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

Muskwa
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

Muskwa 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 Muskwa subpopulation is situated within the Northern Rocky Mountains in the northeastern portion of the province (Fig. 1). The subpopulation's range falls within the Northern Boreal Mountains ecoprovince and is typified by rugged alpine areas (Boreal Altai Fescue Alpine biogeoclimatic zone) and lower elevation forests (Spruce-Willow-Birch and Boreal White and Black Spruce zones; McNay 2011, Watters and DeMars 2016). The range is bounded by the Liard River to the north, the Pink Mountain caribou range to the south, and by the Rabbit and Gataga caribou ranges to the west. To the east, it is bordered by the boreal forests of the Taiga Plains ecoprovince and partially overlaps the Westside Fort Nelson boreal caribou range. Approximately 74% of the 21,595 km^2 range lies within the Muskwa-Kechika Management Area. The range encompasses Stone Mountain Provincial Park and portions of Northern Rocky Mountains, Liard River Corridor and Muncho Lake Provincial Parks.

2.2 HABITAT AND BEHAVIOUR

NM caribou undergo seasonal range shifts in response to snowfall conditions affecting forage availability (Bergerud 1978, Heard and Vagt 1998). These shifts vary among subpopulations, being affected by such factors as topography, predation risk, and snow characteristics (Seip and McLellan 2008). In general, Muskwa caribou occur at higher elevations in late spring, summer and fall then move into lower elevation conifer forests during the winter and early spring (Radcliffe 2000, Gustine and Parker 2008). Considerable variation, however, exists among individuals and among seasons. For example, in late winter, many caribou use wind-swept alpine ridges to access exposed terrestrial lichens,

particularly during high snowfall years, whereas other individuals remain below treeline (Wood 1996). Differing spatial strategies are also found during calving with many females using high elevation sites above treeline while others calve in subalpine conifer forests prior to moving to higher elevation summer ranges (Wood 1996, Radcliffe 2000, Gustine and Parker 2008). Calving generally occurs from mid-May to mid-June (Radcliffe 2000). Similar to the grouping behaviour of other woodland caribou, the average group size of NM caribou is highest during the rut (late September to early October) and smallest during calving (Bergerud et al. 1984, Bergerud and Page 1987).

2.3 POPULATION SIZE AND TREND

Over the past four decades, the Muskwa subpopulation has had relatively few surveys to estimate population size (Table 1). In the late 1970s, surveys recording minimum counts (n = 279-294; Bergerud 1978) likely far underestimated the population's true size, which was thought to be in the thousands during the 1960s and early 1970s (Spalding 2000). In 1990, Bergerud and Elliott (1998) conducted a complete count within a study area situated in the southern half of the current Muskwa range and arrived at an estimate of 3000 caribou. The Muskwa range was not surveyed again until the early 2000s when multiple aerial surveys were conducted over a four year period (2000 – 2004) to estimate herd composition and record minimum counts (Tripp et al. 2006). These surveys were conducted multiple times per year (calving, rut and winter) and used radio-collared animals to derive a sightability correction factor for estimating population size. The highest estimates occurred during the fall rut with values ranging from 617 – 1138 animals. In 2007, a minimum count of 738 caribou was recorded during an aerial survey to census Stone's sheep (*Ovis dalli stonei*), though how the boundaries of this survey related to the current Muskwa caribou range is unclear (BC Ministry of Forests, Lands, and Natural Resource Operations, *unpublished data*). The most recent survey was conducted in 2017 when a minimum count of 172 caribou was recorded during a March flight to estimate juvenile recruitment (BC Ministry of Forests, Lands, and Natural Resource Operations, *unpublished data*).

Juvenile recruitment and adult female survival, two demographic parameters with high influence on caribou population dynamics (DeCesare et al. 2012), have also been estimated intermittently over the past four decades (Table 2). In the late 1970s and 1980s, Bergerud and Elliott (1998) estimated the number of calves per 100 females in late winter to track juvenile recruitment. These values generally exceeded those associated with population stability (28.9 calves:100 females; Environment Canada 2008) and were likely influenced by wolf control conducted during that time period. In 1990, after the cessation of wolf control, juvenile recruitment declined to 17.5 calves: 100 females. The next estimates of juvenile recruitment, as indexed by the percentage of calves in the population, occurred from 2001-2003 (Tripp et al. 2006). These estimates were near or exceeded values associated with population stability (15%; Bergerud 1996). More recent estimates in 2007 and 2017, however, have been lower (8% and 12%, respectively).

Estimates of adult female survival have been less frequent than juvenile recruitment. Using data from the Tripp et al. (2006) study and the 2007 aerial survey, Duncan (2009) derived annual estimates of adult female survival that varied between 86.2 and 94.6% (years monitored: 2000-2004, 2007).

In hunted populations of ungulates such as the Muskwa subpopulation, harvest indices such as catch-per-unit-effort and hunter success rate can give an indication of population trend. Using data from Wildlife Management Units (WMUs) 7-50 and 7-54, harvest indices estimated between 1976 and 2016 have been variable (Fig. 2; see also Duncan 2009); however, since the early 2000s catch-per-unit-effort and hunter success rate have shown a decreasing trend, suggesting a declining population though this inference showed be viewed cautiously in the absence of corroborating evidence (e.g. repeated reliable estimates of population size and/or continued monitoring of adult female survival and juvenile recruitment).

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

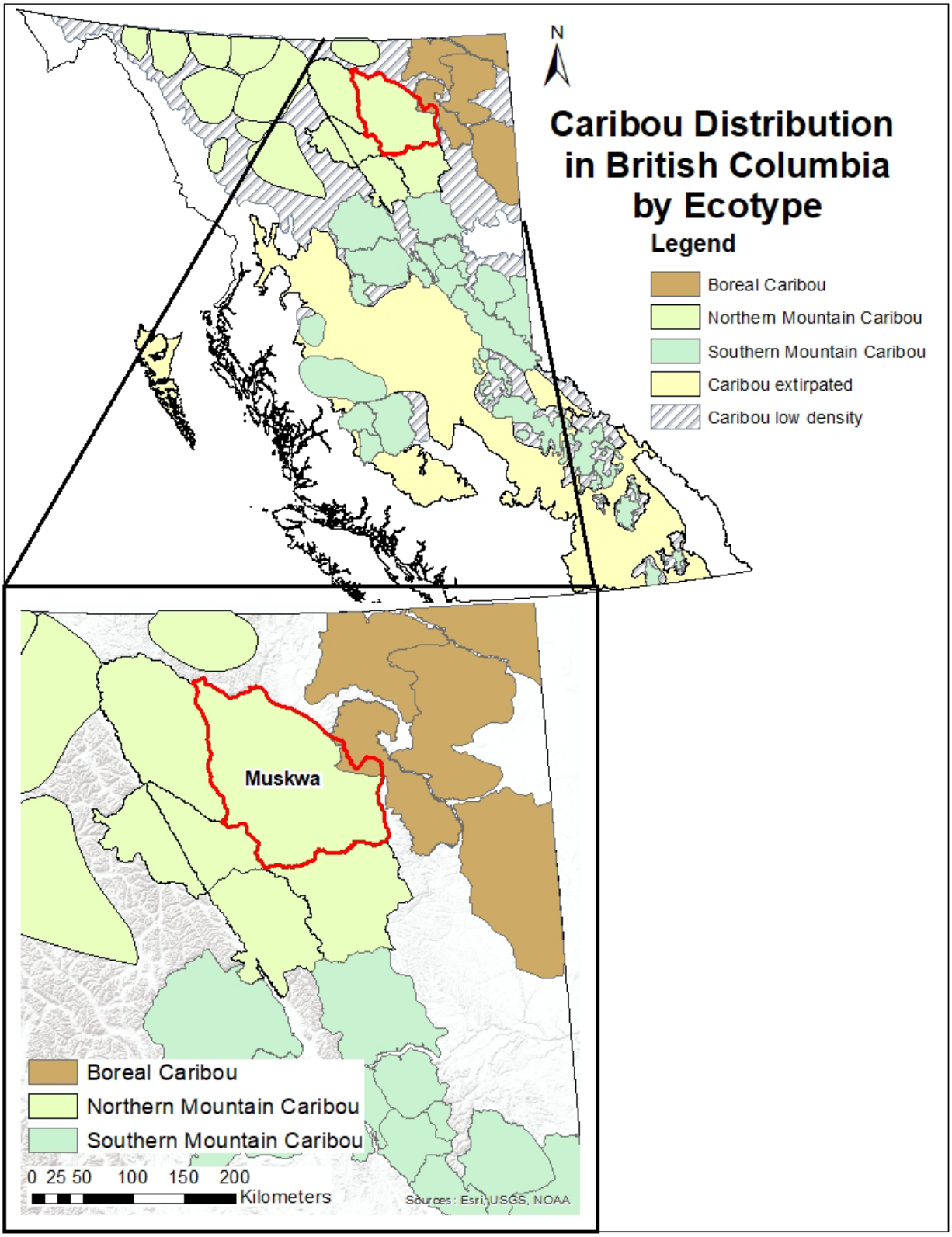

Figure 1: The geographical location of the Muskwa subpopulation of northern mountain caribou. The 21,595 km^2 range (inset: red outline) is situated within the Northern Rocky Mountains of northeastern British Columbia.

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

Year	Estimate	Method	Survey Timing	Reference
1977	279[1]	survey estimate	winter	Bergerud 1978 cited in Duncan 2009
1978	294[1]	survey estimate	winter	Bergerud 1978 cited in Duncan 2009
1990	3000	complete count	winter	Bergerud and Elliott 1998
1996	1250	expert opinion	NA	Heard and Vagt 1998
2000	1250	unknown	unknown	COSEWIC 2002
2000	288	minimum count	rut	Tripp et al. 2006
2001	1138[2]	survey estimate	rut	Tripp et al. 2006
2002	711[2]	survey estimate	rut	Tripp et al. 2006
2003	617[2]	survey estimate	rut	Tripp et al. 20060
2004	738[2]	survey estimate	calving	Tripp et al. 2006
2007	738[3]	minimum count	winter	Duncan 2009
2017	172	minimum count	winter	(BC MFLNRO, *unpublished data*) BC MFLNRO, *unpublished data*

[1] Combined minimum counts from what were known as the Toad River and Racing River herds. The combined survey areas were likely much smaller than the current range of the Muskwa herd

[2] Estimates were derived using a sightability index based on radio-collared animals. Sightability varied from 37-92%. Tripp et al. (2006) conducted multiple surveys per year (calving, rut and winter) during 2000 – 2003 but only estimates from the rut are shown as these were the highest within a given year.

[3] Incidental observations of caribou conducted during an aerial survey to census Stone's sheep

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

Year	Calves: 100 Females	% Calves	Survey Timing	Reference
1979	45.7	-	March	Bergerud and Elliott 1998
1980	28.4	-	March	Bergerud and Elliott 1998
1985	38.6	-	March	Bergerud and Elliott 1998
1987	30.4	-	March	Bergerud and Elliott 1998
1990	17.5	-	March	Bergerud and Elliott 1998
2001	-	14	March	Tripp et al. 2006
2002	-	20	February	Tripp et al. 2006
2003	-	17	March	Tripp et al. 2006
2007	-	8	winter	Duncan 2009 (BC MFLNRO, *unpublished data*)
2017	-	12	March	BC MFLNRO, *unpublished data*

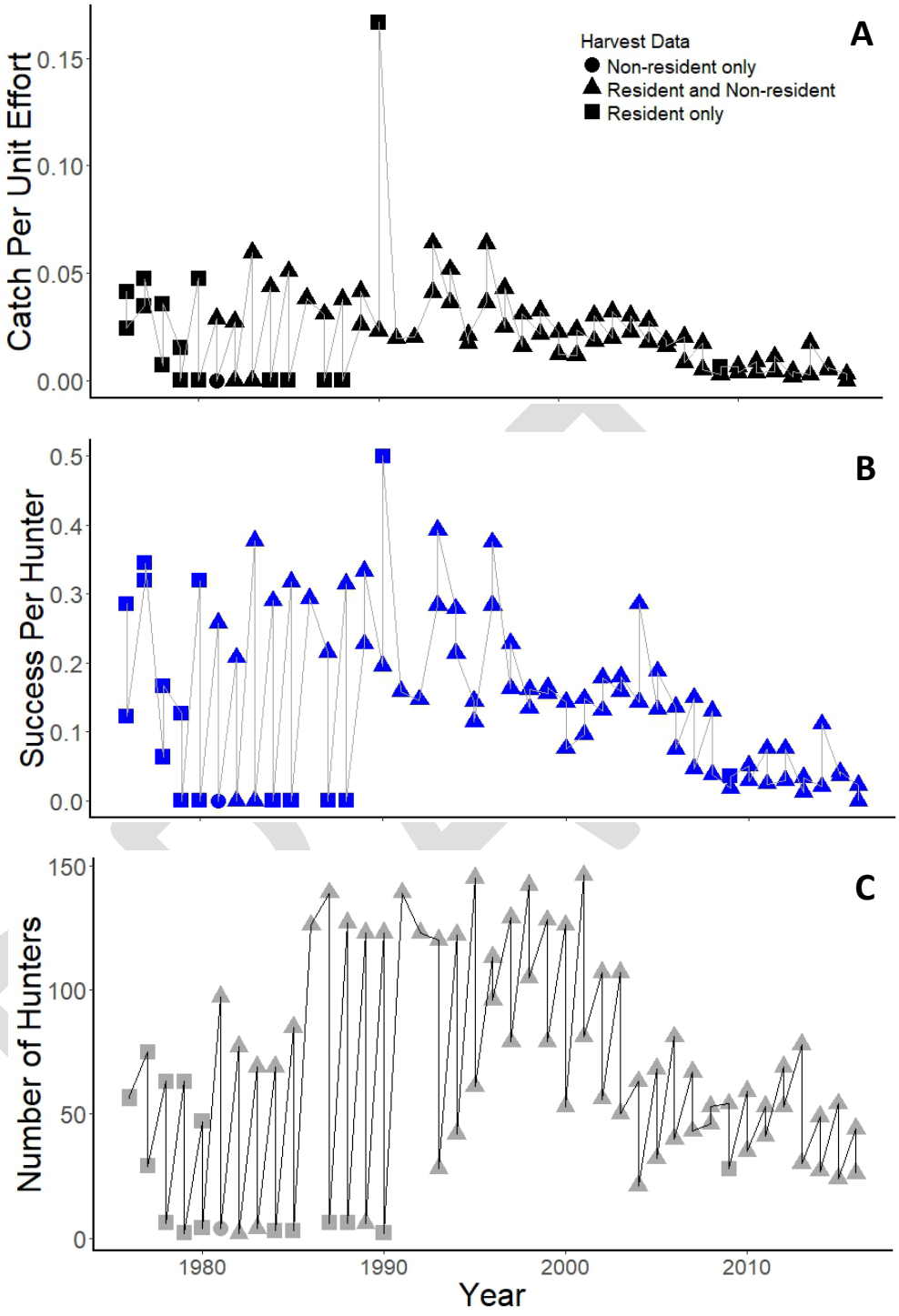

Figure 2: Harvest indices for the Muskwa subpopulation of northern mountain caribou in northeastern British Columbia from 1976 to 2016. Catch per unit effort (A) is the total kills divided by the total number of hunter-days. Success per hunter (B) is the total kills divided the total number of hunters.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

3 THREATS AND LIMITING FACTORS

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

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

3.1 PREDATION

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

Predation is thought to be a major limiting factor influencing the population dynamics of Muskwa caribou (Bergerud and Elliott 1998). During wolf reductions in the 1980s, the Muskwa population is thought to have increased, primarily due to high rates of juvenile recruitment. Adult female survival is also likely to have increased as Bergerud (1996) has suggested that in natural systems similar to those in the Muskwa range, 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). The recent low population size and low rate of juvenile recruitment within the Muskwa range may be indicative of a high predation environment. If predation is indeed a primary driver in this recent population decline, it is unknown whether this current dynamic is within the typical variation expected within a caribou-multi-predator system.

3.2 FOOD LIMITATION

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

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

To date, there have been no studies explicitly evaluating the nutritional condition of Muskwa caribou. Studies, however, have been undertaken in the adjacent 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 Muskwa caribou range are minimal. Using cutblock GIS data up to 2015, the few cutblocks < 20 years old that occur within the range are situated in its northeast corner and comprise < 0.02% of the range's area. The intensity of cutblocks, however, does increase outside of the range boundary, particularly to the northeast.

3.3.1.2 MINING

Impacts from mining primarily relate to direct habitat loss. The effective amount of habitat loss, however, can extend well beyond its physical footprint due to behavioural avoidance of areas surrounding mine infrastructure (Polfus et al. 2011, Johnson et al. 2015). As noted previously, impacts that limit the spatial distribution of caribou can potentially lead to increased predation risk (Fortin et al. 2013, DeMars et al. 2016). Related infrastructure such as roads may further increase predation risk by increasing predator hunting efficiency and facilitating predator movement into caribou habitat (Latham et al. 2011*a*, DeMars and Boutin 2018).

The Muskwa-Kechika Management Area, which comprises a large proportion of the Muskwa caribou range, is mandated to balance responsible resource development outside of Protected Areas with fish and wildlife conservation. As a consequence, there are several mineral tenures located within the Muskwa caribou range. To date, none of these tenures have proceeded to large-scale development and thus there are currently minimal impacts from mining within the Muskwa caribou range.

3.3.1.3 Oil and Gas

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

Impacts from oil and gas exploration and extraction constitute the most ubiquitous form of human disturbance in northeastern British Columbia, including within the Muskwa caribou range (Thiessen 2009, DeMars and Boutin 2018). Such disturbances include polygonal features such as well sites and camps as well as linear disturbances such as seismic lines, pipe lines and roads. For the former, GIS data available from the BC Oil and Gas Commission up to 2016 suggests that there are ~ 80 active, completed or abandoned wells within the Muskwa range. The vast majority of these wells occur in the eastern third of the range. Linear features are the most widespread form of disturbance and their impacts are further discussed in *Section 3.3.3.3 Linear Features* below.

3.3.1.4 Clean Energy

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

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

3.3.1.5 Other

There are currently no other major forms of industrial development within the Muskwa 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 comprises a large proportion of the Muskwa caribou range. Snowmobiling is restricted to specific designated routes, such as the Wokkpash Corridor, the Nonda Creek Corridor and the West Yedhe Creek Trail (http://www.muskwa-kechika.com/management-area/access-management). Because of the remoteness of the Muskwa range, snowmobile use is relatively light compared to other ranges of mountain-dwelling caribou further south in the province.

3.3.2.2 HELI-SKI / CAT-SKI

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

There are no heli-skiing or cat-skiing companies operating within the Muskwa 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 Muskwa subpopulation of NM caribou is likely minimal. As mentioned previously, motorized travel within the Muskwa-Kechika Management Area is restricted to a few designated routes. Hiking and horseback riding both occur within the Muskwa range though their intensity is likely low due to the remoteness of this range and the small number of developed trails.

3.3.2.4 Other

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

3.3.3 Other

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

3.3.3.1 Agriculture

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

Agricultural impacts within the Muskwa caribou range are minimal, being restricted to a few small areas near the community of Toad River.

3.3.3.2 Major Highway Corridors

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

The only major highway impacting the Muskwa subpopulation is the Alaska Highway, which travels in an east-west direction through northern one third the range then travels along the northwest boundary. Muskwa caribou are frequently observed crossing this highway, particularly during winter (Bergerud 1978) and mortalities due to vehicle collisions are known to occur (Tripp et al. 2006).

3.3.3.3 LINEAR FEATURES

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

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

3.3.3.4 HUNTING

Historical records indicate that NM caribou have long been hunted by First Nations in BC (Spalding 2000). Muskwa caribou also have a long history of being hunted following Euro-American settlement of the region. Guided hunting has occurred within the Northern Rocky Mountains at least since the 1940s (Spalding 2000) and Bergerud (1978) suggested that caribou in the Racing River area appeared to be "overhunted" in the 1970s. Currently, licensed hunting for caribou is still allowed within WMUs 7-50, 7-51 and 7-54, which collectively comprise ~ 75% of the Muskwa 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 Muskwa range, see *Section 2.3 Population Size and Trend* and Figure 2 above.

3.3.3.5 POACHING

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

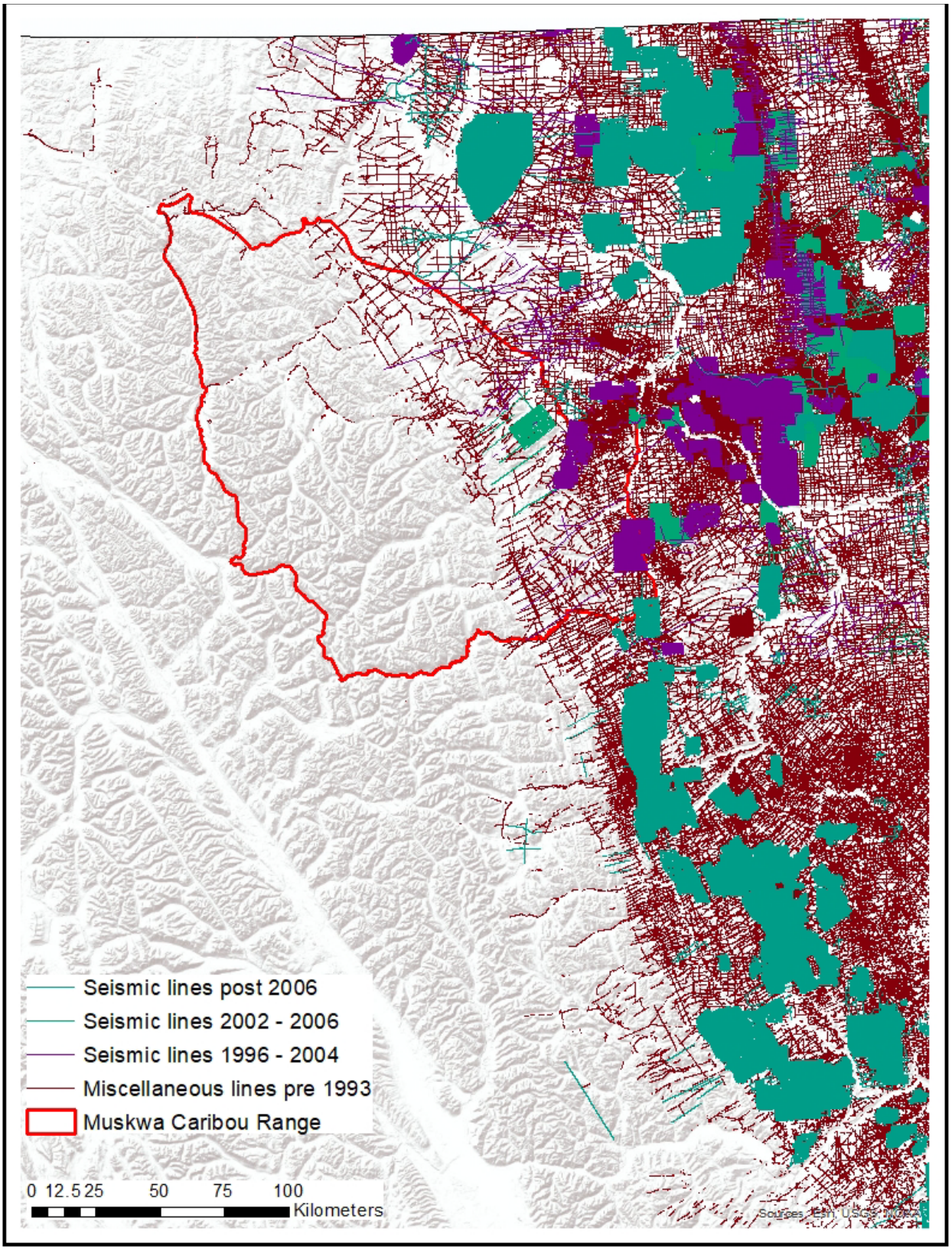

Figure 3: The distribution of seismic lines within the range of the Muskwa subpopulation of northern mountain caribou.

3.4 Natural Disturbance

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

Within the boreal forests of northeastern British Columbia, the median return interval for forest fires is ~ 100 years (Johnstone et al. 2010). Using forest fire data available to 2015, the extent of areas burned < 50 years ago constitutes ~ 11% of the Muskwa range with the majority of these fires situated in lower elevation conifer forests. Within the last 50 years, the largest fire occurred in 1981 (45,218 ha burned) and was situated in the eastern part of the range.

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

3.5 Parasites and Diseases

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

Impacts from parasites and disease on the population dynamics of Muskwa 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 Muskwa 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 Muskwa 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 Muskwa subpopulation as recent demographic data suggests a minimum population size of > 170 animals (see *Section 2.3*). This subpopulation, however, could become subject to small population size effects in the near future if abundances continue to decline.

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 Muskwa subpopulation under five broad categories: habitat management, recreation and access management, predator management, alternate prey management, and population reinforcement. For a review of this subpopulation's harvest history and management, see Sections *2.3 Population Size and Trend* and 3.3.3.4 *Hunting*.

4.1 HABITAT

Protecting and restoring sufficient habitat for caribou to carry out essential life processes and reduce predation risk is fundamental to achieving self-sustaining populations (Environment Canada 2014, Ray

et al. 2015). NM caribou require large tracts of undisturbed habitat and have evolved to inhabit alpine areas and old-growth forests, which separates them – both in terms of elevation and horizontal space – from other ungulates and their generalist predators (Bergerud et al. 1984, Bergerud and Page 1987, Seip 1992). In winter, NM caribou use mature forests and wind-swept alpine areas to access lichen (Johnson et al. 2004). Summer ranges are typified by alpine birch-sedge meadows (Oosenbrug and Theberge 1980, Denryter et al. 2017). Spatial requirements for NM caribou also extend beyond seasonal areas of high use (i.e. habitat cores) and can include "matrix" habitat, areas of relatively low use that may be used during migration (Environment Canada 2012*a*).

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

4.1.1 Protection

Approximately 74% of the Muskwa 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 32% of the range's area, provide even stronger protections as no industrial development is permitted in these areas. An area of Ungulate Winter Range for Stone's sheep also occurs along the range's southwestern boundary.

4.1.2 Enhancement and Restoration

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

4.2 Recreation and Access Management

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

4.2.1 Snowmobile

Snowmobile use within the Muskwa 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. Outside of this Management Area, there are no restrictions on snowmobile activity.

4.2.2 Heli-ski / Cat-ski

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

4.2.3 SUMMER RECREATION

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

4.2.4 OTHER

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

4.3 PREDATORS

Actions aimed at managing predators may include liberalizing hunting and trapping quotas (Cluff and Murray 1995), diversionary feeding (Lewis et al. 2017), managing alternate prey (Serrouya et al. 2017*c*), and lethal control (Bergerud and Elliott 1998, Hervieux et al. 2014). Note that actions such as lethal control are controversial (Boertje et al. 2010, Lute and Attari 2017) and are generally considered short-term strategies used to sustain small and rapidly declining populations until the effects of habitat restoration and protection are realized (Wittmer et al. 2010, Hervieux et al. 2014).

4.3.1 WOLF MANAGEMENT

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

Since the cessation of province-wide wolf control, the Muskwa caribou range has had two documented periods of wolf removals. From 1978 – 1980, an unknown number of wolves were removed by local guide outfitters (Bergerud and Elliott 1998). In the mid- to late-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 caribou range, 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). These removals resulted in high recruitment rates and probable population growth in caribou. The effects of the wolf removal program, however, was short-term as recruitment rates had lowered from 30.4 calves per 100 females in the last year of wolf removal to 17.5 calves per 100 females three years later.

Since the late-1980s, there have been no other wolf removal efforts within the Muskwa range. Currently, there is an eight month general hunting season for wolves with a bag limit of three in WMUs

within and adjacent to the Muskwa range. In 2016, removal of the bag limit was being considered (https://www2.gov.bc.ca/assets/gov/sports-recreation-arts-and-culture/outdoor-recreation/fishing-and-hunting/hunting/regulations/2016-2018/hunting-trapping-synopsis-2016-2018-region7b.pdf).

4.3.2 Cougar Management

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

4.3.3 Other

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

4.4 Alternate Prey

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

4.4.1 Moose Management

Within the last five years, surveys to estimate moose abundance have occurred in two WMUs (7-49 and 7-51) overlapping the Muskwa range. In 2012 and 2013, mid-winter composition surveys in the Toad River drainage (WMU 7-51) estimated a moose density of 0.33 and 0.49 moose / km^2, respectively (Kline 2013*a*, *b*). In 2016, a survey of WMU 7-49, which covers the eastern third of the range, estimated a moose density of 0.14 moose / km^2 (Patterson and Smith 2016). In all surveys, moose were the most abundant ungulate. Moose densities for all four WMUs overlapping the Muskwa range were also estimated by Poole and DeMars (2015). These estimates were based on habitat capability modelling and ranged from 0.13 (WMU 7-51) to 0.48 moose / km^2 (WMU 7-54). For perspective, Bergerud (1996) has suggested that caribou populations will decline when moose densities exceed 0.2 – 0.3 / km^2.

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

4.4.2 Deer Management

White-tailed deer and mule deer are present within the Muskwa caribou range. Mule deer are more abundant (Kline 2013*a*) although the northern distribution and abundance of white-tailed are likely increasing (Latham et al. 2011*b*, Dawe and Boutin 2016). A general hunting season is open for mule deer bucks (four points or larger) and white-tailed deer bucks in WMUs 7-49, 7-50 and 7-54. 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 Muskwa caribou range.

4.4.3 Other

Elk (*Cervus elaphus*) and Stone's sheep are also present within the Muskwa caribou range. For elk, there is a general hunting season in WMUs 7-49 and 7-50 for three-point bulls and larger while harvest is restricted to bulls with six points or larger in WMUs 7-51 and 7-54. For Stone's sheep, there is a general hunting season for full curl rams in WMUs 7-50, 7-51, and 7-54. The bag limit for each species is one. Neither species has been subject to management actions in the context of caribou conservation.

4.5 Population Reinforcement

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

4.5.1 Maternal Penning

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

Maternal penning has not been used within the Muskwa 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 Muskwa 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 Muskwa subpopulation.

4.5.4 OTHER

There have been no other forms of population reinforcement implemented for the Muskwa 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 Muskwa range to understand caribou behaviour and ecology. Bergerud (1978) conducted initial surveys of the "Racing River Herd", the "Tuchodi River Herd" and the "Toad River Herd", which all fall within the current boundary of the Muskwa range. Besides providing minimum counts, these surveys allowed Bergerud (1978) to speculate on the likely seasonal movements of these caribou groups.

The first in-depth research studying Muskwa caribou occurred from 2000-2004 when a total of 46 females were radio-collared (Tripp et al. 2006). The majority of these collars were VHF (n = 43) and these caribou were relocated by aerial telemetry twice per month during the study's first two years then 7-8 times per year in the last two years. The spatial data from the radio-collars allowed for the first analysis of habitat selection by Muskwa caribou and the study concluded that high-elevation parkland

and tundra were important year-round habitats. In addition to these spatial analyses, the study collected demographic information by estimating survival rates and surveying the range by helicopter in spring, fall and late winter to determine herd composition and size. The study also assessed for potential limiting factors by investigating mortality sites.

Recently, a new radio-collaring program has been initiated within the Muskwa range. Between March 2016 and January 2017, a total of 19 GPS radio-collars have been deployed on adult females. Data from these animals will augment earlier analyses by Tripp et al. (2006) to further understand seasonal movements, habitat selection and demography of Muskwa caribou.

4.8 MONITORING

Over the last 50 years, the Muskwa subpopulation has been infrequently surveyed and has been primarily monitored by harvest statistics (Environment Canada 2012*a*). In the mid- to late-1970s, periodic surveys were conducted to estimate the minimum size and composition of the "Racing River Herd", "Tuchodi River Herd", and "Toad River Herd", all of which are part of what is now considered the Muskwa range (Bergerud 1978). The subpopulation did not receive another survey until 1990 when Bergerud & Elliot (1998) conducted a complete census as part of a project studying the effects of wolf removal on ungulate population dynamics. The next surveys occurred a decade later when Tripp et al. (2006) conducted multiple surveys per year from 2000-2004 to assess seasonal changes in herd size and composition.

Since the cessation of the Tripp et al. (2006) study, the provincial government has conducted two late-winter surveys to record minimum counts and juvenile recruitment. The first survey occurred in 2007 and the second in 2017. This latter survey has coincided with a new monitoring initiative for the Muskwa subpopulation, which has resulted in GPS radio-collars being deployed on 19 females. Data from these animals should provide current demographic data that can be used to better monitor population trend and assist in future efforts to estimate population size.

5 IMPLICATIONS TO OTHER WILDLIFE

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

1. *Population Management*

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

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

surveys (e.g. every five years) should be done, however, to validate trend estimates (Serrouya et al. 2017*a*).

- *Manage harvest for sustainable use*

  Current hunting regulations allow for a general season on 5-point bulls within the Muskwa range with no quota on the number of animals harvested. Declining harvest indices over the last decade (see Section 2.3 *Population Size and Trend*), however, suggest a declining caribou population and thus current harvest regulations should be examined to assess whether harvest rates are sustainable for the current population size.

- *Identify limiting factors contributing to suspected population decline*

  The recent (2017) low minimum count of the Muskwa subpopulation combined with low rates of juvenile recruitment, and decreasing harvest indices all suggest that the Muskwa subpopulation is in decline. Understanding the factors driving this decline should be given a high priority.

2. *Habitat Management*

- *Identify then ensure protection of core habitat areas*

  Tripp et al. (2006) conducted initial habitat mapping efforts to identify seasonally important and these analyses should be augmented with the data collected from recently deployed GPS radio-collars. Compared to other caribou ranges, the Muskwa has a high proportion of its area falling within Provincial Parks and Protected Areas and much of the range lies within the Muskw-Kechika Management Area. Nevertheless, the eastern portion of the range is being impacted by oil and gas exploration and development and understanding caribou use of these area should be a priority.

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

8.1 Short Term (Within 6-12 Months)

[BLANK FOR NOW]

8.2 Medium Term (Within 12-24 Months)

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8.3 Long Term (Within 24-48 Months)

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9 Literature Cited

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