agriculture 14
3.3.3.2 Major Highway Corridors 14
3.3.3.3 Linear Features 14
3.3.3.4 Hunting 14
3.3.3.5 Poaching 15
3.4 Natural Disturbance 16

3.5 Parasites and Diseases 16
3.6 Climate Change 16
3.7 Small Population Size Effects 17
4 Management History 17
4.1 Habitat 18
4.1.1 Protection 18
4.1.2 Enhancement and Restoration 19
4.1.3 Access Management 19
4.2 Predators 20
4.2.1 Wolf Management 20
4.2.2 Cougar Management 20
4.2.3 Other 21
4.3 Alternate Prey 21
4.3.1 Moose Management 21
4.3.2 Deer Management 21
4.3.3 Other 22
4.4 Population Reinforcement 22
4.4.1 Maternal Penning 22
4.4.2 Captive Breeding 22
4.4.3 Translocation 23
4.4.4 Other 23
4.5 Stewardship/Outreach 23
4.6 Research 23
4.7 Monitoring 24
5 Implications to Other Wildlife 24
6 Implications to Other Values 24
7 Partners / Neighbours 25
8 Recommended Actions 25
8.1 Short Term (Within 6-12 Months) 27
8.2 Medium Term (Within 12-24 Months) 27
8.3 Long Term (Within 24-48 Months) 27

9 Literature Cited ... 28

1 BACKGROUND

1.1 INTRODUCTION TO THE PROGRAM

2 POPULATION DESCRIPTION

Rabbit 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 Rabbit subpopulation is situated on the western slopes of the Northern Rocky Mountains in the north-central portion of the province (Fig. 1). The subpopulation's range, which encompasses 11,791 km^2, 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 west and north-west by the Kechika River and to the north-east by the Liard River. To the south and south-west, the range is separated from the Gataga caribou range by the Gataga River. To the east, the height of land within the Rocky Mountains separates the Rabbit range from the Muskwa caribou range. The Rabbit range lies almost entirely within the Muskwa-Kechika Management Area. The range also encompasses Portage Brule Rapids Protected Area, Hornline Creek Provincial Park and portions of Muncho Lake, Denetiah, and Dune Za Keyih Provincial Parks.

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). To date, there have been no radio-collaring studies conducted within the Rabbit range and consequently little is known about the seasonal behaviour of caribou in this area (Cichowski 2015). In the adjacent Muskwa range, caribou generally occur at higher elevations in late spring, summer and fall

then move into lower elevation conifer forests during the winter and early spring (Radcliffe 2000, 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 (Wood 1996). This behaviour appears to adopted by at least a portion of the Rabbit subpopulation as caribou were observed using wind-swept alpine ridges during a late-winter survey for Stone's sheep (*Ovis dalli stonei*; Thiessen 2008, Cichowski 2015).

Differing spatial strategies are also found during calving with many females using high elevation sites above treeline while others calve in subalpine conifer forests prior to moving to higher elevation summer ranges (Wood 1996, Radcliffe 2000, Gustine and Parker 2008). Calving generally occurs from mid-May to mid-June (Radcliffe 2000). 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).

2.3 Population Size and Trend

Over the past four decades, the Rabbit subpopulation has had very few surveys to estimate population size (Table 1). In 1965, a minimum count of the Rabbit River herd, which is encompassed by the current boundaries of the Rabbit range, recorded 423 animals (Bergerud 1978). In the late 1970s, Bergerud (1978) surveyed the Rabbit River and Muncho Lake herds and estimated their combined population to be 225-269 caribou (see also Duncan 2009). While both of these herds fall within the Rabbit range, it is unknown how the areal extent of Bergerud's (1978) survey compares to the areal extent of the current range.

Since Bergerud's (1978) survey, information on the population size of the Rabbit subpopulation has relied on expert opinion or incidental counts from aerial surveys focused on other ungulate species. In 1996, 354 caribou were observed during an aerial survey of Wildlife Management Unit (WMU) 7-51 to census mountain goats (*Oreamnos americanus*; Duncan 2009). During this same period, expert opinion estimated the population size to be 800 animals (Heard and Vagt 1998). The next – and last – minimum count occurred in 2007 when 1133 caribou were observed during an aerial survey of WMU 7-51 for Stone's sheep (Duncan 2009). Note that WMU 7-51 encompasses the entirety of the Rabbit range but also includes parts of the Gataga and Muskwa caribou ranges, which limits interpretation of these minimum counts as an index of the true size of the Rabbit subpopulation. Interpretation of these minimum counts is further confounded because the surveys were focused on other ungulates (mountain goats and Stone's sheep) and conducted in alpine areas, which may exclude a portion of the Rabbit subpopulation that may occur below treeline. In the 2014 COSEWIC status report for NM caribou, the size of the Rabbit subpopulation is listed as 1095 (COSEWIC 2014).

Estimates of juvenile recruitment and adult female survival, two demographic parameters with high influence on caribou population dynamics (DeCesare et al. 2012), are also rare for the Rabbit subpopulation. In 1978, Bergerud (1978) estimated the percentage of calves in the population to be 2-

6% for the Rabbit River herd and 11% for the Muncho Lake herd. Both of these estimates were below values associated with population stability (15%; Bergerud 1996), suggesting a declining population. Duncan (2009) used the incidental observation data from the 1996 mountain goat survey and the 2007 Stone's sheep survey to estimate that calves were 18% of the population in 1996 and 14% in 2007. Duncan (2009) also used composition data from the 2007 survey and Bergerud's (1978) regression formula to estimate an annual adult mortality rate of 8.4% (survival = 91.6%).

In hunted populations of ungulates such as the Rabbit subpopulation, harvest indices such as catch-per-unit-effort (CPUE) and hunter success rate can give an indication of population trend. Using data from WMU 7-51, CPUE and success rates have shown a gradually decreasing trend since the late 1990s (Fig. 2), suggesting a declining population though these statistics include caribou harvested in portions of the Muskwa and Gataga ranges. Duncan (2009) used harvest location data to partition caribou kills among the three ranges occurring within WMU 7-51 and this analysis suggested that harvest indices for the Rabbit subpopulation were not declining as rapidly as those estimated for the other two ranges, at least up until 2006.

In general, discerning population trend for the Rabbit subpopulation is difficult due to limited estimates of population size and demographic data. Because of these deficiencies, COSEWIC (2014) has listed the population trend for this subpopulation as unknown.

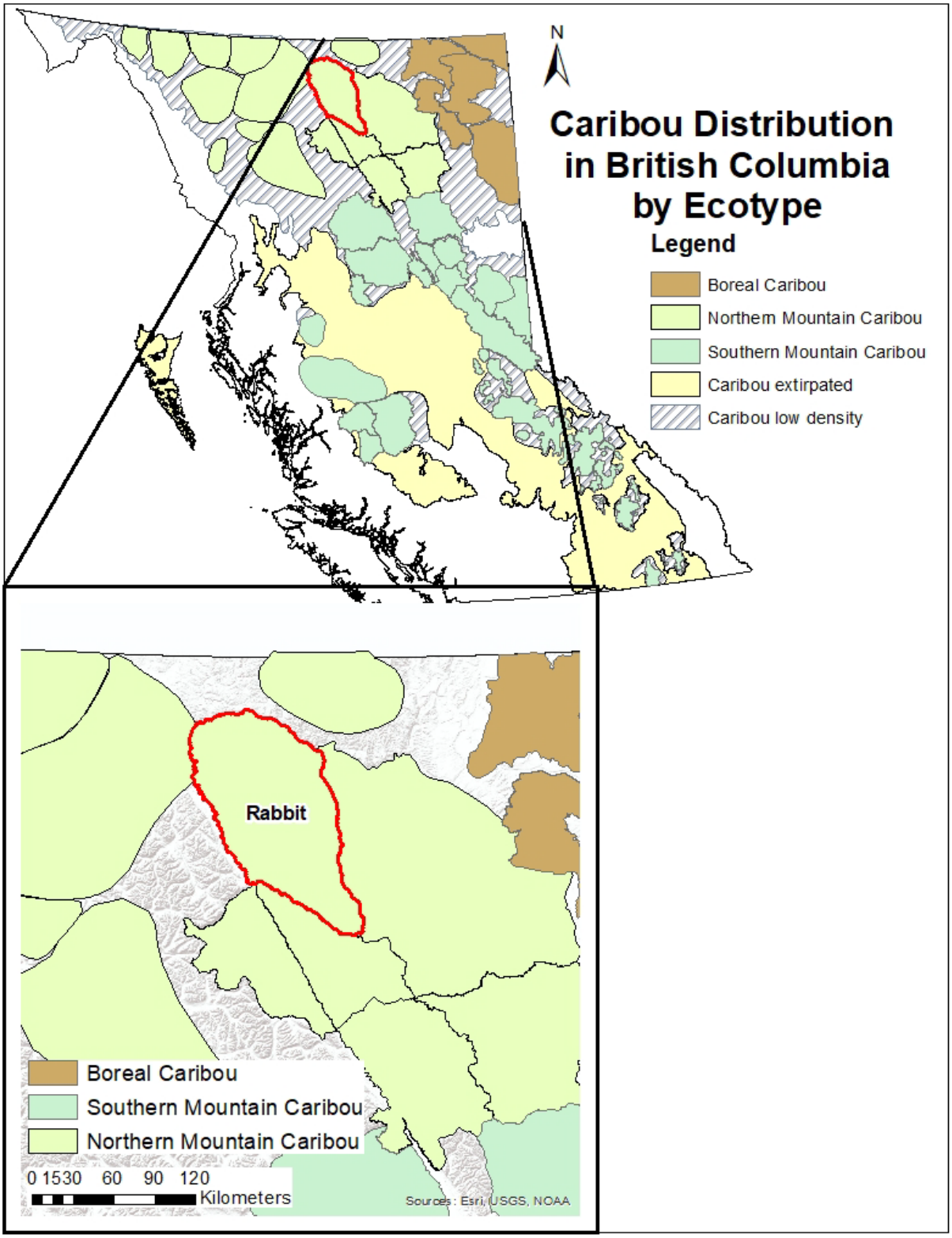

Figure 1: The geographical location of the Rabbit subpopulation of northern mountain caribou. The 11,791 km^2 range (inset: red outline) is situated on the western slopes of the Northern Rocky Mountains of north-central British Columbia.

Table 1: Estimates of population size by year for the Rabbit subpopulation of northern mountain caribou in north-central British Columbia.

Year	Estimate	Method	Survey Timing	Reference
1965	423	survey estimate	winter	Bergerud 1978
1978	225-269[1]	survey estimate	winter	Bergerud 1978; Duncan 2009
1996	354[2]	survey estimate	spring	Duncan 2009 (BC MOE, *unpublished data*)
1996	800	expert opinion	NA	Heard and Vagt 1998
2007	1133[3]	minimum count	winter	Duncan 2009 (BC MOE, *unpublished data*)
2014	1045	unknown	unknown	COSEWIC 2014

[1] Combined minimum counts from what were known as the Muncho Lake and Rabbit River herds, which both fall within the current boundaries of the Rabbit range. It is unknown how the extent of the combined survey areas compare to the current range.
[2] Incidental count from aerial survey to census mountain goats in WMU 7-51.
[3] Incidental count from an aerial survey to census Stone's sheep in WMU 7-51.

Table 2: Estimates of juvenile recruitment in the Rabbit subpopulation of northern mountain caribou in north-central British Columbia. Juvenile recruitment is expressed as the percentage of calves in the population. Percentages exceeding 15% in March (e.g. calves are ~ 9 months old) are generally associated with stable or increasing populations (Bergerud 1996, Environment Canada 2008).

Year	% Calves	Survey Timing	Reference
1978	2 – 6 (Rabbit River herd) 11 (Muncho Lake herd)	February	Bergerud 1978
1996	18	June	Duncan 2009 (BC MOE, *unpublished data*)
2007	14	March	Duncan 2009 (BC MOE, *unpublished data*)

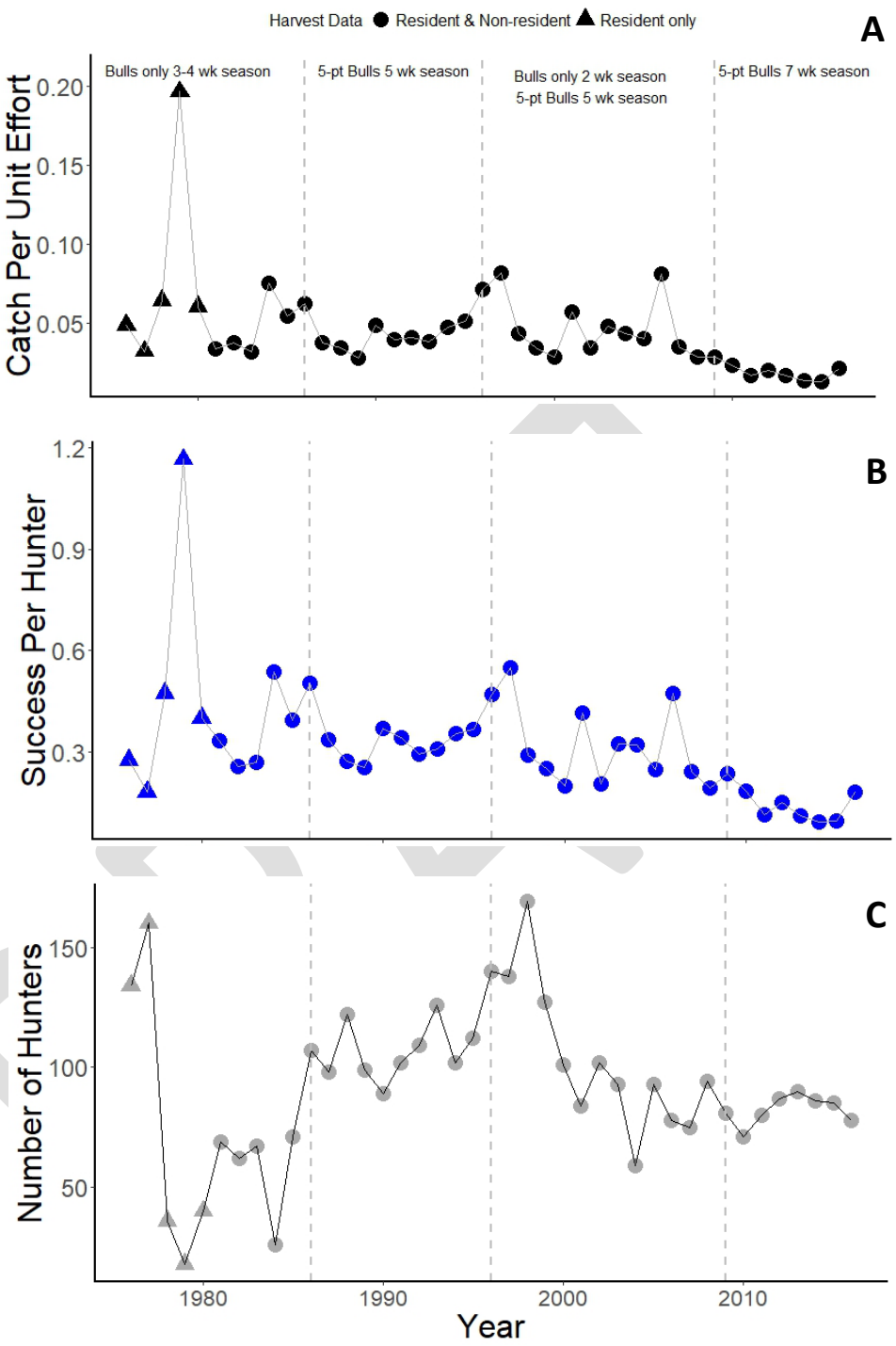

Figure 2: Harvest indices from 1976 to 2016 for Wildlife Management Unit 7-51, which encompasses the range of the Rabbit subpopulation of northern mountain caribou in north-central British Columbia. Catch per unit effort (A) is the total kills divided by the total number of hunter-days. Success per hunter (B) is the total kills divided the total number of hunters. The total number of hunters (C) represents both resident and non-resident hunters. Note that Wildlife Management Unit 7-51 also includes portions of the Muskwa and Gataga caribou ranges.

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*.

To date, there have been no studies assessing predation effects within the Rabbit range. However, in the adjacent Muskwa and Horseranch ranges, predation is thought to be a major limiting factor influencing caribou population dynamics (Bergerud and Elliott 1998). During wolf reductions in the 1980s, both subpopulations are thought to have increased, primarily due to high rates of juvenile recruitment. Adult female survival also likely increased as Bergerud (1996) suggested that in natural systems similar to those in the Muskwa and Horseranch ranges, predation is the primary source of adult mortality. This assertion is supported by a radio-collaring study (n = 46 females) conducted within the northern portion of the Muskwa range from 2000-2003 where four of five known mortalities were due to predation (by wolf or grizzly bear; Tripp et al. 2006). The Rabbit range contains a similar suite of predators and has comparable geography to the Muskwa range; therefore, it is likely that predation effects are similar between these two ranges.

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 populations declines (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).

To date, there have been no studies explicitly evaluating the nutritional condition of Rabbit caribou. Studies, however, have been undertaken in the nearby Pink Mountain and Graham ranges. In the winters of 2001-2002 and 2002-2003, Parker and Gustine (2007) assessed nutritional status of Pink Mountain caribou 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, these 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 other NM caribou 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 Rabbit range are minimal to non-existent. Using cutblock GIS data up to 2015, only one small cutblock that is < 20 years old is evident along the northeast boundary of the range and it appears to be associated with the Alaska Highway corridor. Forestry impacts outside of the range boundary (e.g. < 20 km away) are also minimal to non-existent.

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).

The Muskwa-Kechika Management Area, which encompasses the Rabbit range, is mandated to balance responsible resource development outside of Protected Areas with fish and wildlife conservation. As a consequence, there are a few mineral tenures (< 10 based on Mineral, Placer and Coal Tenure GIS data obtained from DataBC) located within the Rabbit caribou range. To date, none of these tenures have proceeded to large-scale development and thus there are currently minimal impacts from mining within the Rabbit 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).

Using GIS data available from the BC Oil and Gas Commission up to 2016, there are currently no impacts from oil and gas development within the Rabbit range.

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).

There are no wind power or other clean energy developments within the Rabbit range.

3.3.1.5 Other

There are currently no other major forms of industrial development within the Rabbit 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 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).

Snowmobiling and other forms of motorized travel is highly managed within the Muskwa-Kechika Management Area, which encompasses the Rabbit caribou range. Snowmobiling is restricted to specific designated routes (http://www.muskwa-kechika.com/management-area/access-management) and only one route, the West Toad Corridor, is present within the Rabbit range, accessing a small area along its eastern boundary. Because of the remoteness of the Rabbit range, snowmobile use is relatively light compared to other ranges of mountain-dwelling caribou further south in the province.

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 Rabbit 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).

The overall impact of summer recreational activities on the Rabbit subpopulation of NM caribou is likely minimal. As mentioned previously, motorized travel within the Muskwa-Kechika Management Area is restricted to a few designated routes. Hiking and horseback riding both occur within the Rabbit range though their intensity is likely low due to the remoteness of this range and the small number of developed trails.

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 Rabbit range 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).

There are no agricultural impacts within the Rabbit caribou range.

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 Rabbit subpopulation is the Alaska Highway, which traverses the range's northeastern boundary. Caribou are frequently observed crossing this highway, particularly during winter (Bergerud 1978) and mortalities due to vehicle collisions are known to occur (Tripp et al. 2006).

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) 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).

The Rabbit range has been minimally impacted by linear features. Using GIS data from the BC Oil and Gas Commission and Terrain Resource Information Management (TRIM) data depicting miscellaneous lines and forestry roads, no linear features related to industrial activity are evident within the Rabbit range.

3.3.3.4 HUNTING

Historical records indicate that NM caribou have long been hunted by First Nations in BC (Spalding 2000). Rabbit caribou also have a long history of being hunted following Euro-American settlement of the region. Guided hunting has occurred within the Northern Rocky Mountains at least since the 1940s (Spalding 2000). Currently, licensed hunting for caribou is still allowed within WMU 7-51, which encompasses the Rabbit 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 Rabbit 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).

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 Rabbit range with the majority of these fires situated along the range's boundary. Within the last 50 years, the largest fire occurred in 1982 (11,700 ha burned) and was situated on the northern border of the range.

The Rabbit range has been minimally affected by the mountain pine beetle though projections into the year 2020 suggest that infestations may intensify within the lower elevation forests situated in the western part of the range (https://www.for.gov.bc.ca/hre/bcmpb/year13.htm).

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 Rabbit caribou have not been 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 Rabbit 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 Rabbit 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.

Although empirical estimates of caribou population size are lacking for the Rabbit range, current estimates based on expert opinion suggest that population is > 1000 animals (see *Section 2.3*). As such, potential effects from small population size are likely to be minimal to non-existent in the Rabbit subpopulation.

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 Rabbit 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

The Rabbit caribou range lies entirely 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 12% of the range's area, provide even stronger protections as no industrial development is permitted in these areas. An area of Ungulate Winter Range for mountain goat also occurs along the range's southwestern boundary.

4.1.2 ENHANCEMENT AND RESTORATION

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

4.2 RECREATION AND ACCESS MANAGEMENT

The Rabbit caribou range is generally remote and see much lower recreational activity than caribou ranges situated in mountainous areas of southern British Columbia. The entirety of the Rabbit range lies within 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 Rabbit 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.

4.2.2 HELI-SKI / CAT-SKI

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

4.2.3 SUMMER RECREATION

Due to its remoteness, the Rabbit 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 Rabbit 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 (Bergerud and Elliott 1998, 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 Muskwa subpopulation is unknown.

Since the cessation of province-wide wolf control, northeastern British Columbia had two documented periods of wolf removals. From 1978 – 1980, 71 wolves were removed from the Horseranch Mountains and an unknown number of wolves were removed from the Muskwa range by local guide outfitters (Bergerud and Elliott 1998). In the 1980s, wolf removal experiments were conducted in northeastern British Columbia to test the effects of wolf predation on recruitment rates – and consequently population growth rates – of four ungulate species (Bergerud and Elliott 1998). Within the Muskwa study area, wolves were removed in 1984 (60% reduction over a 6775 km^2 area), 1985 (77% reduction over 13,570 km^2) and in 1987 (62% reduction over 10,000 km^2). Within the Kechika study area, which included the Horseranch Mountains, wolves were removed in 1982 (85% reduction over 3833 km^2), 1983 (83% reduction over 7123 km^2), 1984 (76% reduction over 9961 km^2) and 1985 (65% reduction over 18,400 km^2). These removals resulted in high recruitment rates and probable population growth in caribou populations in the two study areas although effects on the intervening Rabbit subpopulation were not documented. Effects of the wolf removal program, however, was short-term as recruitment rates in the

Muskwa study area had lowered from 30.4 calves per 100 females in the last year of wolf removal to 17.5 calves per 100 females three years later.

Since the late-1980s, there have been no other wolf removal efforts within northeastern British Columbia, including the Rabbit 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 Rabbit 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 Rabbit range likely has a low density of cougars, though their population has not been explicitly enumerated. To date, cougar predation of Rabbit caribou has not been documented and consequently cougars have not been subject to management actions in the context of caribou conservation. The current bag limit for cougars in WMUs within and adjacent to the Rabbit 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 Rabbit 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

Within the last five years, two surveys to estimate moose abundance have occurred in a portion of WMU 7-51, which encompasses overlapping the Rabbit range. In 2012 and 2013, mid-winter composition surveys in the Toad River drainage (WMU 7-51) estimated a moose density of 0.33 and 0.49 moose / km^2, respectively (Kline 2013*a*, *b*). In all surveys, moose were the most abundant ungulate. More recently, Poole and DeMars (2015) used habitat capability modelling to estimate a moose density of 0.13 moose / km^2 for WMU 7-51. 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 Rabbit 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 Rabbit caribou range. Mule deer are more abundant (Kline 2013*a*) although the northern distribution and abundance of white-tailed are likely increasing (Latham et al. 2011*b*, Dawe and Boutin 2016). In WMU 7-51, there is a general hunting season is open for mule deer bucks (four points or larger) with a bag limit of one. Hunting is currently closed for white-tailed deer. To date, there have been no management actions targeted toward deer in the context of caribou conservation in the Rabbit caribou range.

4.4.3 Other

Elk (*Cervus elaphus*) and Stone's sheep are also present within the Rabbit caribou range. For elk, there is a general hunting season in WMUs 7-49 and 7-50 for three-point bulls and larger while harvest is restricted to bulls with six points or larger in WMUs 7-51 and 7-54. For Stone's sheep, there is a general hunting season for full curl rams in WMUs 7-50, 7-51, and 7-54. 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 Rabbit 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 Rabbit 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 Rabbit subpopulation.

4.5.4 OTHER

There have been no other forms of population reinforcement implemented for the Rabbit 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 has been limited research conducted within the Rabbit range to understand caribou behaviour and ecology. Bergerud (1978) conducted initial surveys of the "Rabbit River Herd" and the "Muncho Lake Herd", which both fall within the current boundary of the Rabbit range. Besides providing minimum counts, these surveys allowed Bergerud (1978) to speculate on the likely seasonal movements of these caribou groups. To date, no radio-collaring studies have been conducted within the Rabbit range, although such studies have taken place in the adjacent Muskwa (e.g. Tripp et al. 2006) and Gataga (e.g. Elliot 2004) ranges. While inferences from these other ranges may apply to the Rabbit range, more directed research within the Rabbit range will likely better inform management strategies for this subpopulation.

4.8 MONITORING

Over the last 50 years, the Rabbit subpopulation has been infrequently surveyed and has been primarily monitored by harvest statistics (Environment Canada 2012*a*). In the late-1970s, Bergerud (1978) conducted surveys to estimate the minimum size and composition of the "Rabbit River Herd" and "Muncho Lake Herd", which both are part of what is now considered the Rabbit range (Bergerud 1978). Since that time, estimates of minimum size have relied on incidental observations of caribou recorded during surveys targeted toward other ungulate species.

Harvest statistics over the last decade suggest a declining population. Caution is warranted, however, when inferring population trend solely by harvest statistics as such indices may be prone to biases, particularly if hunting regulations change during the monitoring period or if human access to an area is increased (Peacock and Garshelis 2006). Harvest statistics therefore need to be augmented, at least periodically, with other methods and surveys to reliably track population size and trend (see *Section 8: Recommended Actions*).

5 IMPLICATIONS TO OTHER WILDLIFE

Management actions focused on conserving caribou will necessarily have impacts on other wildlife species. Caribou generally 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 Rabbit 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 Rabbit Subpopulation

1. *Population Management*

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

     The Rabbit subpopulation has been surveyed infrequently over the last 30 years and has been primarily monitored by harvest statistics. Such statistics assume that hunter success rates are directly proportional to animal abundance, an assumption that may not always hold (Peacock and Garshelis 2006). Going forward, population size should be estimated at regular intervals (e.g. every 3 years) 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 consistent 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 should still 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 Rabbit range with no quota on the number of animals harvested. Declining harvest indices over the last decade (see Section 2.3 *Population Size and Trend*), however, suggest a declining caribou population and thus current harvest regulations should be examined to assess whether harvest rates are sustainable for the current population size.

   - *Identify limiting factors contributing to suspected population decline*

     Understanding limiting factors is important for effective management of wildlife populations. Currently, inferences on limiting factors for the Rabbit subpopulation rely on information from studies conducted in other subpopulations and it is unknown

whether caribou population dynamics within the Rabbit range are similar to these other areas. For the past decade, decreasing harvest indices suggest that the Rabbit subpopulation is in decline and understanding the factors driving this potential decline should be a management priority.

2. *Habitat Management*

   - *Identify then ensure protection of core habitat areas*

     The Rabbit range lies within the Muskwa-Kechika Management Area, which mandates that wildlife values be balanced with responsible resource development. While the range has had minimal impacts from industrial development to date, it also has few protected areas (e.g. Ungulate Winter Range, Wildlife Habitat Areas or Provincial Parks) and none specifically targeted toward caribou management. Going forward, effective management strategies that incorporate resource development with caribou conservation will require that core habitat areas be identified.

   - *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.

3. *Communication and Involvement*

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

     The Rabbit range has a long history of use by First Nations and incorporating traditional knowledge and perspectives should be integral to any management plan. The Rabbit 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.

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. <http://a100.gov.bc.ca/pub/eswp/>.

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. 2015. Northern BC caribou potential donor subpopulations for captive breeding or augmentation. BC Ministry of Forests, Lands and Natural Resource Operations, Prince George, BC.

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, R. S. McNay, and S. Boutin. 2017. 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.

Elliot, J. P. 2004. Frog Gataga caribou. BC Ministry of Environment, Fort St. John, BC.

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.

Kline, J. 2013*a*. Mid-winter moose composition survey Toad River drainage, Management Unit 7-51. BC Ministry of Forests, Lands and Natural Resource Operations, Fort St. John, BC.

Kline, J. 2013*b*. Moose inventory at Moose Lake in the Toad River drainage, Management Unit 7-51. BC Ministry of Forests, Lands and Natural Resource Operations, Fort St. John, BC.

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. V. Hayssen, editor. 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.

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.

Peacock, E., and D. L. Garshelis. 2006. Comment on "On the regulation of populations of mammals, birds, fish, andiInsects" IV. Science 313:45.1-45.

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.

Radcliffe, G. 2000. Caribou populations and ecology, Northern Muskwa-Kechika. Madrone Consultants Ltd., Prince George, 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. J. Moen, editor. 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. B. Fenton, editor. 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.

Tripp, T., G. Radcliffe, and T. Willmott. 2006. Final project report & data analysis: 2000-2004 caribou populations and ecology, Northern Muskwa-Kechika. Madrone Consultants Ltd., Duncan, 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.