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

Maxhamish Subpopulation

Boreal
Local Population Unit

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

Caribou in the Maxhamish range are a subpopulation of boreal caribou, an ecotype of woodland caribou federally designated as *Threatened* under the *Species at Risk Act*. Boreal caribou are broadly distributed within the boreal forests of Canada, occurring in seven provinces and two territories. At present, this distribution contains 51 recognized ranges, defined as geographic areas containing groups of interacting boreal caribou that are subject to similar ecological conditions that influence their demography (Environment Canada 2012). Within the classification system for caribou adopted by the *Committee on the Status of Endangered Wildlife in Canada*, boreal caribou constitute Designatable Unit 6 (COSEWIC 2011).

In British Columbia, boreal caribou are found in the northeast corner of the province within the Boreal Plains and Taiga Plains ecoprovinces (Fig. 1). There are currently five recognized ranges: Calendar, Chinchaga, Maxhamish, Snake-Sahtaneh, and Westside Fort Nelson. In general, these ranges capture 99% of historic and recent telemetry data (BC MoE / MFLNRO 2017) and range boundaries are delineated by large river corridors or jurisdictional boundaries (Culling et al. 2004). For ranges (n = 3) bounded by provincial and/or territorial borders, caribou are likely part of larger subpopulations that cross jurisdictions. Provincially, boreal caribou are currently *Red-listed* due to suspected declines across their distribution.

2.1 DISTRIBUTION

The range of the Maxhamish subpopulation is situated in the northwest corner of the Taiga Plains ecoprovince (Fig. 1). The 7775 km^2 range is bounded by the Northwest Territories border to the north, by the Liard and Fort Nelson Rivers to the west and south, the Snake-Sahtaneh range to the east and the Petitot River to the northeast. Within the range are three habitat cores – Fortune, Kiwigana and Capot Blanc. Habitat cores are areas with high habitat suitability and encompass > 90% of caribou telemetry locations (Culling et al. 2004, BC MoE / MFLNRO 2017). The Maxhamish range also encompasses Maxhamish Lake Provincial Park and Protected Area.

2.2 HABITAT AND BEHAVIOUR

Across their distribution, boreal caribou occur at low-densities (e.g. ≤ 3 / 100 km^2; COSEWIC 2002) within large tracts of old-growth forest and low-lying peatland complexes (Bradshaw et al. 1995, Culling et al. 2006, DeMars 2015). Within these habitat types, boreal caribou are uniquely adapted to subsist on terrestrial lichens, particularly during the winter (Thompson et al. 2015). The ability to exploit these low-productivity habitats is thought to be an evolutionary strategy for reducing predation risk because it spatially separates caribou from other ungulate species and their generalist predators, which generally favor drier, more productive upland areas (James et al. 2004).

The Maxhamish range is typical of most boreal caribou ranges in their western distribution (i.e. Alberta and British Columbia), consisting of a mosaic of deciduous and mixed-wood uplands, treed peatland complexes and riparian areas. Common upland tree species include white spruce (*Picea glauca*), lodgepole pine (*Pinus contorta*), trembling aspen (*Populous tremuloides*), and paper birch (*Betula papyrifera*). Low-lying peatlands are characterized by black spruce (*Picea mariana*) and tamarack (*Larix laricina*). The terrain is generally flat to undulating with elevations ranging from 400 to 700-m.

Among caribou ecotypes, boreal caribou are considered sedentary as they inhabit boreal forests year-round. Although they do not undergo long-distance migrations like barren-ground caribou, boreal caribou still exhibit seasonal changes in movement and social behaviours (Schaefer et al. 2000, Ferguson and Elkie 2004) and they

have adapted a unique spacing strategy to reduce predation risk. During fall, winter and early spring, boreal caribou generally occur in small groups of 5 – 10 individuals (Rettie and Messier 1998, Culling et al. 2006). Group-living during these periods is likely advantageous because it reduces encounter rates with predators (DeMars et al. 2016) and facilitates early predator detection (Pulliam 1973). Just prior to calving, however, females leave groups and disperse widely on the landscape as individuals. This "spacing out" strategy (*sensu* Bergerud and Page 1987) is evolutionarily advantageous because it eliminates the likelihood of predators killing multiple vulnerable calves on encounter if caribou were to remain in groups at calving (DeMars et al. 2016). Parturient females in the Maxhamish range also show a slight seasonal change in habitat selection, shifting from treed bogs in winter to nutrient-poor fens at calving (DeMars 2015).

2.3 Population Size and Trend

Historical accounts of boreal caribou in northeastern British Columbia are limited to three references from the early 1900s, which is insufficient for evaluating long-term changes in abundance and distribution (Spalding 2000). Traditional ecological knowledge from First Nations suggests that boreal caribou were more widespread and abundant then they are today with declines attributed to impacts from agriculture and natural resource exploration and extraction (FNFN 2017).

Reliable estimates of population size are currently lacking for most boreal caribou ranges, primarily because these animals are difficult to count due to their cryptic nature and preference for forested habitats. Recent advances in fecal DNA mark-recapture methods are promising (e.g. Hettinga et al. 2012) but as yet have not been applied in British Columbia ranges.

The first estimate of population size for the Maxhamish range was provided in 2004 (Culling et al. 2004). This estimate of 306 caribou (80% confidence interval: 220 – 392) was based on density estimates extrapolated from winter ungulate inventories conducted in Wildlife Management Units 7-55 and 7-56. In 2006, an aerial survey of the Maxhamish range using a stratified random block design yielded an estimate of 200 caribou, although application of a sightability correction factor using radio-collared animals suggested that the estimate could be as high as 340 (BC Ministry of Environment 2006). These estimates, however, had low precision (90% confidence interval: ± 71.6%). Subsequent estimates provided by BC Ministry of Environment in 2010 and by Environment Canada in 2012 suggested a population size of 300 caribou (reviewed in Culling and Cichowski 2017).

In December 2012, a large-scale radio-collaring program was initiated as part of the *Boreal Caribou Implementation Plan* released in 2011 (BC Ministry of Environment 2011*a*). The program's objective was to maintain a sample of radio-collared caribou representing ~ 15% of each range's estimated population. Following collar deployments, annual aerial surveys have been conducted to estimate the minimum number of caribou alive in each range (Culling and Culling 2013, 2014, 2015, 2016, 2017). These estimates are derived by relocating radio-collared caribou then enumerating all caribou associated with radio-collared individuals as well caribou groups encountered incidentally. For the Maxhamish range, the highest estimate was recorded in 2013 (n = 132) and subsequent estimates have suggested a slightly declining population (Fig. 2).

Because reliably estimating population size for boreal caribou is difficult, many jurisdictions rely on the "R/M" equation to monitor population trend (Hatter and Bergerud 1991, DeCesare et al. 2012, Hervieux et al. 2013). This equation takes the form

$$\lambda = \frac{1 - M}{1 - R}$$

where λ is the population growth rate , M is the mortality rate estimated from radio-collared individuals and R is juvenile recruitment, defined as calf survival to ~ 10 months of age. DeCesare et al. (2012) recommended that R be adjusted to reflect the ratio of juvenile females to total females in the population. Growing populations are reflected by values $\lambda > 1.0$ whereas λ is < 1.0 for declining populations. For the Maxhamish population, λ values for the first two years of monitoring (2014 and 2015) were significantly below 1.0 then rebounded to > 1.0 the last two years (Fig. 3). Note that population trends are most effectively evaluated over three generations (~ 6.7 years per generation for caribou), which is 20 years for caribou, and thus the short monitoring interval of four years for the Maxhamish range limits inferences on population trend (COSEWIC 2002).

The variability in λ values is reflected in both of its components, adult female survival and juvenile recruitment (Fig. 4). Adult female survival increased from 0.78 to 0.93 over the four-year monitoring period while juvenile recruitment increased from 10 calves: 100 females in 2014 to 29 calves: 100 females in 2016 before dropping back down to 16 calves: 100 females in 2017. As with λ, inferences on trend in these two demographic parameters is limited by the short, four-year monitoring interval.

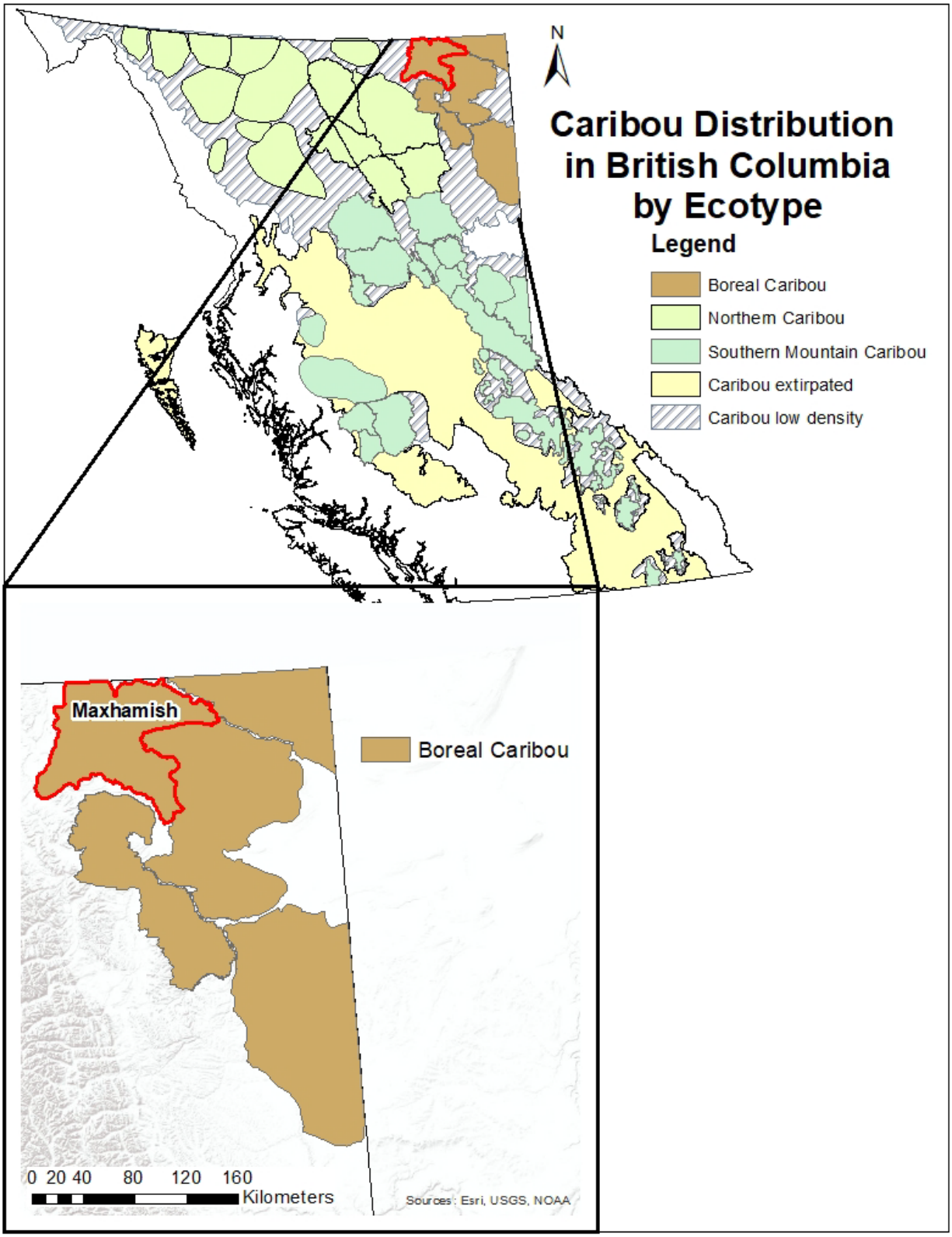

Figure 1: The geographical location of the Maxhamish subpopulation of boreal caribou. The 7775 km^2 range (inset: red outline) is situated in northeast British Columbia along the border with the Northwest Territories.

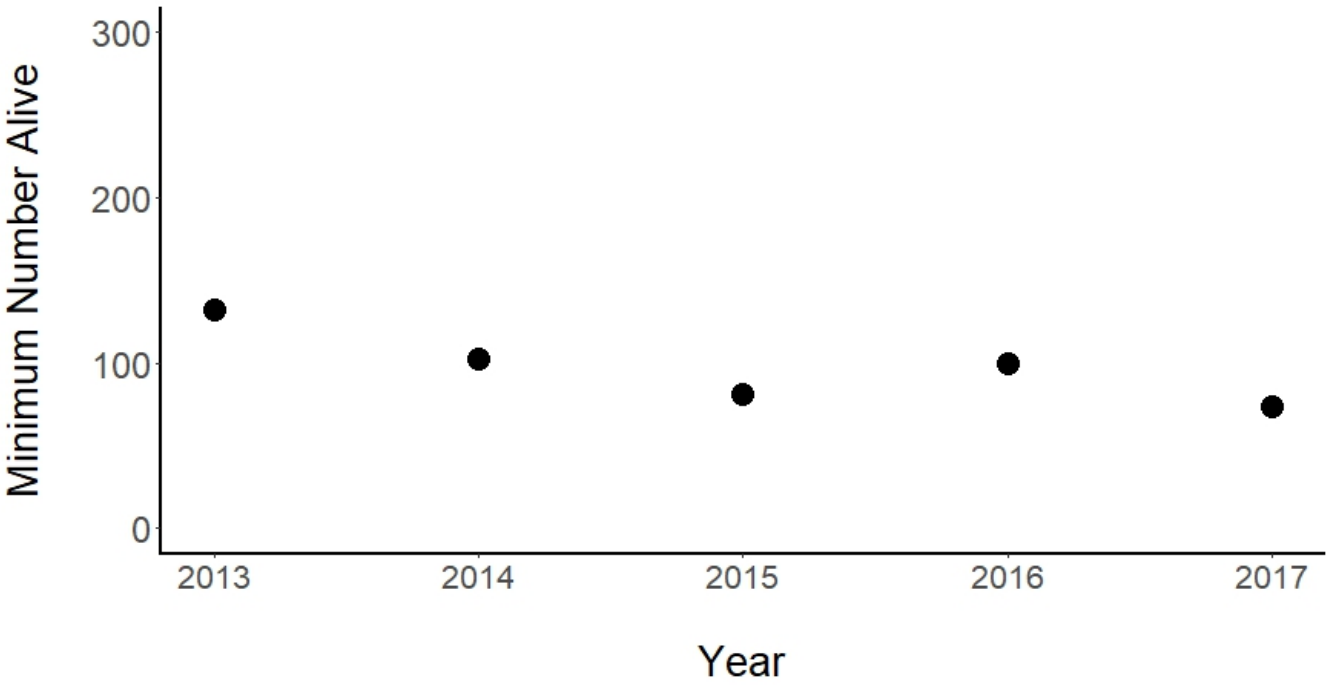

Figure 2: Estimates of the minimum number of caribou alive by year for the Maxhamish subpopulation of boreal caribou. Estimates represent the number of caribou observed during aerial surveys conducted in late winter (March) where all groups containing collared females were enumerated as well as groups incidentally observed.

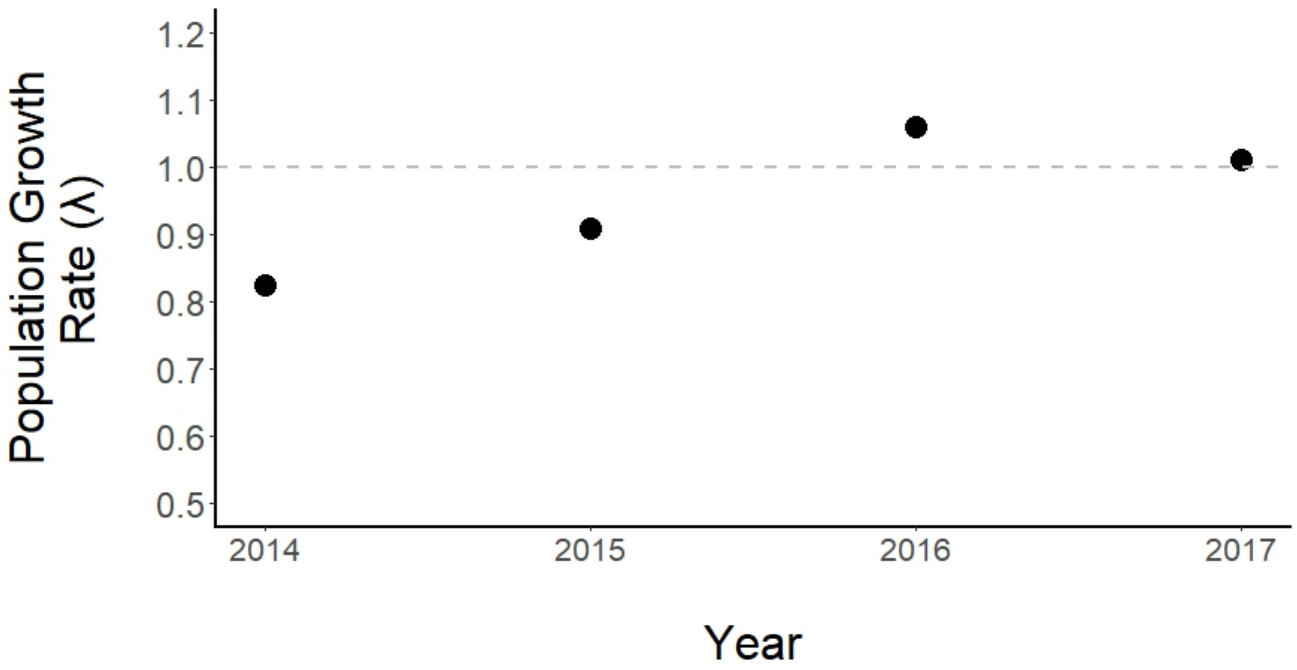

Figure 3: Estimates of annual population growth rates (λ) for the Maxhamish subpopulation of boreal caribou in northeastern British Columbia. Values above 1.0 (horizontal dashed line) indicate population growth whereas values < 1.0 indicate population decline.

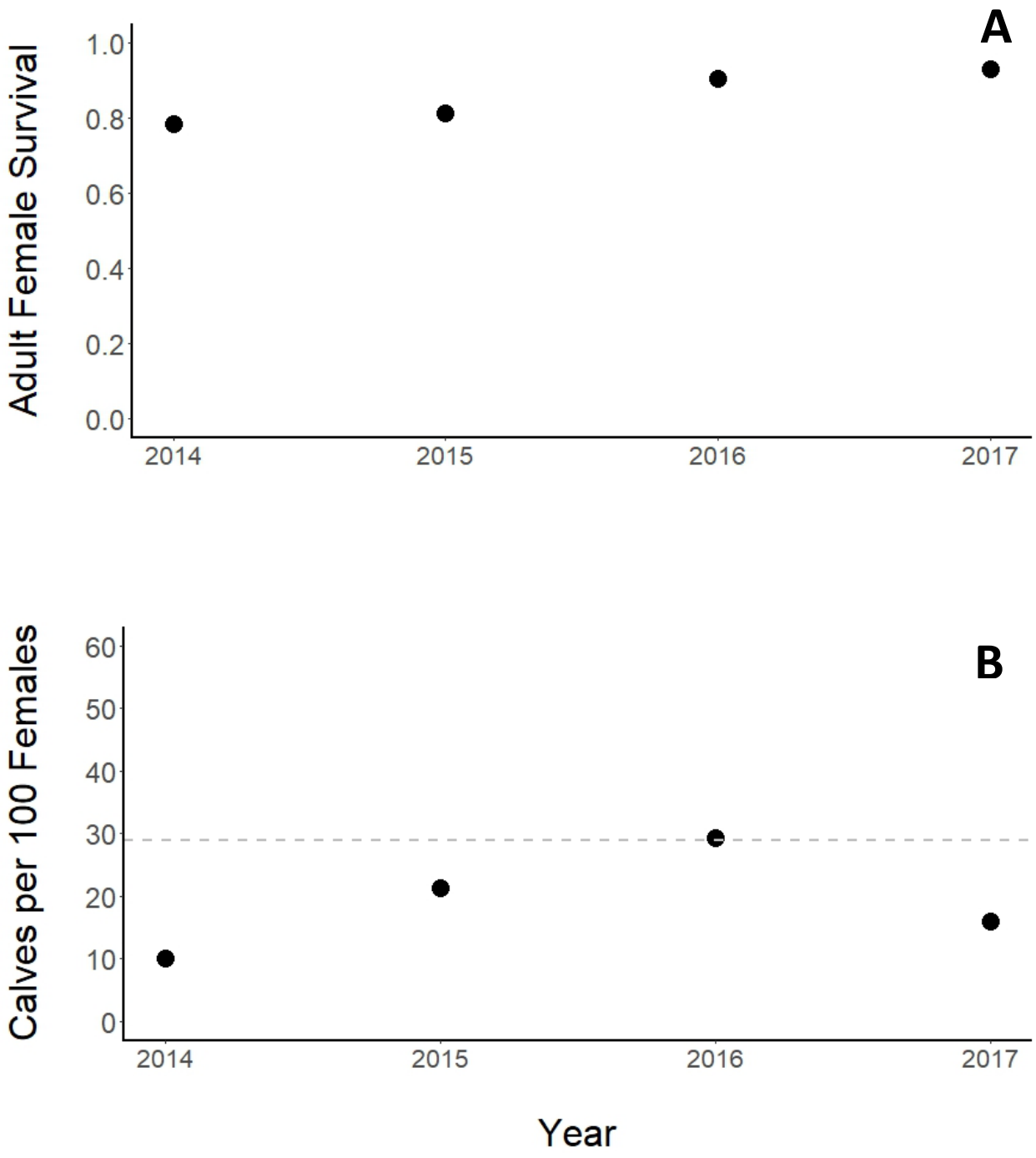

Figure 4: Annual estimates of adult female survival (A) and juvenile recruitment (B) for the Maxhamish subpopulation of boreal caribou in northeastern British Columbia. Estimates of adult female survival were derived from a Kaplan-Meier staggered entry (by month) design with the number of radio-collared individuals starting each monitoring year (1 May – 30 April) varying from 29 to 32. Estimates of juvenile recruitment are indexed by the number of calves per 100 females, which is derived from aerial surveys conducted during late winter (March) and thus calves are counted when they are ~10 months old. Horizontal dashed line represents the ratio of calves-to-adult females that is generally associated with stable populations (Environment Canada 2008).

3 THREATS AND LIMITING FACTORS

Current declines in woodland caribou populations have been ultimately attributed to direct and indirect effects of human activities and climate change (Environment Canada 2008, Vors and Boyce 2009, Festa-Bianchet et al. 2011, Environment Canada 2012). 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, Courtois et al. 2007). 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 *Recovery Strategy* for boreal caribou (Environment Canada 2012) identified a number of threats potentially affecting caribou populations and their habitat. These threats include: habitat alteration from human activities, habitat alteration from natural disturbance (e.g. fire), predation, parasites and disease, hunting, and climate change. This section follows a similar approach, discussing these threats – and others – and their order does not reflect their relative importance to a specific population. 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). Threat effects may also be lagged as demographic or distributional changes in caribou populations may take years to manifest (Vors et al. 2007).

3.1 PREDATION

Increasing rates of predation are the primary proximate cause of decline in most woodland caribou populations (McLoughlin et al. 2003, Wittmer et al. 2005, Apps et al. 2013). Increasing predation has been attributed to changes in the abundances and distributions of predators and alternate prey in response to human-mediated landscape alteration and climate change (Seip 1992, Latham et al. 2011*a*, 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*.

For boreal caribou in northeastern British Columbia, wolf predation has been the leading cause of mortality among radio-collared caribou (n = 240; Culling and Culling 2016, 2017). From 2012 to 2016, a total of 104 mortality sites were investigated (94 radio-collared caribou, 9 uncollared) and of these 72 were attributed to wolves and seven others were suspected to be from wolf predation (Culling and Cichowski 2017). The only other cause of predation-related mortality was attributed to wolverine (n = 3).

The high incidence of wolf predation is likely a result of high wolf densities in northeastern British Columbia. Aerial surveys conducted in 2015 estimated a wolf density of 6.4 – 7.0 wolves / 1000 km^2 in the Calendar range, which is adjacent to Maxhamish, and 13.3 – 15.6 wolves / 1000 km^2 in the Chinchaga range (Serrouya et al. 2015*a*). These estimates exceed densities associated with stable caribou populations (e.g. ≤ 6.5 wolves / 1000 km^2; Bergerud and Elliot 1986).

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 woodland caribou, evidence to date suggests that food limitation is not a primary factor in recent population declines (Wittmer et al. 2005, Festa-Bianchet et al. 2011, McLellan et al. 2012). Such evidence, however, does not preclude any food limitation effect. For example, risk-sensitive foraging in highly altered landscapes that limits caribou distribution may lead to over-grazing that could result in lowered rates of pregnancy, parturition, and over-winter survival (Parker et al. 2009, Heard and Zimmerman 2017), which cumulatively can lower population resilience to other limiting factors such as predation. Food limitations may also result in smaller calves, which could have increased predation risk (Adams et al. 1995).

To assess potential food limitations within woodland caribou, the National Council for Air and Stream Improvement (NCASI) initiated a study in 2012 to assess nutritional condition of animals captured during the deployment of GPS radio-collars in British Columbia and the Northwest Territories (Cook and Cook 2015). This effort included sampling boreal caribou captured in northeast British Columbia. Nutritional condition was indexed by body condition scores and measurements of rump fat obtained by ultrasound. Preliminary results from this study, which is still ongoing, suggested that boreal caribou populations in British Columbia had moderate levels of body fat compared to other caribou populations (e.g. boreal caribou in the Northwest Territories [rated high]; northern ecotype populations in the South Peace [rated low]). Other findings suggested that females raising a calf the previous year had lower indices of body fat. At the population level, this nutritional deficit may affect productivity in subsequent years by lowering pregnancy rates, reducing over-winter survival of the fetus, and/or lowering calf birth weights and subsequently reducing calf survival (Cook et al. 2004, Parker et al. 2009). The extent to which this potential nutrition deficit factors into current declines of many boreal caribou populations is unclear. Moreover, determining the magnitude of food limitation effects is difficult in a high predation environment because predation may occur before effects on body condition become evident (Boutin and Merrill 2016).

3.3 HUMAN ACTIVITIES

Human activities within and adjacent to caribou range are believed to be a primary driver of current declines in woodland caribou populations (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, Lesmerises et al. 2018) and indirectly increasing predation (Courtois et al. 2007, 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 (Seip 1992, James et al. 2004, Serrouya et al. 2011, 2015*b*). 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).

The Maxhamish range has had minimal impacts from logging. Analyses of forestry GIS data up to 2015 suggests that cutblocks < 15 years old comprise < 0.5% of the total range area (https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=50580&recordSet=ISO19115). The majority of cutblocks are situated along the Fort Nelson River near the range's southern border and in the range's southwest corner where the boreal plains transition into the Northern Rockies. Logging also results in the creation of forestry access roads and such features may facilitate predator movements that ultimately result in increased predation of caribou. The impacts of roads on caribou-predatory dynamics are further discussed in *Section 3.3.3.3 Linear Features* below.

3.3.1.2 MINING

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

There are no impacts from mining within the Maxhamish boreal 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 (McKenzie et al. 2012, DeMars and Boutin 2018, Dickie et al. 2017; 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 Maxhamish caribou range (Thiessen 2009*a*, DeMars and Boutin 2018). Such disturbances include polygonal features such 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 suggests that there are > 350 active, completed or abandoned wells within the Maxhamish 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 clean energy facilities located within the Maxhamish boreal caribou range.

3.3.1.5 OTHER

There are currently no other major forms of industrial development within the Maxhamish boreal 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, Lesmerises et al. 2018), 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 may have the highest potential impact on boreal caribou. Compacted trails from snowmobiles may facilitate movement of predators into winter habitats of caribou, thereby increasing predation risk (Droghini and Boutin 2017). Snowmobiling has also been shown to displace caribou from preferred areas and the degree 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).

Snowmobiling impacts within the Maxhamish boreal caribou range are minimal and are likely restricted to trappers accessing trap lines and occasional recreationalists accessing Maxhamish Lake.

3.3.2.2 HELI-SKI / CAT-SKI

Impacts from heli- and cat-skiing are primarily restricted to mountain-dwelling populations of woodland caribou. There are no heli-skiing or cat-skiing activities in the Maxhamish caribou range.

3.3.2.3 SUMMER RECREATION

Recreational activities in the snow-free seasons can also impact caribou populations. Off-road vehicles trails and those associated with 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).

Summer recreational activities are generally rare in the Maxhamish range. The area of highest use is likely Maxhamish Lake and the all-terrain vehicle trail accessing it.

3.3.2.4 OTHER

There are no other forms of recreation currently impacting the Maxhamish caribou range.

3.3.3 OTHER

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

3.3.3.1 AGRICULTURE

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

There are no agricultural areas within the Maxhamish boreal caribou range.

3.3.3.2 MAJOR HIGHWAY CORRIDORS

Major highways may alter or impede caribou movements and can constitute a direct source of mortality (i.e. road kill) for caribou (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 Maxhamish range has one major highway – Highway #77 – running north to south through the central portion of the range. It runs between the Capot Blanc and Kiwigana cores and bisects the Fortune core. The highway generally has low traffic volume and caribou are known to cross it.

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. 2016) 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).

Linear features are the most ubiquitous form of human-caused disturbance within the Maxhamish range. In 2015, the mean density of linear features was estimated to be 3.33 km/km^2 (SD = 2.89; DeMars and Boutin 2018 [Appendix A]). The spatial extent of linear features is such that most areas of the range are within 500-m of a linear feature and areas devoid of linear features – on a per km basis – are rare, constituting ≤ 3% of the range's area (DeMars and Boutin 2018 [Appendix A]). Note that the age, width and state of regeneration on linear features within the Maxhamish range is 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 and traditional knowledge indicate that boreal caribou have long been hunted by First Nations residing in northeastern BC (Spalding 2000, FNFN 2017). There has been no recreational hunting for boreal caribou in British Columbia (COSEWIC 2002) and First Nations subsistence hunting is likely rare (FNFN 2017).

3.3.3.5 POACHING

The current impact of illegal hunting is unknown but is likely small due to the relative remoteness of the Maxhamish range.

3.4 NATURAL DISTURBANCE

Boreal caribou populations are subject to impacts natural disturbances, particularly from forest fires (Dalerum et al. 2007, Sorensen et al. 2008). 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).

Within the boreal plains 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 ~ 2% of the Maxhamish range. Within this time frame, the largest fire occurred in 2012 (3976 ha burned) and was situated in the west-central portion of the range between the Capot Blanc and Fortune cores.

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).

In 2013, a three-year study was initiated to investigate the health status of boreal caribou populations in northeast British Columbia (Schwantje et al. 2014). Caribou exposure to parasites and diseases is evaluated by collecting biological samples from animals captured during radio-collar deployment and from mortality site investigations. During the project's first year, a number of potential threats to boreal caribou were identified, including the pathogenic bacterium *Erysipelothrix rhusiopathiae*, the protozoan parasite *Neospora caninum*, and high winter tick (*Dermacentor albipictus*) loads (Schwantje et al. 2014). Subsequent analyses have suggested that increased exposure to *E. rhusiopathiae* may have contributed to the high rate of mortality observed in 2013 (Schwantje et al. 2016). Further, winter tick may be an emerging threat to boreal caribou in the region as moderate to severe infestations were observed in all ranges. The study will be concluded in 2017 and key final objectives are to

determine how spatiotemporal variation in landscape factors influence caribou health and, by extension, demography, and to develop effective tools for assessing and monitoring caribou health.

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 caribou to access 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 and fire intensity) may further impact caribou through mechanisms outlined in *Section 3.4*.

The Maxhamish range is situated along the border with the Northwest Territories and this northerly location has thus far limited the impact of climate change effects. For example, white-tailed deer are rare within the Maxhamish range whereas white-tailed deer abundances have increased significantly in more southerly ranges of boreal caribou (Latham et al. 2011*b*, Dawe and Boutin 2016). Recent analyses using demographic data from northeast British Columbia, however, 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 Maxhamish subpopulation has been 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.

Effects from small population size are likely to be minimal in the Maxhamish subpopulation. Recent demographic data suggests a minimum population size of > 50 animals and estimated growth rates over the past two years suggest an increasing population (see *Section 2.3*).

4 Management History

Boreal caribou have been listed as *Threatened* by the *Committee on the Status of Endangered Wildlife in Canada* since 2002 but in many jurisdictions they have been a management concern prior to this designation due to

suspected long-term population declines (Bergerud 1974, Edmonds 1986, Rettie and Messier 1998, Dzus 2001). Bergerud (1974) was among the first to suggest that observed declines in woodland caribou populations were due to increasing predation ultimately facilitated by human-mediated landscape alteration. Because of this link, early management recommendations for boreal caribou, such as those developed in Alberta, focused on protecting habitat and managing its distribution in multi-use landscapes, though many recommendations were never officially implemented (reviewed in Dzus 2001). In 2008, the *Scientific Review for the Identification of Critical Habitat* for boreal caribou documented strong relationships between caribou demographic performance and landscape alteration and suggested alteration effects were best measured at the range scale (Environment Canada 2008). In 2012, the *Federal Recovery Strategy* refined this relationship, suggesting that boreal caribou populations had a 60% probability of being self-sustaining if > 65% of the area within a range is undisturbed (Environment Canada 2012). Attaining 65% undisturbed habitat is now a primary focus of current range plans aimed at stabilizing and recovering populations of boreal caribou (ECCC 2017).

For small and rapidly declining caribou populations residing in highly altered ranges (e.g. < 65% undisturbed area), habitat restoration will likely be insufficient to prevent their extirpation in the short-term because it may take decades to restore old-growth conditions conducive to caribou persistence (Schneider et al. 2010, Wittmer et al. 2010). Consequently, other tools for population management have been developed to sustain caribou populations until the effects of habitat protection and restoration can be realized. Such actions include managing populations of predators (Hervieux et al. 2014, Lewis et al. 2017) and / or alternate prey (Serrouya et al. 2015*b*, 2017*c*), and population reinforcement (Smith and Pittaway 2011, Hayek et al. 2016).

In British Columbia, boreal caribou were ranked as vulnerable and *Blue-listed* in 2000, a designation for species of special concern. This listing coincided with more active management of boreal caribou, beginning with a five-year radio-collaring study of caribou in the Snake-Sahtaneh range (Culling et al. 2006). This study resulted in the development of industry guidelines for operating within caribou range (Culling et al. 2004). Further monitoring of boreal caribou populations via radio-collaring and aerial surveys occurred over the subsequent five years (Rowe 2006, Thiessen 2009*b*, Thiessen and DeMars 2010). In 2010, the *Implementation Plan for the Ongoing Management of Boreal Caribou in BC* (BCIP) resulted in the formation of the Research Effectiveness and Monitoring Board (REMB), which has since overseen boreal caribou research in the region. The BCIP also provided measurable targets for managing boreal caribou habitat and the industrial footprint within caribou ranges (BC Ministry of Environment 2011*a*). These targets and other conservation objectives have since been revised in the recently released *Boreal Caribou Recovery Implementation Plan* (BCRIP; BC MoE / MFLNRO 2017).

This section reviews management actions undertaken for the Maxhamish subpopulation under five broad categories: habitat management, recreation and access management, predator management, alternate prey management, and population reinforcement.

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 2012, Ray et al. 2015). Boreal caribou require large tracts of undisturbed habitat and have evolved to inhabit old-growth forests and low-lying peatland complexes, which separates them from other ungulates and their generalist predators (Rettie and Messier 2000, James et al. 2004). Spatial requirements for caribou may extend beyond range boundaries as abundances of alternate prey and predators in surrounding "matrix" habitat may influence caribou-predator dynamics due to predators "spilling over" into caribou range (Holt 1984). In Alberta, the *Alberta Caribou Committee Governance*

Board suggested that a 20-km buffer be applied to caribou ranges, an extent that reflects the average territory size of wolf packs in western boreal forests (Athabasca Landscape Team 2008).

Impacts to caribou habitat are generally assessed at the range scale in a cumulative effects framework (Environment Canada 2008, 2012). The 2012 federal *Recovery Strategy* suggests that populations of boreal caribou have a higher probability of being self-sustaining when their range contains at least 65% undisturbed habitat (Environment Canada 2012). This threshold is calculated by adding up the spatial extents of burned areas ≤ 40 years post-fire and anthropogenic disturbances, which are buffered by 500-m. In 2012, Environment Canada estimated that undisturbed habitat comprised 42% of the Maxhamish range.

4.1.1 PROTECTION

Prior to the release of the BCIP in 2010, management actions for protecting boreal caribou habitat were primarily dictated by *Ungulate Winter Range* (UWR) and *Wildlife Habitat Areas* (WHA) designated by the *Forest and Range Practices Act* (FRPA; Goddard 2009). UWRs protected habitats critical for over-winter survival while WHAs protected other habitats used during demographically periods such as calving and rutting. Proposed UWR and WHA polygons for boreal caribou were located within core areas (Culling et al. 2006) but did not capture the entirety of these cores due to FRPA restrictions on the amount of the timber harvesting land base that can be impacted. In the Fort Nelson Forest District, a maximum of 6,666 ha and 6,580 ha could be impacted by UWRs and WHAs, respectively. However, because boreal caribou predominantly use low-lying peatlands that have limited timber value, the proposed UWRs and WHAs encompassed 977,381 ha, of which 701,074 were areas where no further forestry-related disturbance was allowed (Goddard 2009). Note that disturbances from oil and gas exploration and extraction were excluded from the FRPA. In subsequent years, UWR and WHA boundaries were further refined, resulting in ca. 1.5 million ha of UWR and ca. 275,000 ha of WHAs across all boreal caribou ranges (BC Ministry of Environment 2011*a*). Within the Maxhamish range, UWRs constitute ~ 60% of the range's area. The range has no WHAs but does contain Maxhamish Lake Provincial Park, which encompasses ~ 3.4% of the range's area.

In 2010, the BCIP introduced additional measures for protecting caribou habitat. These measures included developing fire suppression strategies within caribou range, the establishment of UWRs and WHAs under the *Oil and Gas Activities Act* and the creation of Resource Review Areas (BC Ministry of Environment 2011*a*). RRAs are areas where petroleum and natural gas tenure sales were deferred for a period of five years, at which point their effectiveness in supporting BCIP goals and objectives would be determined. There are no RRAs within the Maxhamish range.

The recently released BCRIP has since revised the implementation actions for habitat protection contained within the 2011 BCIP (BC MoE / MFLNRO 2017). These new actions include maintaining < 6% early seral habitat (young forest ≤ 35 years for burns and ≤ 25 years for cutblocks) within a given range, prohibiting the creation of new early seral habitat within 15 of the 16 caribou core areas, and applying a 4:1 habitat offset for the development of new linear features, resulting in a net decrease in the linear feature footprint over time with a goal of reducing linear features to < 2 km/km^2 across all ranges.

4.1.2 ENHANCEMENT AND RESTORATION

To date, enhancement and restoration activities within ranges of boreal caribou have been limited with management actions primarily focused on protecting caribou habitat. Within the Maxhamish range, restoration

from logging impacts (e.g. cutblocks) has primarily relied on standard re-planting practices and natural regeneration.

Proposed actions by the BCRIP should see an increase in habitat restoration within the Maxhamish range. These actions include prioritizing disturbance features for restoration, focusing restoration efforts on core areas, and implementing a 4:1 offset for the creation of new linear features, which should result in the restoration of existing and decommissioned linear features (BC MoE / MFLNRO 2017).

4.2 Recreation and Access Management

Access management to boreal caribou ranges within northeastern British Columbia has primarily focused on developing operating guidelines and best practices for the oil and gas industry (Culling et al. 2004, BC Ministry of Environment 2011*b*). These practices have focused on reducing the disturbance footprint within caribou ranges and avoiding activities during demographically important periods such as calving. For reducing the disturbance footprint, guidelines have reduced the allowable width of seismic lines and roads, dictated that shared access corridors be used, and limited well sites to < 2 ha.

Boreal caribou ranges in northeast British Columbia are generally remote and see much lower recreational activity than caribou ranges situated in mountainous areas; consequently, there are minimal limitations on recreational activities within boreal caribou ranges.

4.2.1 Snowmobile

There are currently no restrictions on snowmobiling within the Maxhamish range.

4.2.2 Heli-ski / Cat-ski

The Maxhamish range is situated in the boreal plains and thus is not subjected to impacts from heli- and cat-skiing.

4.2.3 Summer Recreation

Currently, there no regulations on summer activities (e.g. off-road vehicles, hiking, mountain biking) within the Maxhamish range.

4.2.4 Other

There are no other restrictions on access and recreation within the Maxhamish 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*b*), and lethal control (Hervieux et al. 2014). Note that actions such as lethal control are controversial (Boertje et al. 2010, Lute and Attari 2017) and are generally considered short-term strategies used to sustain small and rapidly declining populations until the effects of habitat restoration and protection are realized (Wittmer et al. 2010, Hervieux et al. 2014).

4.3.1 Wolf Management

Within British Columbia, active management of wolves began in the early 1900s with the introduction of a bounty program, which lasted until 1955 (BC Ministry of Forests, Lands and Natural Resource Operations 2014). Predator control programs were also initiated during the 1940s and the combined effect of these initiatives resulted in wolf populations declining to their lowest estimated numbers provincially in the late 1950s.

Because of the remoteness of boreal caribou ranges, it is unclear what effect bounty and predator control programs specifically had on wolf populations in northeast British Columbia. In 2015, an aerial survey of the adjacent Calendar range estimated a wolf density of 6.4 – 7.0 / 1000 km^2 (Serrouya et al. 2015*a*). This density is at or slightly above thresholds associated with stable caribou populations (e.g. 6.5 wolves / 1000 km^2; Bergerud and Elliot 1986).

To date, there have been no management actions targeted toward wolves in the Maxhamish range. Trapping of fur-bearing animals does occur in northeast British Columbia but the effect of trapping on wolves within the Maxhamish range is likely minimal. Effects of licensed hunting are also likely minimal, although the current bag limit is three in most WMUs in northeast British Columbia and the removal of bag limits is being considered.

4.3.2 Cougar Management

Cougars are absent or rare in the Maxhamish range and therefore 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 Maxhamish range is one.

4.3.3 Other

There have been no management actions targeted toward other predators (e.g. bears and wolverine) within the Maxhamish range.

4.4 Primary Prey

Declines in boreal caribou populations 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*b*, Boutin and Merrill 2016).

4.4.1 Moose Management

Within the boreal plains of northeastern British Columbia, moose are the most abundant ungulate species (Thiessen 2010, McNay et al. 2013). Over the last seven years, boreal caribou ranges in northeast British Columbia have been surveyed to estimate moose densities and population size. In 2010, the estimated density within the Maxhamish range ranged from 0.04 to 0.16 moose / km^2 (Thiessen 2010). A repeat survey of the Fortune core in 2016 yielded an estimated density of 0.08 moose / km^2 (Webster and Lavallee 2016). These estimates are within thresholds associated with stable caribou populations (e.g. < 0.2 – 0.3 / km^2, Bergerud 1996; < 0.3 / km^2, Wilson 2009).

To date, there has been no active management of moose in the context of caribou conservation within the Maxhamish 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 considered rare within boreal caribou ranges of northeastern British Columbia although the northern distribution and abundance of white-tailed are likely increasing (Latham et al. 2011*b*, Dawe and Boutin 2016). Within the Maxhamish range, the hunting season for white-tailed deer is limited to males while there is no recreational hunt for mule deer. There are currently no management actions targeted toward deer in the context of caribou conservation in northeastern British Columbia.

4.4.3 Other

No other ungulate species are known to occur within the Calendar range.

Beaver, however, are known to be a primary prey item of wolves in northeast British Columbia and elsewhere during the snow-free season (Culling et al. 2006, Latham et al. 2013). Prior to European settlement of North America, beaver were abundant but subsequent exploitation led to their near extinction by the early 1900s (Naiman et al. 1988). With declines in trapping pressure, populations have been rebounding across the continent and populations are likely increasing in northeastern British Columbia. In 2011, Thiessen and DeMars (2012) estimated beaver density in the Parker and Prophet cores and the resulting estimates (0.21 and 0.33 active lodges / km^2) were within the range of densities estimated elsewhere in Canada. Subsequent surveys to estimate beaver density in other boreal caribou ranges (e.g. Maxhamish and Calendar) were conducted in 2012 by the provincial government but these data have yet to be analyzed (Culling and Cichowski 2017). To date, there have been no management actions directed toward beaver populations within the Maxhamish caribou range.

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.

To date, maternal penning has not been used to reinforce the Maxhamish subpopulation.

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 Maxhamish 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 North America and are reviewed in Bergerud and Mercer (1989) and Hayek et al. (2016).

There have been no translocation efforts undertaken for the Maxhamish subpopulation.

4.5.4 Other

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

4.6 Stewardship/Outreach

[NO IDEA WHAT TO PUT HERE....LEAVING THIS FOR GOVERNMENT FOLKS TO FILL IN]

4.7 Research

Over the last 25 years, a large body of research has emerged focused on understanding the population dynamics and ecology of boreal caribou (e.g. Bradshaw et al. 1995, Stuart-Smith et al. 1997, Rettie and Messier 1998, 2000, McLoughlin et al. 2003; also reviewed in Festa-Bianchet et al. 2011). Within British Columbia, the majority of research has occurred within the last 15 years. The first formal study was a five-year project initiated in 2000 within the Snake-Sahtaneh range (Culling et al. 2006). This comprehensive study monitored 57 adult female caribou fitted with GPS and VHF radio-collars to assess habitat selection, spatial distribution and demography. Information from this study resulted in the first delineations of range boundaries in British Columbia, including the identification of core habitat areas (Culling et al. 2004). Similar to other populations within their western distribution (e.g., Stuart-Smith et al. 1997, Rettie and Messier 2000), boreal caribou showed high rates of selection for treed peatlands. Key demographic findings included low rates of calf survival, particularly during the neonate period, and relatively high survival of adult females. The study also assessed predator ecology within the Snake-Sahtaneh by deploying radio-collars (18 GPS) on 31 wolves and nine black bears (all GPS). The strongest overlap between caribou and predators occurred during the calving season (May and June). Wolves were also found to be highly associated with beaver habitats during the snow-free season.

In 2004, a smaller scale study of caribou and wolves was conducted in the Chinchaga range, with GPS radio-collars deployed on 12 female caribou and 13 wolves (Rowe 2007*a*). Similar to previous findings within the Snake-Sahtaneh range, this study showed high rates of adult female survival and calf mortality for Chinchaga caribou. Radio-collared females also selected for areas dominated by low-lying, forested wetlands and dietary analyses from fecal samples confirmed that terrestrial lichen was a major forage resource during the winter.

In 2006, a similar small scale radio-collaring study (n = 8 female caribou) was conducted within the Maxhamish range (Rowe 2007*b*). This study again corroborated inferences on habitat selection with caribou generally using low-gradient treed peatlands and the majority of GPS locations occurring within delineated core areas. Rates of calf recruitment in 2006 were also found to be low (6 calves / 100 females).

In 2011, a multi-range research project was initiated to investigate caribou-predator dynamics during the calving season (DeMars and Boutin 2014). This study initially deployed 25 GPS radio-collars on female caribou distributed among four ranges. In subsequent years, the study incorporated data from radio-collars deployed as part of REMB's boreal caribou monitoring initiatives (see below) and also deployed radio-collars on wolves (*n* = 23) and black bears (*n* = 19). A key output from this project was the first predictive map of caribou calving habitat within northeast British Columbia. This project also resulted in the development of a non-invasive method for estimating rates of parturition and neonate survival (DeMars et al. 2013), evaluated how linear features contribute to caribou-predator spatial overlap and lowered rates of neonate survival (DeMars and Boutin 2018), and yielded insights into potential mechanisms influencing the "spacing-out" behaviour of female caribou at calving (DeMars et al. 2016).

The release of the BCIP resulted in the creation of the REMB to oversee research conducted on boreal caribou in British Columbia. With the REMB's oversight and support, a number of research projects have been initiated and/or completed over the last seven years. These projects include:

- Evaluating the spatial dynamics of caribou, moose and wolves and the resultant effects on caribou demography (Mumma and Gillingham 2017, Mumma et al. 2017). Results from this project suggest that linear features increase the spatial overlap among caribou, moose and wolves with increasing overlap negatively affecting caribou survival.
- A number of studies evaluating habitat restoration and recovery strategies (DeMars and Benesh 2016, Pigeon et al. 2016, Tigner et al. 2016, Fitzpatrick et al. 2017, Golder Associates 2017, Serrouya et al. 2017*a*).
- An evaluation of management options for stabilizing and recovering boreal caribou populations (Sutherland et al. 2016).
- Traditional ecological knowledge studies (Leech et al. 2016) and a trial of First Nations trapping methods for controlling wolves in caribou range (Sittler et al. 2016).
- An ongoing, multi-range study investigating the health status of boreal caribou populations in northeast British Columbia (Schwantje et al. 2014, 2016; see also *Section 3.5*).
- Demographic responses of boreal caribou to variation in seasonal weather effects (DeMars et al. 2017).

Although not directly overseen by the REMB, additional research on boreal caribou has been conducted over the last five years. These studies include investigating the foraging ecology and nutritional condition of boreal caribou (Cook and Cook 2015, Denryter et al. 2017), assessing beaver density and habitat selection within caribou range (Thiessen and DeMars 2012), and evaluating caribou habitat selection and response to anthropogenic features in the Parker core of the Westside Fort Nelson range (Wilson and DeMars 2015).

Collectively, the large body of research conducted since 2000 has significantly improved the understanding of boreal caribou ecology in northeast British Columbia. A number of knowledge gaps remain, however, including determining proximate and ultimate causes of calf mortality, evaluating within and between range movements of males, and determining sustainable thresholds for linear features within caribou range (see review of knowledge gaps in Culling and Cichowski 2017). Going forward, the REMB will continue to provide oversight to caribou research in northeast British Columbia until July 2018, after which the provincial government will likely lead ongoing research and monitoring activities (S. Wilson, *personal communication*). With the release of the BCRIP in 2017, future directions will likely include adaptive management-based research aimed at testing management actions for stabilizing and recovering boreal caribou populations (BC MoE / MFLNRO 2017).

4.8 MONITORING

Monitoring of boreal caribou populations in northeast British Columbia began with the Culling et al. (2006) study in 2000. This four-year study, which deployed radio-collars on 57 female caribou and was restricted to the Snake-Sahtaneh range, yielded the first demographic estimates of adult female survival and juvenile recruitment. The study also provided the first quantification of space use by boreal caribou in British Columbia.

Monitoring of boreal caribou by the provincial government began in the mid-2000s. In 2004, an aerial survey was conducted to estimate moose and boreal caribou populations within Wildlife Management Units 7-55 and 7-56, which cover portions of the Calendar, Maxhamish and Snake-Sahtaneh ranges (Backmeyer 2004). From 2004 – 2006, survival and movements of 12 female caribou in the Chinchaga range were monitored with GPS radio-collars (Rowe 2007*a*). In 2008, ten VHF radio-collars were deployed on females in the Parker core (n = 4) and Maxhamish range (n = 6) to aid in monitoring (Thiessen 2009*b*). Over the following two years, thirty more radio-collars (9 VHF and 21 GPS) were deployed with collars now distributed across all boreal caribou ranges in British Columbia (2009: Parker = 3, Maxhamish = 5, Prophet core = 2; 2010: Calendar = 1, Chinchaga = 3, Fort Nelson core = 2, Maxhamish = 9, Snake-Sahtaneh = 5; Thiessen 2009*b*, Thiessen and DeMars 2010). These collared animals facilitated counts of minimum number alive, contributed to understanding caribou space use, and allowed the estimation of annual rates of juvenile recruitment and rates of adult female survival.

The BCIP, released in 2010, recommended more intensive monitoring of boreal caribou populations, including developing strategies to monitor changes in demography and habitat suitability (BC Ministry of Environment 2011*a*). For the former, a comprehensive strategy was initiated in the winter of 2012-2013 with oversight from the REMB. The strategy's objective was to maintain a sample of radio-collared individuals within each range equating to ~ 15% of each range's estimated population size. This objective resulted in 164 radio-collars being deployed on individual females distributed among all six caribou ranges (Culling and Culling 2013). In the Maxhamish range, 25 collars (18 VHF, 7 GPS) were initially deployed. Since this initial deployment, radio-collared animals have been monitored monthly to estimate survival rates and determine causes of mortality (Culling and Culling 2013, 2014, 2015, 2016, 2017). The higher per-range sample of radio-collared animals has also allowed for more robust estimates of minimum population size and juvenile recruitment within each range. Range-specific sample sizes have been maintained by re-deploying a sufficient number of radio-collars annually to compensate for mortalities and non-functioning collars, which has resulted in 239 adult female caribou being fitted with radio-collars between December 2012 and April 2016 (Culling and Culling 2017). Oversight from the REMB is expected to end after the March 2018 juvenile recruitment survey, after which the provincial government will assume responsibility for caribou population monitoring.

Ongoing monitoring will be necessary to achieve the primary goals outlined in the recently released draft BCRIP (BC MoE / MFLNRO 2017). These goals include achieving self-sustaining populations and maintaining a positive trend in habitat recovery within each boreal caribou range. For population monitoring, a sufficient number of radio-collars will need to be maintained to effectively monitor population trend, particularly given the difficulty in estimating population size. For habitat monitoring, efficient methods for evaluating habitat status over large spatial scales will be required, in addition to defining when habitat is restored.

Predator populations have also been monitored in northeast British Columbia to support the management of boreal caribou. Culling et al. (2006) deployed GPS radio-collars on wolves and black bears to assess habitat selection by each species and their potential spatial overlap with caribou habitat. Rowe (2007*a*) deployed GPS radio-collars on 13 wolves in the Chinchaga range with similar objectives of assessing seasonal movements, habitat selection and home range size. In 2009, three wolves were radio-collared in the Calendar range (Thiessen 2009*b*). During their three-year study from 2011 -2013, DeMars and Boutin (2014) also deployed GPS radio-collars on wolves in packs distributed across all boreal caribou ranges as well as on black bears in three ranges. While the collaring efforts by Culling et al. (2006) and DeMars and Boutin (2014) were more research-based, the REMB initiated more focused monitoring of wolves in 2013 (Culling and Culling 2014). This initiative attempted to maintain a broad distribution of ~ 20 radio-collared wolves with territories overlapping caribou range. Collaring efforts for the REMB initiative continued annually with the last deployments occurring during the winter of 2016-2016. As of 30 April 2017, only four wolf collars were believed to be still active (Culling and Culling 2017). As a complement to the radio-collaring program, REMB also supported aerial surveys to estimate wolf densities in the Calendar range, Parker core, and the Chinchaga RRA (Serrouya et al. 2015*a*). Going forward, monitoring of wolf populations will likely continue as a key implementation action of the draft BCRIP is to control wolf populations such that densities are < 3 wolves / 1000 km^2 (BC MoE / MFLNRO 2017).

Because population declines within many boreal caribou ranges have been attributed to apparent competition with moose (Seip 1992, Bergerud 1996), boreal caribou management in northeast British Columbia has also included monitoring moose populations. In 2004, Backmeyer (2004) surveyed WMU 7-55, which is adjacent to the Maxhamish range, to estimate moose and boreal caribou numbers simultaneously, though the objective was not necessarily to compare their dynamics. In 2010, Thiessen (2010) used distance sampling to estimate moose densities within the Horn River Basin, a geologic formation that encompasses parts of the Calendar, Maxhamish, Snake-Sahtaneh and West Side Fort Nelson ranges. Results from this survey were used to assess relationships between moose and caribou population dynamics (Thiessen and DeMars 2010). In 2013, moose surveys were replicated in seven core areas (Etsho, North Kotcho, East Kotcho, Prophet, Clark, Etthithun, and Milligan) and the Chinchaga RRA (McNay et al. 2013). Surveys were repeated in the Clark and Fortune cores and Chinchaga RRA in 2016 (Webster and Lavallee 2016). Collectively, these surveys have provided a baseline of moose abundance and distribution within caribou range. The draft BCRIP does not specifically indicate whether monitoring of moose populations will be continued from a caribou management perspective; rather, such monitoring will likely be managed by the Peace-Liard Moose Management Plan, which is collaboratively led by the provincial government and First Nations (BC MoE / MFLNRO 2017).

5 IMPLICATIONS TO OTHER WILDLIFE

Management actions focused on conserving caribou will necessarily have impacts on other wildlife species. Caribou require landscapes where densities of other ungulates and predators are low; thus, management actions undertaken for caribou may result in population sizes of moose, deer, and wolf that are much lower than those

currently experienced (Serrouya et al. 2015*b*, 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

Boreal caribou have long been valued by First Nations in northeast British Columbia, being an historically important food source as well as being used for specific cultural practices (Leech et al. 2016, FNFN 2017). Many First Nations no longer hunt caribou due to their low numbers, but recovering their populations to where sustenance hunting is sustainable has been identified as a high priority (Leech et al. 2016, FNFN 2017).

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*b*). Lowered populations of big-game species such as moose, elk 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*b*), 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

The stated recovery goal in the federal *2012 Recovery Strategy* for boreal caribou is to achieve self-sustaining populations within all ranges across their current distribution (Environment Canada 2012). Self-sustaining populations are defined as those that, on average, demonstrate stable or increasing population growth over the short-term and are of sufficient size to withstand stochastic events and persist over the long-term. Because current declines of boreal caribou populations are ultimately driven by landscape alteration, self-sustaining status in the *Recovery Strategy* is explicitly linked to habitat conditions within a population's range. Specifically, populations have a higher probability (60%) of being self-sustaining when the amount of undisturbed habitat exceeds 65%. The *Recovery Strategy*, however, recognizes that for rapidly declining populations in highly disturbed ranges, other interim actions (e.g., predator and alternate prey management, population augmentation) will be necessary to support caribou populations until the effects of protecting and restoring habitat can be realized.

In 2017, the provincial government released the *Boreal Caribou Recovery Implementation Plan* (BCRIP), which outlines a general strategy for stabilizing and recovering boreal caribou populations in the province. The BCRIP has two over-arching goals: to maintain a positive habitat trend across each range; and, to stabilize and achieve viable caribou populations within each range. For the former, measures to protect and restore habitat will be required and progress toward this goal will be tracked by assessing the amount of early seral forest and the density of linear features within each range. For the latter, population viability will be tracked by the population growth rate (λ) and its two components, adult female survival and juvenile recruitment.

To achieve these recovery goals, the BCRIP outlines a number of implementation objectives. These include limiting the amount of early seral habitat to < 6% of a range's area, prohibiting forest harvesting in 15 of the 16 habitat cores, requiring a net decrease in the density of linear features by applying a 4:1 offset, modifying existing RRAs, managing wildfires, and evaluating the necessity and feasibility of non-habitat related actions (e.g. predator and alternate prey management, population augmentation) to support caribou populations in the short-term.

Adaptive management will be required to effectively implement the recommended actions to reach recovery goals. This approach involves using known information to select actions predicted to achieve a desired outcome, monitoring the response of such actions, then modifying management plans in response to new information. Having an adaptive approach will in part be necessary because the recommended management actions are generally linked. For example, reducing the amount of early seral habitat should result in a reduction of non-caribou ungulates, which in turn should result in a reduction of predators, thereby reducing the need for active predator control.

Appendix C of the draft BCRIP outlines an action plan for the Maxhamish boreal caribou range (BC MoE / MFLNRO 2017). Because recent data suggests that the Maxhamish caribou population may be approaching stability, the recommended actions primarily focus on habitat protection and recovery. Achieving recovery objectives and goals will also require continued monitoring of caribou populations and their habitat.

Summary of Recommended Actions for the Maxhamish Range

1. *Caribou Habitat Protection and Restoration*
    - Management of early seral forest. Currently, the amount of early seral forest is < 1%, which is below the maximum threshold target of 6%
    - No forest harvesting or road building within core areas
    - Broad-scale habitat restoration, primarily focusing on linear features
    - Habitat offsetting
    - Establish RRAs over untenured portions of core areas until habitat protection targets are achieved.
    - Manage wildfires to minimize the creation of early seral forests
2. *Access Management*
    - Update standard operating practices for industry

Summary of Monitoring Recommendations for the Maxhamish Range

- Deploy and maintain radio-collars on at least 5% of the caribou population
- Annual surveys to estimate juvenile recruitment and minimum number alive
- Surveys to estimate wolf numbers every three to five years
- Continuous tracking of linear feature restoration but summarized every five years
- Estimation of linear feature density every one to five years
- Estimation of the extent of early seral habitat every five years
- Summarize habitat conditions every five years relative to criteria specified in the federal *Recovery Strategy*

8.1 Short Term (Within 6-12 Months)

[place holder] (activity, budget)

8.2 Medium Term (Within 12-24 Months)

[place holder] (activity, budget)

8.3 Long Term (Within 24-48 Months)

[place holder] (activity, budget)

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., 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.

Athabasca Landscape Team. 2008. Athabasca caribou landscape management options report. Edmonton, AB.

Backmeyer, R. J. 2004. Moose and boreal caribou inventory: Management units 7-55 and 7-56. BC Ministry of Water, Land and Air Protection, Fort St. John, BC.

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

BC Ministry of Environment. 2011*a*. Implementation plan for the ongoing management of Boreal Caribou (*Rangifer tarandus caribou* pop. 14) in British Columbia. Victoria, BC.

BC Ministry of Environment. 2011*b*. Interim operating practices for oil and gas activities in identified boreal caribou habitat in British Columbia. 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.

BC MoE / MFLNRO. 2017. Boreal caribou recovery implementation plan [draft]. BC Ministry of Environment and Ministry of Forests, Lands, and Natural Resource Operations, Victoria, BC.

Bergerud, A. T. 1974. Decline of caribou in North America following settlement. The Journal of Wildlife Management 38:757–770.

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., and J. P. Elliot. 1986. Dynamics of caribou and wolves in northern British Columbia. Canadian Journal of Zoology 64:1515–1529.

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.

Bradshaw, C. J. A., D. M. Hebert, A. B. Rippin, and S. Boutin. 1995. Winter peatland habitat selection by woodland caribou in northeastern Alberta. Canadian Journal of Zoology 73:1567–1574.

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.

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.

Cook, J. G., B. K. Johnson, R. C. Cook, R. A. Riggs, T. Delcurto, L. D. Bryant, and L. L. Irwin. 2004. Effects of summer-autumn nutrition and parturition date on reproduction and survival of elk. Wildlife Monographs 155:1–61.

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.

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

Courtois, R., J.-P. Ouellet, L. Breton, A. Gingras, and C. Dussault. 2007. Effects of forest disturbance on density, space use, and mortality of woodland caribou. Ecoscience 14:491–498.

Culling, D. E., and D. Cichowski. 2017. Boreal caribou (*Rangifer tarandus*) in British Columbia: 2017 science review. BC Oil and Gas Research and Innovation Society, Victoria, BC.

Culling, D. E., and B. A. Culling. 2013. BC boreal caribou implementation plan: 2012-13 collar deployment and late winter recruitment survey. Diversified Environmental Services, Fort St. John, BC.

Culling, D. E., and B. A. Culling. 2014. BC boreal caribou implementation plan: 2013-2014 field activities progress report. Diversified Environmental Services, Fort St. John, BC.

Culling, D. E., and B. A. Culling. 2015. BC boreal caribou implementation plan: Year III (2014-2015) field activities progress report. Diversified Environmental Services, Fort St. John, BC.

Culling, D. E., and B. A. Culling. 2016. BC boreal caribou implementation plan: Year IV 2(015-2016) field activities progress report. Diversified Environmental Services, Fort St. John, BC.

Culling, D. E., and B. A. Culling. 2017. BC boreal caribou implementation plan: Year V (2016-2017) field activities progress report. Diversified Environmental Services, Fort St. John, BC.

Culling, D. E., B. A. Culling, R. Backmeyer, and T. Antoniuk. 2004. Industry guidelines for boreal caribou ranges in northeastern British Columbia. Diversified Environmental Services, Fort St. John, BC.

Culling, D. E., Culling, Brad A., Raabis, Teresa J., and Creagh, Alex C. 2006. Ecology and seasonal habitat selection of boreal caribou in the Snake-Sahtaneh watershed, British Columbia 2000 to 2004. Diversified Environmental Services, Fort St. John, BC.

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. 2015. Calving behavior of boreal caribou in a multi-predator, multi-use landscape. Ph.D. thesis, University of Alberta, Edmonton, AB.

DeMars, C. A., M. Auger-Méthé, U. E. Schlägel, and S. Boutin. 2013. Inferring parturition and neonate survival from movement patterns of female ungulates: a case study using woodland caribou. Ecology and Evolution 3:4149–4160.

DeMars, C. A., and K. Benesh. 2016. Testing functional restoration of linear features within boreal caribou range. BC Oil and Gas Research and Innovation Society.

DeMars, C. A., and S. Boutin. 2014. Assessing spatial factors affecting predation risk to boreal caribou calves: implications for management. Final report. Science, Community and Environmental Knowledge fund, Victoria, BC.

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

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

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

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

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

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

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

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

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.

Dzus, E. 2001. Status of the woodland caribou (*Rangifer tarandus caribou*) in Alberta. Alberta Wildlife Status Report, Alberta Environment, Fisheries and Wildlife Management Division, and Alberta Conservation Association, Edmonton, AB.

ECCC. 2017. Report on the progress of recovery strategy implementation for the woodland caribou (*Rangifer tarandus caribou*), boreal population in Canada for the period 2012-2017. Species at Risk Act Recovery Strategy Series, Environment and Climate Change Canada, Ottawa, ON.

Edmonds, J. 1986. Draft restoration plan for woodland caribou in Alberta. Alberta Forestry, Lands, and Wildlife, Fish and Wildlife Division, Edmonton, AB.

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

Ferguson, S. H., and P. C. Elkie. 2004. Seasonal movement patterns of woodland caribou (*Rangifer tarandus caribou*). Journal of Zoology 262:125–134.

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.

Fitzpatrick, J., N. Jenni, J. Keim, P. Dewitt, and S. R. Lele. 2017. Developing and monitoring the efficacy of functional restoration of linear features for boreal woodland caribou - 1-year summary of monitoring data Parker caribou range. Matrix Solutions, Edmonton, AB.

FNFN. 2017. Medzih action plan: Fort Nelson First Nation boreal caribou recovery plan. Fort Nelson First Nations, Fort Nelson, BC.

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.

Goddard, A. 2009. Boreal caribou in northeastern British Columbia: biological rationale, data summary and literature review. Peace Region Technical Report, BC Ministry of Environment, Fort St. John, BC.

Golder Associates. 2017. Pilot boreal caribou habitat restoration program year 1 (2017) implementation report. Golder Associates, Edmonton, AB.

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

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

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

Heard, D., 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.

Hervieux, D., M. Hebblewhite, N. J. DeCesare, M. Russell, K. Smith, S. Robertson, and S. Boutin. 2013. Widespread declines in woodland caribou (*Rangifer tarandus caribou*) continue in Alberta. Canadian Journal of Zoology 91:872–882.

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.

Hettinga, P. N., A. N. Arnason, M. Manseau, D. Cross, K. Whaley, and P. J. Wilson. 2012. Estimating size and trend of the North Interlake woodland caribou population using fecal-DNA and capture-recapture models. The Journal of Wildlife Management 76:1153–1164.

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

Holt, R. D. 1984. Spatial heterogeneity, indirect interactions, and the coexistence of prey species. The American Naturalist 124:377–406.

James, A. R., S. Boutin, D. M. Hebert, and A. B. Rippin. 2004. Spatial separation of caribou from moose and its relation to predation by wolves. Journal of Wildlife Management 68:799–809.

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.

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

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

Kutz, S., E. Hoberg, L. Polley, and E. 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, K. H. Knopff, M. Hebblewhite, and S. Boutin. 2013. Wolves, white-tailed deer, and beaver: implications of seasonal prey switching for woodland caribou declines. Ecography 36:1276–1290.

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.

Leech, S., P. Bates, and Bluberry River First Nations. 2016. BRFN indigenous knowledge study of Chinchaga muskeg caribou and Pink Mountain caribou. Blueberry River First Nations, BC.

Lesmerises, F., F. Déry, C. J. Johnson, and M.-H. St-Laurent. 2018. Spatiotemporal response of mountain caribou to the intensity of backcountry skiing. Biological Conservation 217:149–156.

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.

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

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

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

Mumma, M. A., and M. P. Gillingham. 2017. Assessing caribou survival in relation to the distribution and abundance of moose and wolves. BC Oil and Gas Research and Innovation Society, Prince George, BC.

Mumma, M. A., M. P. Gillingham, C. J. Johnson, and K. L. Parker. 2017. Understanding predation risk and individual variation in risk avoidance for threatened boreal caribou. Ecology and Evolution.

Naiman, R. J., C. A. Johnston, and J. C. Kelley. 1988. Alteration of North American streams by beaver. BioScience 38:753–762.

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

Pigeon, K., M. Hornseth, D. McNearney, and L. Finnegan. 2016. Analysis and improvement of linear features to increase caribou functional habitat in west-central and north-western Alberta. fRI Research Caribou Program, Hinton, AB.

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.

Pulliam, H. R. 1973. On the advantages of flocking. Journal of Theoretical Biology 38:419–422.

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.

Rettie, W. J., and F. Messier. 1998. Dynamics of woodland caribou populations at the southern limit of their range in Saskatchewan. Canadian Journal of Zoology 76:251–259.

Rettie, W. J., and F. Messier. 2000. Hierarchical habitat selection by woodland caribou: its relationship to limiting factors. Ecography 23:466–478.

Rowe, M. 2006. 2006 Maxhamish range boreal caribou inventory: Kiwigana, Fortune, and Capot-Blanc core areas. BC Ministry of Environment, Fort St. John, BC.

Rowe, M. 2007*a*. Boreal caribou and wolf movement and habitat selection within the Chinchaga range. BC Ministry of Environment, Fort St. John, BC.

Rowe, M. 2007*b*. Boreal caribou movement and habitat selection within the Maxhamish range. Peace Region Technical Report, BC Ministry of Environment, Fort St. John, BC.

Schaefer, J. A., C. M. Bergman, and S. N. Luttich. 2000. Site fidelity of female caribou at multiple spatial scales. Landscape Ecology 15:731–739.

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, W. L. (Vic) Adamowicz, and S. Boutin. 2010. Triage for conserving populations of threatened species: The case of woodland caribou in Alberta. Biological Conservation 143:1603–1611.

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

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

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

Schwantje, H., B. J. Macbeth, S. Kutz, and B. Elkin. 2016. British Columbia boreal caribou health program progress report: year 2 (February 1, 2015 - March 31, 2016). British Columbia Oil and Gas Research and Innovation Society, Victoria, BC.

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., 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., M. Dickie, C. DeMars, and S. Boutin. 2017*a*. Predicting the effects of restoring linear features on woodland caribou populations. Alberta Biodiversity Monitoring Institute, Edmonton, AB.

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., H. van Oort, and C. DeMars. 2015*a*. Wolf census in three boreal caribou ranges in British Columbia: results from 2015. Alberta Biodiversity Monitoring Institute, Edmonton, AB.

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*b*. 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. L., L. Tsakoza, and S. McNay. 2016. Reducing the threat of predation by wolves within the Prophet caribou range. Wildlife Infometrics Report, Mackenzie, BC.

Smith, K. G., and L. Pittaway. 2011. Little Smoky Woodland Caribou Calf Survival Enhancement Project. Rangifer 31:97–102.

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.

Stuart-Smith, K., C. J. A. Bradshaw, S. Boutin, D. M. Hebert, and A. B. Rippin. 1997. Woodland caribou relative to landscape patterns in northeastern Alberta. The Journal of Wildlife Management 61:622–633.

Sutherland, G., R. S. McNay, and R. Serrouya. 2016. Feasibility of some direct management options to recover populations of boreal caribou. Wildlife Infometrics Inc., Mackenzie, BC.

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

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

Thiessen, C. 2010. Horn River Basin moose inventory January / February 2010. Peace Region Technical Report, BC Ministry of Environment, Fort St. John, BC.

Thiessen, C., and C. A. DeMars. 2010. Peace region boreal caribou monitoring: annual report 2009-10. BC Ministry of Forests, Lands and Natural Resource Operations, Fort St. John, BC.

Thiessen, C., and C. A. DeMars. 2012. Density and resource selection of beaver (*Castor canadensis*) in two boreal caribou ranges in north-east British Columbia: October 2011. BC Ministry of Forests, Lands and Natural Resource Operations, Fort St. John, BC.

Thompson, I. D., P. A. Wiebe, E. Mallon, A. R. Rodgers, J. M. Fryxell, J. A. Baker, and D. Reid. 2015. Factors influencing the seasonal diet selection by woodland caribou (*Rangifer tarandus tarandu*) in boreal forests in Ontario. Canadian Journal of Zoology 93:87–98.

Tigner, J., M. Taylor, C. Parker, C. Shapka, and P. Bentham. 2016. Natural recovery on low impact seismic lines in northeast British Columbia. Explor / Golder Associates.

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.

Vors, L. S., J. A. Schaefer, B. A. Pond, A. R. Rodgers, and B. R. Patterson. 2007. Woodland caribou extirpation and anthropogenic landscape disturbance in Ontario. Journal of Wildlife Management 71:1249–1256.

Webster, D., and M. Lavallee. 2016. Aerial moose survey in north east BC 2016. Eco-Web Ecological Consulting Ltd., Fort St. John, BC.

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.

Wilson, S. F. 2009. Recommendations for predator-prey management to benefit the recovery of mountain caribou in British Columbia. Ministry of Environment [Environmental Stewardship Division], Victoria, BC.

Wilson, S. F., and C. A. DeMars. 2015. A Bayesian approach to characterizing habitat use by, and impacts of anthropogenic features on, woodland caribou (*Rangifer tarandus caribou*) in northeast British Columbia. Canadian Wildlife Biology & Management 4:107–118.

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, 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. The role of predation in the decline and extirpation of woodland caribou. Oecologia 144:257–267.