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

Frog
Subpopulation

Northern Mountain Population

BRITISH COLUMBIA

Recommended Citation:

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EXECUTIVE SUMMARY

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1 BACKGROUND

1.1 INTRODUCTION TO THE PROGRAM

2 POPULATION DESCRIPTION

Frog 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 range of the Frog subpopulation is located within the Cassiar Mountains in the north-central portion of the province (Fig. 1). The range, which lies entirely within the Muskwa-Kechika Management Area, is situated 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, Boreal White and Black Spruce, and Engelmann Spruce – Subalpine Fir zones; McNay 2011). The original range boundary encompassed 5,039 km^2; however, Sittler et al. (2015) proposed an expansion south and westward based on GPS radio-collar data, which would increase the range's area to 7,458 km^2. The range is bounded to the east by the upper Kechika River and the Northern Rocky Mountain Trench, which separates the range from the adjacent Gataga caribou range. The range's northern boundary extends to the Jack Stone Creek drainage. To the northwest, the range boundary follows the boundary of the Muskwa-Kechika Management Area. The range's original southern boundary extended to the Porcupine Creek drainage northwest of the community of Fort Ware. The proposed new boundary would extend ~ 25 – 40 km southward from this original boundary (Sittler et al. 2015). Two provincial parks occur within the Frog range: Dune Za Keyih Provincial Park and Finlay-Russel Provincial Park and Protected Area.

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). For the Frog subpopulation, a radio-collaring study (n = 55 females) conducted between 2000 and 2003 found that caribou generally selected higher elevation habitats (alpine and subalpine tundra) in late spring, summer and fall then move into lower elevation conifer forests during the winter and early spring (Elliot 2004). Considerable variation, however, may exist 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, MacDonald et al. 2009).

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, Elliot 2004). 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

There have been no formal surveys to estimate population size of the Frog subpopulation (Duncan 2009). In 1996, expert opinion suggested that the Frog subpopulation numbered 150 caribou (Table 1; Heard and Vagt 1998) and the same number was estimated by regional biologists in 2002 (COSEWIC 2002). Eight years later, McNay and Hamilton (2010 cited in Sittler et al. 2015) estimated the herd to be 250 caribou. In the 2014 COSEWIC status report for NM caribou, the size of the Frog subpopulation is listed as 199 (COSEWIC 2014).

Areas adjacent to the original southern range boundary were surveyed for caribou presence in 2009, 2010, 2012 and 2013 (MacDonald et al. 2009, McNay 2012, Sittler et al. 2015). These areas are encompassed by the revised boundary proposed by Sittler et al. (2015). McNay (2012) estimated that 80 caribou were observed during the 2009 survey, which was conducted in April. The 2010, 2012 and 2013 surveys were conducted in the fall. The 2010 survey recorded 92 caribou in the same area as the 2009 survey and 3 animals within the southern part of the original Frog range (McNay 2012). The 2012 recorded 75 caribou again using the same area as the previous two surveys and also observed 18 caribou within the southern portion of the original range boundary (Sittler et al. 2015). In 2013, 6 caribou were recorded in an area further south than previous years (~40 km south of the original range boundary; Sittler et al. 2015).

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 Frog subpopulation. Estimates of juvenile recruitment are confined to fall (October – November) surveys conducted between 2010 and 2013 (Table 2). In 2010, calves comprised 12% of the caribou observed in an area adjacent to the range's original southern boundary (McNay 2012, Sittler et al. 2015). Surveys conducted in the same area in 2012 and 2013 recorded similar values (13% and 14% respectively; Sittler

et al. 2015). These values are near those associated with stable populations (~15%; Bergerud 1996), although the reported values are from fall surveys and therefore do not represent recruitment in the usual sense (e.g. 9-month old calves). For adult female survival, Elliot (2004) estimated an annual survival rate of 90% from 2000-2003, though his sample (n = 55 radio-collared females) likely included animals from the adjacent Gataga subpopulation. Sittler et al. (2015) deployed radio-collars on 30 females found within the "trace occurrence" area situated between the Frog, Gataga, Finlay and Spatsize ranges. These animals were monitored for various periods from 2012 – 2015 with five mortalities recorded. These data could be used to retrospectively estimate an annual survival rate for this time period although this sample of caribou may include animals not associated with the Frog subpopulation.

In hunted populations of ungulates such as the Frog subpopulation, harvest indices such as catch-per-unit-effort (CPUE) and hunter success rate can give an indication of population trend. The Frog range is overlapped by Wildlife Management Unit (WMU) 7-40, which also includes a small portion of the Finlay caribou range, and WMU 7-52, which also overlaps the Horseranch caribou range. CPUE and success rates have been variable within both WMUs and do not show a consistent trend, possibly indicating a relatively stable population (Fig. 2; Duncan 2009). Duncan (2009) used harvest location data to identify kills for WMU 7-52 that actually occurred within the Frog range. This analysis suggested that generally ≤ 7 bulls per year have been harvested between 1986 and 2006 in this portion of the range.

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

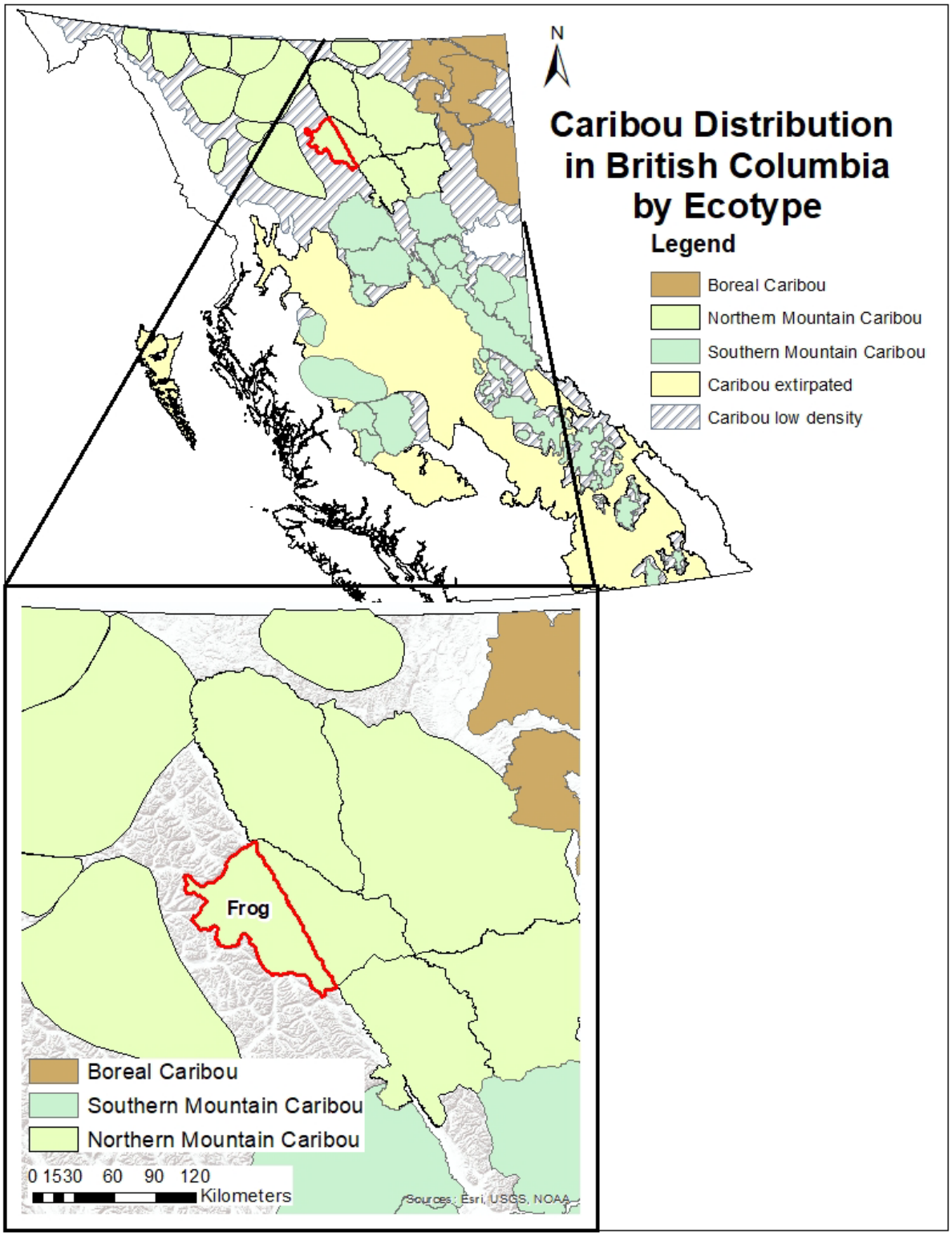

Figure 1: The geographical location of the Frog subpopulation of northern mountain caribou. The range (inset: red outline) is situated within the Cassiar Mountains of north-central British Columbia. This figure depicts the range's original 5,039 km^2 extent; however, recent GPS radio-collar data from Frog caribou suggests that the range be expanded south and westward (Sittler et al. 2015).

Table 1: Estimates of population size and area-restricted minimum counts by year for the Frog subpopulation of northern mountain caribou in north-central British Columbia.

Year	Estimate	Method	Survey Timing	Reference
1996	150	expert opinion	NA	Heard and Vagt 1998
2002	150	expert opinion	NA	COSEWIC 2002
2009	80[1]	minimum count	April	McNay 2012
2010	250	expert opinion	NA	McNay and Hamilton 2010 (cited in Sittler et al. 2015)
2010	95[1]	minimum count	October	McNay 2012
2012	93[1]	minimum count	October	Sittler et al. 2015
2013	6[2]	minimum count	November	Sittler et al. 2015

[1] Minimum counts from the southern portion of the original Frog range and areas outside but within 30 km of the range's original southern boundary.
[2] Minimum count from an area further south of the 2010 and 2012 surveys but within 50 km of the range's original southern boundary.

Table 2: Estimates of the percentage of calves in the Frog subpopulation of northern mountain caribou in north-central British Columbia. Percentages were estimated from aerial surveys conducted in the fall over areas along and adjacent to the range's original southern boundary.

Year	% Calves	Survey Timing	Reference
2010	12	October	Sittler et al. 2015
2012	13	October	Sittler et al. 2015
2013	15	November	Sittler et al. 2015

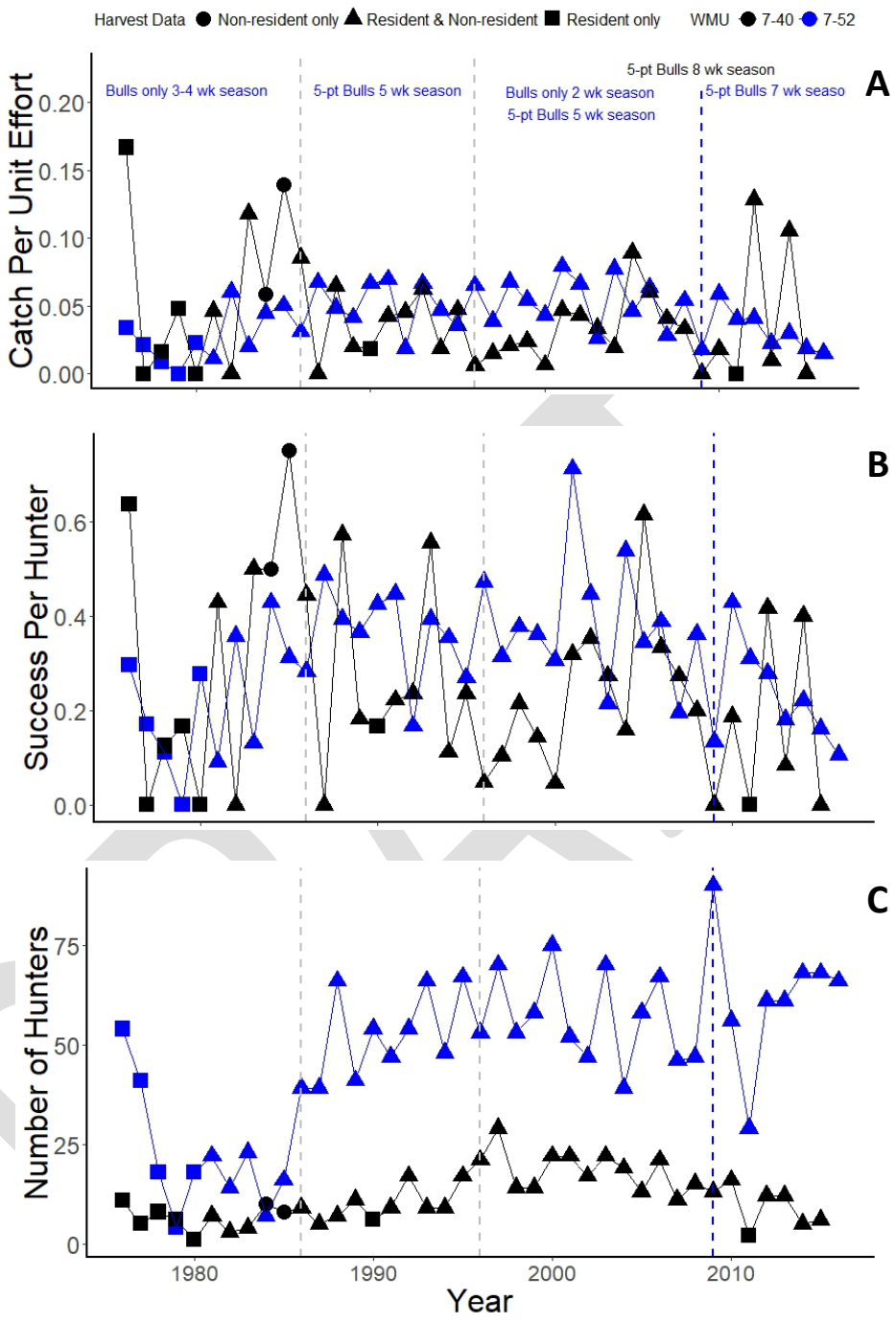

Figure 2: Harvest indices from 1976 to 2016 for Wildlife Management Units (WMUs) 7-40 and 7-52, which overlap the range of the Frog subpopulation of northern mountain caribou in north-central British Columbia. Catch per unit effort (A) is the total kills divided by the total number of hunter-days. Success 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 WMU 7-40 also overlaps a small portion of the Finlay caribou range and WMU 7-52 includes portions of the Horseranch caribou range. Hunting regulations prior to 2006 are from Duncan (2009), whose analyses did not include WMU 7-40.

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 formal studies assessing predation effects within the Frog range. Elliot (2004) assessed habitat use and selection by 55 radio-collared female caribou but did not report cause of mortality for any of the 14 animals that died during the course of study. Sittler et al. (2015) investigated mortality sites of four radio-collared caribou that were monitored for various periods between 2012 and 2015 in areas adjacent to the range's southern boundary. Three of these mortalities were confirmed to be predation-caused (two by wolves, one by lynx).

Inferences from other nearby NM caribou ranges such as the Spatsizi, Muskwa and Horseranch ranges suggest that predation is a major limiting factor influencing caribou population dynamics (Bergerud and Elliot 1986, Bergerud and Elliott 1998). In the Spatsizi range, predation was found to be the primary cause of calf mortality and low rates of calf recruitment contributed to declining caribou numbers during the late 1970s (Bergerud and Elliot 1986). During wolf reductions in the 1980s, the Muskwa and Horseranch subpopulations were thought to have increased, primarily due to increased 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 Frog range contains a similar suite of predators and has comparable geography to the Spatisizi and Muskwa ranges; therefore, it is likely that predation effects on caribou population dynamics are similar among the three 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 Frog 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 Frog caribou range are minimal to non-existent due to its relative remoteness with few roads (Elliot 2004, Sittler et al. 2015). An analysis using cutblock GIS data up to 2015 shows no cutblocks occurring within the range.

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).

Elliot (2004) suggested that portions of the Frog range were being considered for hard rock mining and Sittler et al. (2015) made a similar suggestion a decade later, though they noted mining developments had not yet proceeded within the range. Current GIS analyses show a small number of mineral claims located in the range's northwest corner. Because the Frog range is situated within the Muskwa-Kechika Management Area, which is mandated to balance responsible resource development outside of Protected Areas with fish and wildlife conservation, these mineral claims could be developed in the future.

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 Frog 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 Frog range.

3.3.1.5 Other

There are currently no other major forms of industrial development within the Frog 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 Frog caribou range. Snowmobiling is restricted to specific designated routes and none of these occur within the Frog range (http://www.muskwa-kechika.com/management-area/access-management). Because of its remoteness (no road access), snowmobile use within the Frog range is likely minimal to non-existent.

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 Frog 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 Frog subpopulation of NM caribou is likely minimal. Hiking and horseback riding both occur within the Frog range though their intensity is likely low due to the remoteness of this range (no road access) 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 (no road access), ski touring impacts within the Frog 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 impacts from agriculture within the Frog 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).

There are no major highways within or adjacent to the Frog range.

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 Frog range has been minimally impacted by linear features as there has been no logging or oil and gas exploration conducted within its boundary.

3.3.3.4 HUNTING

Historical records indicate that NM caribou have long been hunted by First Nations in BC (Spalding 2000). 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 WMUs 7-40 and 7-52, which overlap the Frog 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 Frog 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 north-central 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 Frog range with the majority of these fires situated in the northern half of the range. Within the last 50 years, the largest fire occurred in 1982 (7,172 ha burned) and was situated on the range's northern boundary.

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

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

3.6 CLIMATE CHANGE

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

Impacts of climate change on the Frog 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 Frog subpopulation has been specifically impacted by these predicted effects of climate change.

3.7 SMALL POPULATION SIZE EFFECTS

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

Currently, potential effects from small population size are likely to be minimal in the Frog subpopulation as recent estimates suggest a population size of ~200 – 250 (see *Section 2.3*), though these estimates are primarily based on expert opinion. It also unclear the extent to which Frog caribou interact with neighboring ranges (e.g. Spatsizi, Gataga) and the "trace occurrence" zone adjacent to the range's southern boundary.

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 Frog 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 Frog caribou range lies within the Muskwa-Kechika Management Area, which is managed to maintain wilderness values. Provincial Parks and Protected Areas within the Muskwa-Kechika Management Area, which encompass ~14% of the range's area, provide even stronger protections as no industrial development is permitted in these areas. Approximately 84% of the range's area is also designated as Ungulate Winter Range for Stone's sheep.

4.1.2 ENHANCEMENT AND RESTORATION

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

4.2 RECREATION AND ACCESS MANAGEMENT

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

4.2.1 SNOWMOBILE

Snowmobile use within the Frog 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 and none of these occur within the Frog range.

4.2.2 HELI-SKI / CAT-SKI

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

4.2.3 SUMMER RECREATION

Due to its remoteness and lack of road access, the Frog range sees relatively light summer recreational use. Within the Muskwa-Kechika Management Area, motorized vehicles are restricted to a few specified access routes and none of these occur in the Frog range. 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 Frog 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 Frog 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. 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. Effects of wolf removal on caribou population dynamics is areas outside of the study area, including the Frog range, are unknown.

Since the late-1980s, there have been no other wolf removal efforts within northeastern British Columbia, including the Frog range. Currently, there is an eight month general hunting season for wolves with a bag limit of three in WMU 7-52 and an eleven month general season with no bag limit in WMU 7-40. In 2016, removal of the bag limit was being considered for WMU 7-52 (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 Frog range likely has a low density of cougars, though their population has not been explicitly enumerated. To date, cougar predation of Frog caribou has not been documented and consequently cougars have not been subject to management actions in the context of caribou conservation. Within WMU 7-52, there is a general hunting season for cougars with a bag limit of one. There is no general hunting season for cougars within WMU 7-40.

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 Frog 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

WMUs within the Frog range have received few surveys to estimate moose densities and/or abundance. For WMU 7-52, Poole and DeMars (2015) used habitat-based extrapolation from other surveys conducted in the Liard Game Management Zone (7Pd) to estimate a moose density of 0.23 moose / km^2. Current estimates of moose density within WMU 7-40 are unknown.

To date, there has been no active management of moose in the context of caribou conservation within the Frog range. Licensed general hunting for moose within WMU 7-40 is restricted to a 12-week season

for spike-fork bulls with a bag limit of one. Within WMU 7-52, there is a 2-week general season for all bulls then a 9-week season for spike-fork bulls, tripalm bulls, or bulls with > 10 points. 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 Frog caribou range. Mule deer are more abundant (Kline 2013) although the northern distribution and abundance of white-tailed are likely increasing (Latham et al. 2011*b*, Dawe and Boutin 2016). Within WMU 7-40, there are general hunting seasons for both mule deer and white-tailed deer bucks. Within WMU 7-52, there is a general hunting season is open for mule deer bucks (four points or larger) while hunting is closed for white-tailed deer. The bag limit for each species is one. To date, there have been no management actions targeted toward deer in the context of caribou conservation in the Frog caribou range.

4.4.3 Other

Elk (*Cervus elaphus*) and Stone's sheep are also present within the Frog caribou range. For elk, there is a general hunting season in WMUs 7-40 and 7-52 for six-point bulls and larger. For Stone's sheep, there is a general hunting season for full curl rams in these same WMUs. 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 Frog 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 Frog 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 Frog subpopulation.

4.5.4 OTHER

There have been no other forms of population reinforcement implemented for the Frog 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 Frog range to understand caribou behaviour and ecology. As noted in *Section 2.3 Population Size and Trend*, there have been no formal surveys to estimate population size in the Frog range. The first radio-collaring study occurred from 2000-2003 when 55 VHF radio-collars were deployed on adult females in the Frog and Gataga ranges (Elliot 2004). Data from these animals were used to assess seasonal range use and habitat selection. In the last decade, research has been conducted within the caribou "trace occurrence" zone adjacent to the southern boundary of the Frog range. These efforts have included aerial surveys (McNay 2012) and the deployment of radio-collars to understand caribou movements and refine range boundaries in this area (Sittler et al. 2015).

Recently, a new radio-collaring program has been initiated within the Frog range (J. Strong, MFLNRORD biologist, *personal communication*).. In late winter 2017, seven GPS radio-collars have been deployed on adult females. Data from these animals should provide further insights into seasonal movements, habitat selection and demography of Frog caribou.

4.8 MONITORING

Over the last 50 years, the Frog subpopulation has been infrequently surveyed and has been primarily monitored by harvest statistics (Environment Canada 2012*a*; see *Section 2.1 Population Size and Trend)*. From 2000 – 2003, caribou movements within the Frog and Gataga ranges were monitored with VHF radio-collars (n = 55; Elliot 2004). While these data yielded inferences on adult female survival, it is unclear whether the data were used to evaluate and monitor population trend.

In late-winter 2017, a new monitoring program was initiated within the Frog range with the deployment of seven GPS radio-collars on adult females (J. Strong, MFLNRORD biologist, *personal communication*). These collared animals should assist with future surveys to estimate population size and composition with such demographic data allowing for more direct monitoring of population trend.

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 Frog 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 Frog Subpopulation

1. *Population Management*

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

  Over the last 30 years, the Frog subpopulation 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 Frog range with no quota on the number of animals harvested. Hayes et al. (2003) suggested that harvest rate should not exceed 2% of the population. Although precise estimates of population size for the Frog range are lacking, expert opinion suggests a population size of ~ 200-250 animals. Over the last decade, the number of bulls harvested per year has averaged 15 within WMUS 7-40 and 7-52 combined. While the extent of WMUs 7-40 and 7-52 exceeds that of the Frog range, further analyses should be conducted to ensure that current harvest rates are sustainable.

- *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 Frog subpopulation rely on information from studies conducted in other subpopulations and it is unknown whether caribou population dynamics within the Frog range are similar to these other areas.

2. *Habitat Management*

   - *Identify then ensure protection of core habitat areas*

     The Frog range lies within the Muskwa-Kechika Management Area, which mandates that wildlife values be balanced with responsible resource development. To achieve this mandate, core habitat areas for caribou within the Frog range should be identified to inform the development of effective management strategies that incorporate resource development with caribou conservation.

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

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8.2 Medium Term (Within 12-24 Months)

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8.3 Long Term (Within 24-48 Months)

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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., 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.

Hayes, R. D., R. Farnell, R. M. Ward, J. Carey, M. Dehn, G. W. Kuzyk, A. M. Baer, C. L. Gardner, and M. O'Donoghue. 2003. Experimental reduction of wolves in the Yukon: ungulate responses and management implications. Wildlife Monographs 1–35.

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. 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.

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.

MacDonald, F., L. Giguere, and R. S. McNay. 2009. Late-winter habitat and its use by caribou in the Upper Pelly and Finlay-Russell portion of the Muskwa-Kechika Management Area. Wildlife Infometrics Inc. Report, Wildlife Infometrics Inc., Mackenzie, BC.

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. 2012. Fall population survey of woodland caribou in the Thutade-Upper Finlay River area of north-central British Columbia. Wildlife Infometrics Inc. Report, Wildlife Infometrics Inc., Mackenzie, BC.

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.

Sittler, K., R. S. McNay, and L. Giguere. 2015. Herd boundary refinement for the Chase, Spatsizi, and Frog caribou herds in north-central British Columbia: Final report 2012-2015. Wildlife Infometrics Inc. Report, Wildlife Infometrics Inc., Mackenzie, BC.

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.

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.