

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

Barkerville Subpopulation

Quesnel Highlands
Local Population Unit



BRITISH
COLUMBIA

Recommended Citation:

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EXECUTIVE SUMMARY

DRAFT

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1 BACKGROUND

1.1 INTRODUCTION TO THE PROGRAM

The Barkerville woodland caribou subpopulation was designated as Southern Mountain Caribou (Designatable Unit (DU) 9 – Southern Group) by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; COSEWIC 2011, Environment Canada 2012a, Environment Canada 2014). As a group, the Southern Mountain group of woodland caribou is recommended as *endangered* by Canada (Environment Canada 2014) and is red-listed by the Province of British Columbia (British Columbia Conservation Data Centre 2017).

Woodland Caribou are further divided into Local Population Units by Environment Canada. Within the Southern Mountain Caribou group there are eleven Local Populations. The Barkerville subpopulation is in the Quesnel Highlands Local Population together with the Wells Grey (North) subpopulation (Environment Canada 2014).

Range plans are required for all woodland caribou populations that are designated as threatened or endangered in Canada (Environment and Climate Change Canada 2016). The endangered designation for the Barkerville subpopulation is due to its low numbers (see below), but current monitoring indicates that population is increasing (Environment Canada 2014).

This document describes the current situation in British Columbia and Canada for caribou and particularly for the Barkerville caribou subpopulation. It compiles relevant research, knowledge and management actions into guidance for the management and recovery of the Barkerville Southern Mountain caribou subpopulation within in the Quesnel Highlands Local Population Unit.

2 POPULATION DESCRIPTION

Southern Mountain Caribou (formerly known as mountain caribou) live in the Interior Wet Belt that stretches from northern Idaho and Washington States to central British Columbia. In contrast to Central and Northern Mountain Caribou, they remain in mature subalpine forest habitat year-round. In winter, Southern Mountain Caribou live in a deep snowpack and feed on lichens that grow on trees (Government of British Columbia 2017a).

2.1 DISTRIBUTION

The Barkerville caribou subpopulation is found on the west side of the Rocky Mountains, north and south of Wells, BC, in the Quesnel Highlands (Figure 1).

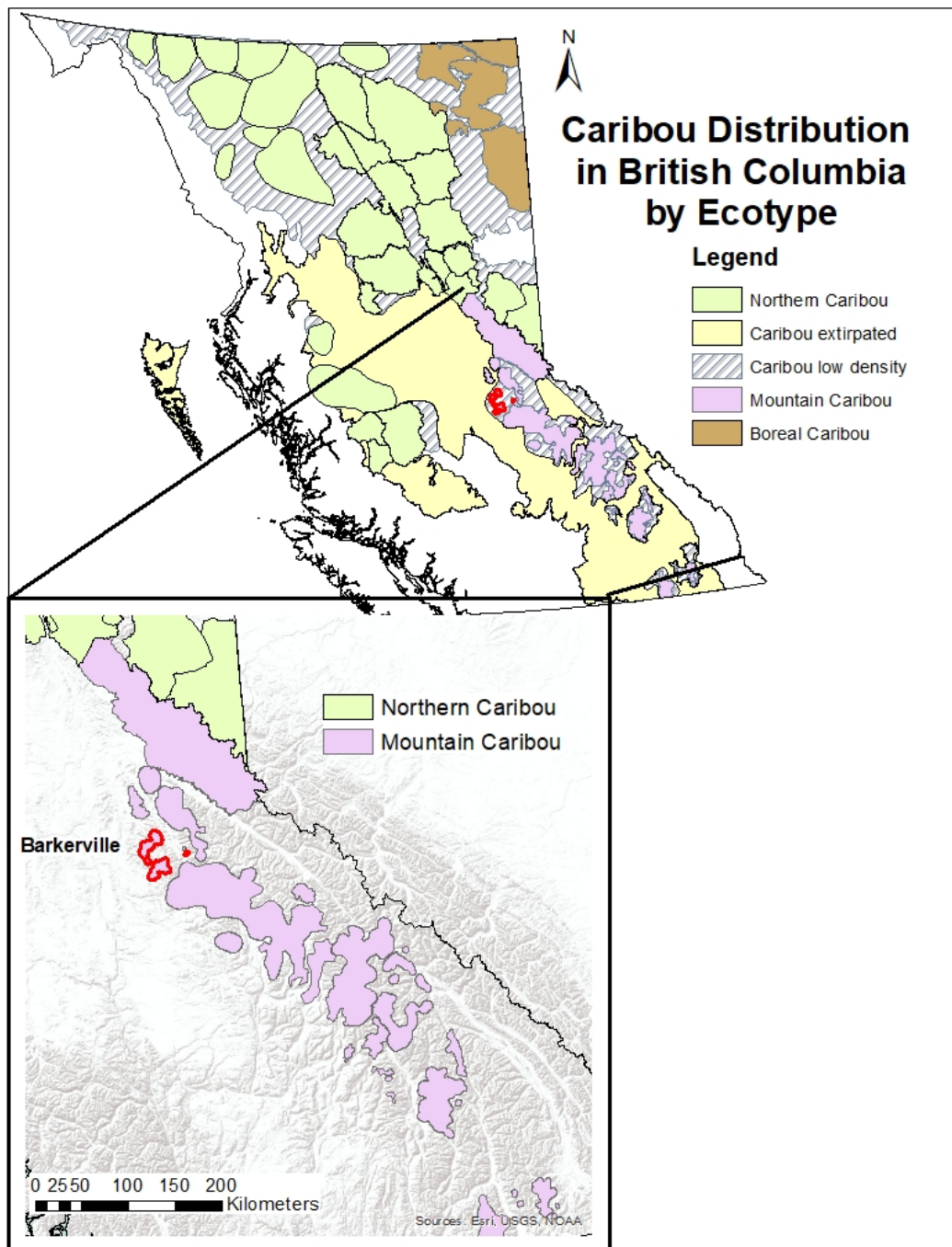


Figure 1: The geographical location of the Barkerville subpopulation of woodland caribou. The 741 km² range (inset: red outline) is situated within both the Cariboo Region of east-central British Columbia.

2.2 HABITAT AND BEHAVIOUR

The Barkerville subpopulation have been identified as mountain caribou due to their ecological and behavioural habits (Stevenson and Hatler 1985, The Mountain Caribou Technical Advisory Committee 2002).

Their primary habitat includes mature coniferous forests where arboreal lichen is abundant and available during the deep snow winters (Wittmer et al. 2005a). White spruce and subalpine fir dominate low elevation habitats. Englemann spruce dominates mid elevation habitats while high elevation are alpine tundra habitats dominated by low shrubs and herbaceous vegetation (Stevenson and Hatler 1985).

Mountain caribou in the Quesnel Highlands area do not make a well defined, seasonal migration but rather range generally over their home range using high and low elevation habitats (Seip 1992b). While most mountain caribou can be found at high elevations in early winter, many are also at middle elevations at this time of the year. Similarly, in late winter and spring, most mountain caribou are at high elevations, but some are found at middle and low elevations. Throughout the year, lichen is a dominant part of their diet together with buds from coniferous trees, but this is supplemented with grasses, forbs and shrubs in the spring and summer.

2.3 POPULATION SIZE AND TREND

The estimated mean Barkerville caribou subpopulation has been consistently below 100 animals since systematic counts began in the 1980s (Figure 2). Since 1993 the general population trend has been increasing (Figure 2). This is unusual among caribou populations in British Columbia and corresponds to specific habitat protection and management of predator – prey dynamics in the Quesnel Highlands where the Barkerville subpopulation resides (see below).

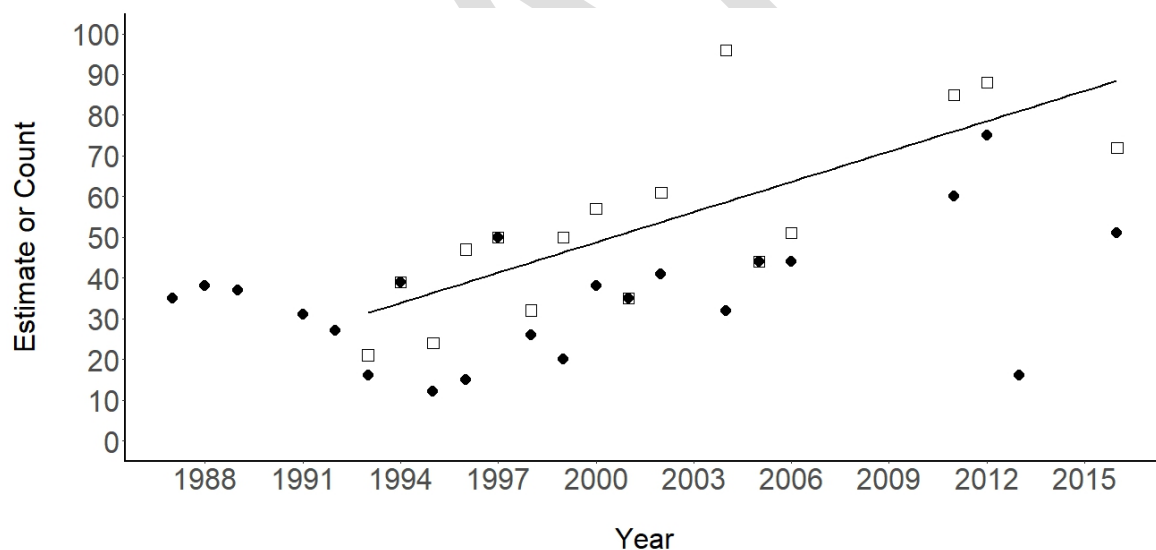


Figure 2: Caribou counts (filled dots) and estimates (hollow squares) for the Barkerville sub-population. A least-squares linear smoothed line of population estimates is drawn ($y = -3580 + 1.8x$, $P = 0.02$, $r^2 = 0.7$). Estimates are calculated in NOREMARK using mean-sightability of radio collared caribou during winter flights from 1996-2006 (mean sightability = 0.857, $n=13$, S.E.M. = 0.118). Counts made by Government of British Columbia staff in all years except 2013 when surveys were contracted to third-party. Prior to 1992, surveys were conducted over an area broader than Barkerville subpopulation and sightability is not available (Roorda and Wright 2004, 2010, Dodd 2017).

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Caribou recruitment, measured as percent of calves in the population observed during a spring census (Bergerud and Elliot 1986), varies considerably among years and ranges between approximately 3% and 20% (Figure 3). Since 1996, only one year (2004) has seen below threshold recruitment.

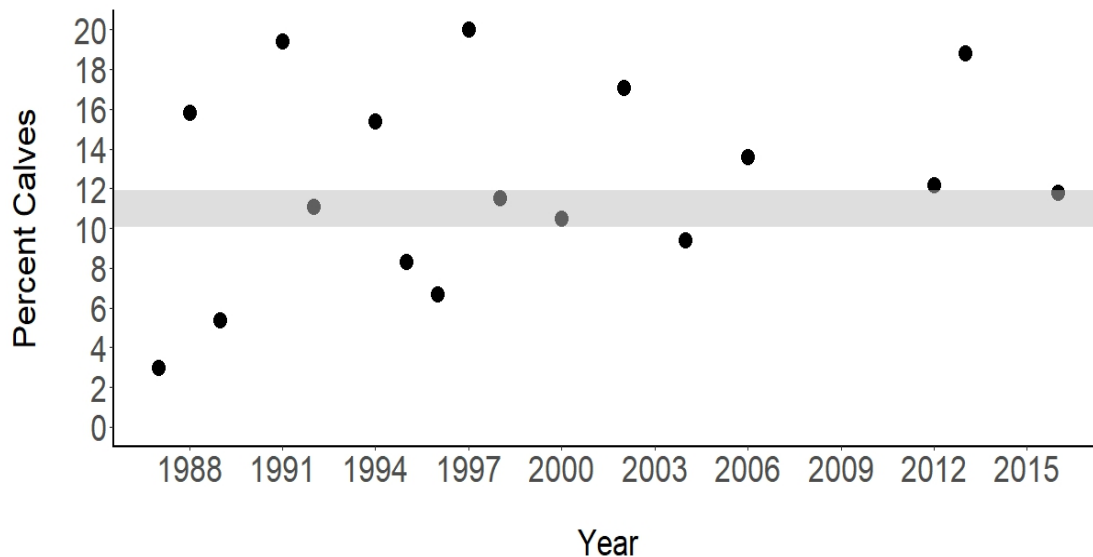


Figure 3: Caribou population recruitment measured in the Barkerville caribou subpopulation range. Recruitment is defined here as the percent of the estimated population that is in the calf cohort. Recruitment lower than approximately 10 to 12% is considered below a threshold that will balance natural mortality (grey band; Bergerud and Elliot 1986).

3 THREATS AND LIMITING FACTORS

Primary threats to caribou and their habitat have been noted by McNay et al. (2008), COSEWIC (2015) and a variety of independent studies (e.g. James et al. 2004, Wittmer et al. 2005b, Courtois et al. 2007, Seip et al. 2007, Wittmer et al. 2007). Here, threats are treated in isolation, but this does not discount the likelihood that they interact. Cumulate effects assessment (Sorensen et al. 2008, Johnson et al. 2015) is beyond the scope of this plan, but elements such as predation, human activities, and climate change are known to relate to one another. Work on boreal caribou has demonstrated the value in developing comprehensive range planning for woodland caribou that considers interacting threats (Angelstam et al. 2004, Environment Canada 2012b).

Here, the following threats are considered:

1. Predation
2. Food limitation
3. Human activities
 - a. Industrial
 - b. Recreational
 - c. Other
4. Natural disturbance
5. Parasites and diseases

6. Climate change
 7. Hunting and poaching
- Small population size effects

3.1 PREDATION

GPS collar and radio telemetry studies have indicated that the dominant, proximal cause of woodland caribou mortality is predation (Wittmer et al. 2013). Woodland caribou have evolved with their predators and have persisted despite millennia of predation (Bergerud 1988). While the predator species killing caribou vary regionally (wolf, black bear, grizzly bear, cougar), their impact on woodland caribou populations has increased as the result of three dominant processes: apparent competition mediated by alternative prey hyperabundance (Hebblewhite et al. 2007), apparent competition mediated by expanding alternative prey distribution (Wittmer et al. 2007, DeCesare et al. 2010b, Latham et al. 2011a, Latham et al. 2011c), and enhanced predator access to woodland caribou habitat (James and Stuart-Smith 2000a, Latham et al. 2011b). More generally, Bergerud (2007) has calculated that wolf densities greater than 6.5 wolves/1000 km² will result in woodland caribou declines. More recently, the federal recovery strategy identifies 3 wolves/1000 km² as a target (Environment Canada 2014).

Predation rates of the Barkerville caribou subpopulation were included with other mountain caribou populations in British Columbia during a 20-year (1984 – 2004) study (Seip 1992a, Allison 1998, Wittmer et al. 2005a). Predation on caribou was measured by visiting sites where collared animals had been killed. During that period, among the more northerly subpopulations 18 radio-collared caribou were killed by wolves, 11 were killed by bears, 1 was killed by a cougar and 1 was killed by a wolverine (Fig. 3 in Wittmer et al. 2005a). This result demonstrates both the variety of caribou predators and the dominance of wolves as caribou predators.

3.2 FOOD LIMITATION

Woodland caribou are herbivores and rare among animals as lichen eaters (Johnson et al. 2004). While lichen makes up the bulk of their winter diet (Johnson et al. 2000, Parker et al. 2005), it is a smaller proportion of their summer diet (Denryter et al. 2017). And although habitat selection is predominantly thought to be influenced by predator avoidance, selected habitats must also be able to satisfy the animals' nutritional needs (O'Brien et al. 2006, Brown et al. 2007). Trade-offs between these two fundamental demands (avoiding predators, finding food) raises the potential for woodland caribou to be food or energy limited as they seek predator refugia (Poole et al. 2000, Gustine et al. 2006). When it has been considered, estimates of caribou food abundance typically far exceeds population needs (Courtois et al. 2007).

A 1980s study of caribou in the Barkerville subpopulation range recorded food habits and diet quality (Seip 1992b). Lichen is 80% of their winter diet with conifer needles, buds and twigs making up the other 20%. Nitrogen content of these food types, as indicated by fecal N levels, is low. In spring they add fresh grazing and browse but continue to eat lichen and conifer browse. 12% of mortality due to malnutrition, but two of these happened during the summer when food was abundant, suggesting that disease or age may have contributed (Seip 1992b). No caribou died of malnutrition in winter during the study. Although old growth forest with abundant lichen growth has declined within their range, Barkerville caribou do not appear to be food limited.

3.3 HUMAN ACTIVITIES

Human activities have consequences for woodland caribou conservation throughout British Columbia. This section focusses on the consequences of human industrial, recreational and other (agriculture, highway, linear feature clearing) activities (Wolfe et al. 2000).

3.3.1 INDUSTRIAL

Industrial activities include forestry, mining, oil, gas and clean energy development. Caribou are affected by industrial activities both due to the infrastructure that is associated with it as well as the resulting impacts on their habitat. A key concept to measure and understand industrial effects on caribou is the Zone of Influence (ZOI; Polfus et al. 2011). This is the area beyond the actual footprint of an industrial development or activity that affects caribou (Dyer et al. 2001). Zones of influence vary by activity and by the presence and absence of people.

3.3.1.1 FORESTRY

Woodland caribou are an old-growth forest dependent species (Bergerud 2000). Hence, forest management affects their distribution and population dynamics. Although Mountain Caribou populations live seasonally in treeless, alpine ecosystems, all spend some of the year in forests. For this reason, forestry and natural disturbances will affect woodland caribou populations through habitat destruction and fragmentation (Smith et al. 2000). Forestry effects include very general “habitat loss” that reduces the amount of old-growth forest, to reduction in forest-based food resources to creating more, early seral forest habitat for apparent competitors (see below) such as deer and moose (Simpson and Woods 1987, Cichowski 1989, Seip 1990, Stevenson 1991, Cumming 1992). Factors, such as the type of forest (Cichowski 1989) and the size of cutblocks (Edmonds and Bloomfield 1984), play a role in the effect of forestry practices on woodland caribou populations. The ZOI of clearcuts for woodland caribou in Newfoundland was found to be 15 km beyond the actual cut block (Chubbs et al. 1993). Hence, even an array of small forestry clearings can have a significant influence on caribou habitat availability.

The Barkerville caribou subpopulation is largely within the Quesnel Timber Supply Area (TSA) with a small area overlapping the Williams Lake TSA. Blocks 5 and 6 of the fragmented Cascadia TSA are also within the Barkerville caribou subpopulation range. The allowable annual cut (AAC) for blocks 6 to 8 of the Cascadia TSA is 81,986 m³ (British Columbia Ministry of Forests 2017). The current AAC for the Quesnel TSA is 2,607,000 cubic metres, effective June 16, 2017 (British Columbia Ministry of Forests 2017). The forests in this range have been very fragmented by forestry with 214 cutblocks within or bordering on the subpopulation range totaling 64 km² of cuts (8.6% of its area). Adding a 15 km ZOI to all cutblocks would easily encompass the entire subpopulation range. Harvesting began in 1963 and continues.

3.3.1.2 MINING

Mine sites deter caribou both for the activities that occur there when they are active as well as for the habitat they destroy. Mines have a 2 km ZOI when they are active, but this shrinks to the physical footprint of the mine site when mines are dormant, inactive or abandoned (Polfus et al. 2011).

There are diverse mining operations in the Barkerville caribou subpopulation range, including aggregate (Devil’s Canyon) and gravel (Cariboo, Timon Creek) pits, gravel reserves (Yellowhawk Creek, Wendle Park, Summit Creek, Promise Creek) and various Placer permits. None of these are large or with extensive infrastructure.

3.3.1.3 OIL AND GAS

Oil and gas development threaten caribou populations through habitat destruction, human activity, access, habitat fragmentation and elevated predation (Dyer et al. 2001, Boutin et al. 2012, Hervieux et al. 2013). Given the spatial scope of developments and the range of activities that take place in caribou habitat to develop oil and gas resources (well sites, access roads, pipelines, seismic lines) cumulative effects of this combined with other activities (e.g. forestry, hydroelectric) also play a large role in threatening resident caribou herds (Nitschke 2008).

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A study of the energy consequences to caribou of being disturbed by oil and gas exploration found that individuals in active plays can lose more than 15% of body mass over winter attributed to noise displacement (Bradshaw et al. 1998).

There is no oil and gas exploration or development in the Barkerville caribou subpopulation range.

3.3.1.4 CLEAN ENERGY

Clean energy refers to hydroelectric dams and wind farms. Hydroelectric reservoirs in caribou range can destroy or fragment habitat and cut off movement corridors. Research in southern British Columbia correlated hydroelectric development with declines in caribou populations (Simpson 1987b). Hydroelectric dams, during their construction and operation have a ZOI that exceeds their footprint (Nellemann et al. 2003). Wind farm development can destroy caribou habitat, reduce forage availability, displace caribou and increase early-seral habitat that promotes growth of alternative prey populations (British Columbia Ministry of Environment 2014).

There are no wind or hydroelectric developments or proposals within the Barkerville caribou subpopulation range. But the Hen Ingram Lake pumped storage hydroelectric facility proposal is immediately south of their range.

3.3.1.5 OTHER

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

3.3.2 RECREATION

Recreational use of caribou habitat refers largely to fall and winter activities, including snowmobiling, commercial heli-skiing, commercial cat-skiing and hunting. In some jurisdictions, winter tour skiing and mountaineering are also relevant recreational activities as is summer use with off highway vehicles (OHVs). Numerous studies have shown that woodland caribou to varying degrees avoid mechanized winter activities (Simpson 1987a, Simpson and Terry 2000, Mahoney et al. 2001, Kinley 2003, Wilson and Hamilton 2003, Seip et al. 2007). Despite numerous records of displacement, no study has been able to draw a link between winter recreational use and woodland caribou population decline.

3.3.2.1 SNOWMOBILE

Snowmobile use in caribou habitat can result in their displacement (Simpson 1987a, Apps et al. 2001, Kinley 2003). Studies in British Columbia and elsewhere have shown that caribou are far less likely to occupy winter habitats that are being used for recreational snowmobiling than equivalent habitats without snowmobile use (Mahoney et al. 2001, Seip et al. 2007). The mechanisms of displacement include caribou avoiding or fleeing snowmobiles while they are in use, ease of access to caribou habitat by hunters and the facilitation of predator movement into caribou winter habitat from packed trails created by snowmobiles (Bergerud 1988, Polfus 2010).

Recreational snowmobile use is popular in the Quesnel Highlands within the Barkerville caribou subpopulation range (Price and Roorda 2006). Snowmobiles are used on 80% of winter weekends in most areas in the Quesnel Highlands and, during a 4 year study, there were 21 times when snowmobile users came within 500 m of caribou (Price and Roorda 2006). There are 655 km² of legal snowmobile closure areas over 9 separate blocks within the Barkerville range (plus that part of the range that is within Bowron Lake Provincial Park (Figure 1)). There is only one snowmobile access trail; the 2.7 km long Bald Mountain trail open year-round that allows users to cross the Hardscrabble Mountain closure. Compliance for voluntary snowmobile closures to protect caribou winter range varied between 78.3 and 98.2% during that time (Price and Roorda 2006).

3.3.2.2 HELI-SKI / CAT-SKI

Helicopter skiing and cat skiing are backcountry recreational activities that enable off-piste skiers to access high mountain terrain using either a helicopter or a tracked snow-cat that shuttles them to the top of ski runs. This is a commercial activity with numerous operators in British Columbia represented under one umbrella organization, HeliCat Canada (HCC). In southern British Columbia, HCC partners with the British Columbia government and non-government organizations to monitor caribou and heli-cat ski operations and minimize operational impacts.

Silvertip Heli-ski operates a helicopter tenure adjacent to the Barkerville caribou subpopulation range on Mount Tinsdale. Silvertip is a HeliCat Canada member and they have reported caribou sightings in their annual wildlife observations (Government of British Columbia 2017c).

3.3.2.3 OTHER

Backcountry tour skiing and mountaineering are recreational activities that occur in caribou habitat and can have an impact on woodland caribou conservation. Backcountry skiing (a term embracing of backcountry ski touring, unsupported, off-piste skiing and snowmobile assisted off-piste skiing) and mountaineering bring their participants into alpine areas that overlap with mountain caribou populations at sensitive times of the year (rut, winter). Unexpected encounters between individuals and people who are not in a vehicle can be very stressful for caribou and they can show a very strong flight response (McKay 2007).

Backcountry and cross-country skiing occur in and adjacent to the range of the Barkerville caribou subpopulation. There are skiing and hiking trailheads adjacent to their range at Mount Burdett and along Breakneck Ridge. Many backcountry ski routes are largely within Bowron Lake Provincial Park (exploreBC 2017). There are no backcountry ski lodges in the subpopulation range. Backcountry skiing is not a significant threat to the Barkerville subpopulation.

3.3.3 OTHER

Other human activities occur in caribou habitat and have the potential to harm caribou and / or affect caribou populations. Agriculture, transportation corridors, electrical transmission rights-of-way, oil and gas exploration and pipelines and hunting all have known effects on caribou populations (James and Stuart-Smith 2000b, Wolfe et al. 2000).

3.3.3.1 AGRICULTURE

The effects of agriculture on caribou conservation are largely the result of conversion of low-elevation habitat to crops and pasture (habitat destruction) and the food subsidy they provide for alternative prey (deer, elk, moose). Habitat conversion is functionally similar to clearcut logging in that it removes overstory vegetation and can alter landscape properties like vegetation composition and local snow depth. Growing hay and grain crops within or adjacent to caribou range has the potential to increase the regional population size of deer, elk and moose that eat crops (Bowden 1985, Côté et al. 2004, Butler et al. 2008, Hatter et al. 2017). Access to crops improves population growth of these species and their predators like bears and wolves. These, in turn, predate caribou, putting downward pressure on caribou populations.

Spread of disease and parasites from and to cattle is also a threat to woodland caribou from agricultural operations (Neiland et al. 1968, Trainer 1973, Wobeser 1976, Sifton 2001), and is discussed in section 3.5 (Parasites and Disease).

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None of the subpopulation range of Barkerville caribou falls within an Agricultural Land Reserve (ALR) and agriculture at scales that could affect caribou is absent from this area.

3.3.3.2 MAJOR HIGHWAY CORRIDORS

Where they occur in caribou habitat, highways have strong, negative effects on caribou populations (Johnson and Todd 1977, Curatolo and Murphy 1986, Apps and McLellan 2006). Vehicle activity on highways poses a movement barrier for caribou as they are either reluctant to approach a roadway or get killed trying to cross it (Dyer et al. 2002, Rytwinski and Fahrig 2012). Habitat and population fragmentation results as populations are unable to move between ranges and populations decline. Highways and roadways can also provide access to people to caribou range that increases the potential for disturbance. Linear disturbances, such as roadways have a large ZOI (Wolfe et al. 2000, Oberg 2001, Polfus et al. 2011, Whittington et al. 2011).

Highway 97 runs adjacent to the western edge of the Barkerville caribou subpopulation range, but there are no major roads in the range. Regional Highway 26 (Barkerville Highway) runs through the subpopulation range connecting the townsites of Wells and Barkerville to Highway 97.

3.3.3.3 LINEAR FEATURES

Linear features are narrow land disturbances that tend to traverse entire ranges. They include seismic cut lines, pipelines, forestry roads and overhead power transmission rights-of-way. Linear features are not necessarily cleared to a roadway standard, but enable both four-wheel-drive access and ease travel for predators and alternative prey (Hebblewhite et al. 2010a). One hypothesized effect is that linear features facilitate predator movement into and within prey habitat thereby increasing predator-prey overlap (DeMars and Boutin 2017).

While there are no linear features (non-highway) such as seismic lines or electrical transmission corridors in the Barkerville caribou subpopulation range, the density of cutblocks in the area has precipitated in a network of logging roads in the region. There are 373 individual forest road segments (both active and retired) either entirely within or crossing into the subpopulation range for a total of 960 km. This is 1.3 km of forestry road / km² range area.

3.3.3.4 HUNTING

The Barkerville caribou subpopulation range spans both the Omineca and Cariboo resource districts and is covered by districts 7-6 (Omineca) and 5-15, 5-16 (Cariboo). There is no caribou hunt in any of these districts, and no season in 5-16 (Bowron Lake Provincial Park), but there are seasons for many other game species including mule deer, white-tailed deer, moose (limited entry) and mountain goat (limited entry). While reduction in alternative prey through hunting pressure can be beneficial to woodland caribou, active hunting in their winter range may also contribute to accidental death by hunters who misidentify their prey.

3.3.3.5 POACHING

Caribou poaching is an unregulated, indiscriminate and largely unknown source of mortality across their range. Animals are taken in any season, of any age or sex and in any number. This kind of additive mortality can have a profound impact on caribou populations in British Columbia (Johnson 1985) and interacts with habitat management and human access (Stevenson 1990).

There are no records of caribou poaching of Barkerville caribou from the Omineca or Cariboo regions from Conservation Officer Service records.

3.4 NATURAL DISTURBANCE

Fire as a natural disturbance can have large-scale and long-lasting impacts on woodland caribou (Environment Canada 2014). Fire kills individuals, destroys habitat and changes predator-prey dynamics by improving habitat for alternative prey and increasing wolf-caribou spatial overlap (Robinson et al. 2012). Fire suppression, on the other hand, has increased the possibility of very large and intense fires that could alter entire range areas (Environment Canada 2012a). Mountain pine beetle infestations are also natural disturbances with large-scale and long-term effects (Cichowski and Williston 2005).

Only about 36.5 km² of wildfires have burned in the Barkerville caribou subpopulation range since 1933 (5% of the range area). Most of the historical fires occurred in 1936 and 1981 in two large fires that are now over 80 and 30 years old respectively. In 2017, a 17 km² fire burned in the Swift River area of the Barkerville caribou subpopulation range. Influencing factors such as climate change may exacerbate the frequency, size and intensity of wildfires (Harding and McCullum 1997).

Mountain pine beetle (MPB) has been very active in the TSA. Pine stands have been affected by a high level of infestation that occurred in British Columbia over the past 30 years. MPB peaked in the Prince George and Vanderhoof Districts in 2004 and in the nearby Fort St. James District in 2006. Within the range of the Barkerville caribou subpopulation there has been 380 km² of severely affected MPB forest (50%), 296 km² moderately affected (40%) and 1,426 km² of lightly affected pine forest (197%). Note that surveys were repeatedly assessed pine stands from 1983 to 2008 with overlapping areas progressing from light to moderate to severe infestation resulting in a cumulative area coverage well exceeding 100% of the range area. There is very little of the Barkerville caribou subpopulation range that has not seen an MPB infestation.

3.5 PARASITES AND DISEASES

Caribou are generally susceptible to a range of native and introduced diseases and parasites found in other ungulate species. Brucellosis is a contagious disease of ruminants which can cause spontaneous abortions particularly among first time breeding females (Neiland et al. 1968). The bacteria causing brucellosis in caribou is primarily *Brucella suis* that also affects swine (Jones 2014). Caribou are highly susceptible to the meningeal worm (*Parelaphostrongylus tenuis*) that is fatal in some, but not all, deer species (Anderson 1972, Trainer 1973). Early reports of woodland caribou declines in eastern Canada attributed it to their overlap with white-tailed deer who are meant to be the primary host of *P. tenuis* (Cringan 1956). Besnoitiosis is a disease caused by infection with the protozoan parasite *Besnoitia besnoiti* and is known in wildlife and livestock around the world (Walden et al. 2014). It can cause spontaneous abortions in pregnant females and infertility in males, but it is primarily expressed as facial hair loss in infected animals. It has been found in free-ranging woodland caribou in northern Saskatchewan in 1976 (Wobeser 1976), captive caribou (Glover et al. 1990).

Caribou are also susceptible to tape worms (*Echinococcus granulosus*, *E. multilocularis*, *Taenia ovis krabbei*), bot flies (Oestrinae), warble flies (Hypodermatinae), liver flukes (*Fascioloides magna*), lumpy jaw (*Actinomyces bovis*), muscle worms (*Parelaphostrongylus andersoni*, *P. odocoilei*), and winter tick (*Dermacentor albipictus*) (Miller et al. 2014b).

There is no reported occurrence of brucellosis or tuberculosis in British Columbia in any species, severe symptoms of Besnoitiosis have not been found in caribou in British Columbia (Miller et al. 2014a). However, many of the other parasites can be found in woodland caribou in British Columbia with affects on individuals, but no reported population-effects on the Barkerville subpopulation. Chronic wasting disease, which has the potential

for strong negative effects on this subpopulation has not been detected in British Columbia in any species (Schwantje 2015).

3.6 CLIMATE CHANGE

For species such as woodland caribou that undergo seasonal migrations, have predators with seasonal cycles, respond to plant and insect phenology and are sensitive to snow depth and season length, climate change will have direct effects (Vors and Boyce 2009). With alpine tundra habitats predicted to shrink in a warming climate, the effects of climate change on caribou may be profound (Harding and McCullum 1997, Swift and Ran 2012). Natural resource industries, such as forestry and oil and gas are both vulnerable and have a role to play in climate change mitigation (Houghton et al. 2001). How they adapt may also have consequences for caribou (Racey 2005). Climate change adds much complexity to managing caribou for long-term recovery, including how it affects the distribution of alternative prey (Seip 2008, Dawe and Boutin 2016) and available food (Parker et al. 2009).

Climate change models for British Columbia suggest that areas in the Cariboo Mountains will experience increased winter snow loads (Dawson et al. 2008, Griesbauer and Green 2010) that could affect food access and mobility for animals. Such a change could be positive for snow adapted, arboreal lichen eating caribou. This benefit could be negated by more frequent freeze-thaw cycles (Plummer et al. 2006) that will improve the ability to predators to move across frozen crusts as well as access to food for caribou (Gillett et al. 2004, Dawson et al. 2008). Predictions of forest type shifts due to climate change mediated by fires suggest that black spruce may be replaced by white spruce and lodgepole pine, affecting caribou habitat (Hebda 1997).

There is no research that has directly studied climate change effects on Barkerville caribou.

3.7 SMALL POPULATION SIZE EFFECTS

Small population effects include several threats to caribou populations that are unique to small (approximately less than 50 animals) and isolated subpopulations. These include reproductive and genetic isolation (McDevitt et al. 2009), predation (Sinclair et al. 1998, Abrams 2002), Allee effects where small groups are more vulnerable to predators (McLellan et al. 2010), risk of demographic bottlenecks where single-sex or male-dominated cohorts lead to population decline and increased chance that localized natural events such as avalanches (McClung 2001), fires or floods that kill a disproportionate number or key members of a small herd (Hebblewhite et al. 2010b). Movement barriers that prevent inter-population dispersal exacerbate small population effects by preventing small or extirpated populations of rescue (Gilpin 1990). Small population effects can be a particular hazard for species with slow growth rates (Laikre et al. 1997).

The breeding population of the Barkerville caribou subpopulation is small (less than 100; Figure 2) but above the threshold where small population effects may be severe. Nevertheless, accidents account for a relatively large proportion of all annual mortalities (18%) in the Quesnel Highlands (Seip and Jones 2010). With under 100 individuals and a fragmented population, risk of accidental death may have large and cumulative consequences.

The genetic viability of caribou subpopulations is dependant upon their size and dispersal (inter-population migration) ability (Weckworth et al. 2012). Small populations are subject to genetic drift that is a simple function of their small and unique gene pool as well as reduced gene flow (Boulet et al. 2007). Populations that are small and declining are particularly susceptible to genetic isolation (Laikre et al. 1997, Weckworth et al. 2012). The Barkerville caribou subpopulation may have been small enough in its recent history to experience a bottleneck,

and further fragmentation or declines could result in genetic anomalies that will be impossible to correct without translocation or other intervention (cf. McDevitt et al. 2009, Weckworth et al. 2012).

4 MANAGEMENT HISTORY

4.1 HABITAT

Caribou habitat in the range of the Barkerville caribou subpopulation is complex as not all animals follow the same seasonal patterns of habitat selection all the time. While most spend fall and winter in high elevation subalpine fir, some select mid elevation spruce/subalpine fir and others select low elevations in the cedar/hemlock forest (Seip 1992b). What is common among animals is selection for stands >80 years old and avoidance of young stands (Seip 1992b, Terry et al. 2000).

Habitat management in this area is overseen by the provincial government and implemented by the forestry industry through application of their AAC (see above). Active restoration takes place in the form of cutblock replanting that accelerates seedling establishment (Cichowski 1989, Cichowski 1996). For their part, forestry regulations prescribe practices to manage resource use and protect forests that are caribou habitat (Seip 1998). Because caribou in the Barkerville caribou subpopulation range use a wide range of habitats, such protections need to be wide ranging to be effective and understanding the impact of habitat management in this area requires a comprehensive analysis using landscape tools such as remote sensing (Sachs et al. 1998, Herzog et al. 2001).

4.1.1 PROTECTION

Provincial park legislation does not automatically protect caribou habitat from forestry, mining and petroleum resource activities. When land is acquired for a provincial park, with it comes the mineral and coal leases as well as timber and related licences (with compensation) (Government of British Columbia 1996a). Hunting is also prohibited (Government of British Columbia 1996b). Petroleum and natural gas tenures are permitted by the British Columbia Park Act (Section 33 Government of British Columbia 1996a) but are not relevant in this subpopulation range.

Within, and adjacent to, the range of the Barkerville caribou subpopulation there are several provincial parks and protected areas. Bowron Lake, Cariboo River, Wendle Provincial Parks and the Mount Tinsdale Ecological Reserve all affect this subpopulation's range. In addition, there are 8 Wildlife Management Areas within or crossing into the subpopulation's range, all established to protect caribou winter range using modified or no timber harvest. These cover 460 km², or 62%, of the subpopulation's area. At the north end of the Barkerville caribou range, an Ungulate Winter Range protection has been designated to regulate forestry-related activities in caribou habitat (Klaczek and Heard 2016).

4.1.2 ENHANCEMENT AND RESTORATION

Large-scale habitat restoration and enhancement for caribou protection and recovery generally refers to oil and gas activities (well sites, seismic lines) rather than forestry. Habitat restoration is very expensive and rarely undertaken at a scale that is beneficial to caribou (Schneider et al. 2010, Dickie et al. 2017). Small-scale habitat restoration actions, like decommissioning roads, replanting seismic lines or installing movement and visual barriers along pipelines can be effective (MacNearney et al. 2016, Pigeon et al. 2016, DeMars and Boutin 2017). Nevertheless, it is considered an essential step for caribou recovery in the absence of protection required for natural habitat regrowth that can take tens of decades.

There is no large-scale, active habitat restoration being conducted in the Barkerville caribou subpopulation range.

4.2 RECREATION AND ACCESS MANAGEMENT

Road access to woodland caribou habitat elevates conservation threats including conflicts with snowmobiles, hunting pressure, habitat fragmentation and in some cases predation (James et al. 2004, Apps and McLellan 2006, Seip et al. 2007, Apps and Dodd 2017). A key element of caribou life history is how they seek separation from competitors (moose, deer, elk) and their predators (Bergerud and Elliot 1986, Wittmer et al. 2007). Constructed access roads into woodland caribou habitat connects them to their threats and contributes to population declines (Dussault et al. 2012).

The large number of forestry cutblocks in the Barkerville caribou subpopulation range has left a legacy of road access in the region (see Linear Features above). There are 373 individual forest road segments (both active and retired) either entirely within or crossing into the subpopulation range for a total of 960 km. This is 1.3 km road / km² range area. This is very high (Dyer et al. 2002, Smith 2004, Apps and McLellan 2006, Beauchesne et al. 2014, COSEWIC 2015, Bennett 2017). Managing user access to this road network is paramount to caribou persistence and recovery here, and access restrictions for motorized vehicles are in place in most areas (Klaczek and Heard 2016, Government of British Columbia 2017b).

4.2.1 SNOWMOBILE

A recognition of the impact of snowmobile encounters on caribou habitat use (Kinley 2003, Price and Roorda 2006, Seip et al. 2007) has prompted a closure of much of the range of the Barkerville caribou subpopulation to snowmobile use (Klaczek and Heard 2016).

4.2.2 HELI-SKI / CAT-SKI

Management of the Barkerville caribou subpopulation is included under the umbrella of the Mountain Caribou Recovery Implementation Plan, approved in 2007. As a result of this, restrictions and increased scrutiny of commercial heli-skiing operations are in place (see above; Klaczek and Heard 2016). This means that HeliCat Canada, an organization that represents most helicopter and cat-ski operators in British Columbia and all of those that operate in the subpopulation range, comply with guidelines to avoid caribou and their habitat during their activities. Silvertip Heliski operate in this area (see above). They record and report all wildlife observations, have adopted best management practices to avoid caribou encounters and undertake an annual review of their practices with respect to wildlife, particularly caribou, interactions.

See section 3.3.2.2 for general threat information.

4.2.3 OTHER

There are no specific management actions to regulate or limit other recreational activities such as backcountry skiing or summer (non-hunting) OHV use.

4.3 PREDATORS

Unsustainable predation is acknowledged as a key, proximal mechanism of woodland caribou decline across Canada (Bergerud and Elliot 1986, Bergerud 1988). Woodland caribou metapopulations have persisted despite ongoing predation from wolves, bears (black and grizzly) and cougars for millennia, but the existential impact of predators on caribou is a recent phenomenon. Human changes to habitats, fragmentation, movement

barriers, dynamics of alternative prey and predator access to caribou habitat have led to conditions where caribou subpopulations are permanently extirpated.

Shrinking old-growth forest caribou habitat has forced caribou into increasingly smaller ranges, making their home range potentially more predictable to predators. Seasonal migratory routes track through predator rich areas and bringing them into closer proximity to alternative prey species that can sustain higher predator populations (Seip 1992a, Apps et al. 2013). Road and seismic line clearing and winter trail packing makes travel for predators into caribou critical habitats more efficient, elevating, in particular, wolf predation (Dickie et al. 2016). And, finally, a shift in forest structure towards younger age classes has favoured moose, deer and elk at densities that can support greater predator densities. Not only does this shift bring woodland caribou into closer proximity to predators, but it also promotes greater predator abundance (Hebblewhite et al. 2007).

Although habitat changes facilitate unsustainable predation, habitat regrowth and restoration occurs too slowly to recover woodland caribou in the short-term. As a result, direct predator management is a caribou recovery tool to ensure that populations persist long enough to benefit from habitat restoration efforts (Wilson 2009, Brook et al. 2014, Hervieux et al. 2014).

4.3.1 WOLF MANAGEMENT

Wolves are an important, year-round caribou predator. Caribou populations in northern British Columbia were shown to decline when wolf densities were 9–10/1000 km² but increased at wolf densities from 1–4/1000 km² (Bergerud and Elliot 1986). For this reason, target wolf densities that would enable caribou recovery are set to 6.5/1000 km². In the absence of effective habitat or alternative prey management to achieve these densities, direct wolf management must be undertaken to achieve caribou conservation goals.

Wolf control was conducted in the Quesnel Highlands for two years as part of a study between 1984 and 1989 (Seip 1992b). Prior to wolf management only 2.5% of female caribou had calves that survived from spring calving to the fall rut survey (Seip 1992b). When wolf management was taking place, or in places where wolves were not seen, 39% of females had calves that survived this period (Seip 1992b).

Another wolf study in the Quesnel Highlands, within the Barkerville caribou range ran from 2001 to 2010 (with a lapse in 2004; Roorda and Wright 2004, 2010). From 2001 to 2004, 30 wolves were killed in the study area and 16 were sterilized. Between 2007 and 2010, 40 wolves were collared to track movements and mortality rates, 34 were killed and 31 were sterilized. In 2010 wolf density was 5.5 wolves/1000 km² in the active control area which is below the recommended threshold of 6.5 wolves / 1000 km² (Bergerud 2007, Roorda and Wright 2010). This effort is one management action that is attributed to the gradual increase in the Barkerville caribou subpopulation since 1993 (Ray et al. 2015).

A wolf management program began in 2008 in the Narrow Lake area adjacent to the Barkerville subpopulation range, but only 2 wolves were removed in the first year. The wolf population is occasionally censused in the area (Young and Freeman 2003).

4.3.2 COUGAR MANAGEMENT

Cougars are uncommon in the Barkerville caribou subpopulation range (Spalding 1994) but their population is likely increasing. Cougar hunting in the Cariboo region is gaining popularity but the number of successful hunts is increasing slowly. From 1976 through 2013, if any cougars were killed only 1 or 2 were killed by both resident and non-resident hunters each year for a total of 16 kills over that time. In British Columbia,

particularly in the south (Wittmer et al. 2005a), cougars are a significant caribou predator. Cougar densities respond positively to deer density, and as deer densities climb, so will cougar densities. Nevertheless, in northern British Columbia, there are only rare reports of cougar predation on caribou.

4.3.3 OTHER

Grizzly bears, black bears and wolverines are also woodland caribou predators (Seip 1992a, Wittmer et al. 2005a). However, their protection status, seasonality and / or low predation rate and dependence on caribou as food does not warrant management to benefit caribou populations. In rare cases associated with intensive caribou management programs (captive breeding, maternity penning) bear or wolverine removal may be conducted.

Grizzly and black bears are relatively abundant in the Barkerville caribou subpopulation range, and are spring predators of calves (Wittmer et al. 2005a). To date, bear management to reduce their densities to favour caribou population numbers is not being conducted, but hunting pressure is high. Over 1700 black bears and 204 grizzly bears have been killed by resident and non-resident hunters since 1976 (~46 and 5 per year on average respectively).

4.4 PRIMARY PREY

Moose, elk, white-tailed deer and mule deer (including black-tailed deer) share large, mammalian predators such as wolves, bears and cougars. In what is known as apparent competition (Holt 1977), an increase in one prey population will lead to a decrease in a second prey population. It appears as if these two, prey species are competing with each other, but the decline of the second prey species is due to the boost that their shared predator population experiences because of the high density of the first prey species. Woodland caribou have avoided apparent competition by occupying habitats distant from other deer species. However, changes to their habitats, movement barriers and facilitated predator access have limited their ability to continued isolation. Across their range, woodland caribou populations have been subject to apparent competition (DeCesare et al. 2010b, Wittmer et al. 2013). For this reason, managing primary prey, either directly through hunting quotas, or indirectly through habitat management has become a needed management action.

4.4.1 MOOSE MANAGEMENT

Throughout British Columbia, moose are a common and sustaining prey of wolves (Messier 1994). But their expanding range (Bergerud and Elliot 1986), a wolf numerical response to moose densities (Messier and Joly 2000) and apparent competition with woodland caribou mean that even moderate moose densities in or adjacent to caribou range poses a threat to caribou persistence (Seip and Cichowski 1996, Lessard et al. 2005, Serrouya et al. 2017). Moose densities respond positively to early seral forest habitat and negatively to human hunting, and moose numbers have been falling around the province in response to harvest pressure (Moose Management Technical Team 2015). Lessard et al. (2005) found that a 10% increase in the moose harvest could stabilize caribou populations.

Moose populations have been systematically surveyed in this region since the 1980s (Borthwick and Mackay 2008). A 2013 analysis of the existing data suggested that moose densities in this area are between 0.29 and 0.11 animals / km² and below the target for the Cariboo Region of 0.4 moose / km² (McNay et al. 2013). This is similar to the density achieved by Serrouya et al. (2017) where adult caribou survival rates increased and suggests that further management to further reduce moose densities is unnecessary.

4.4.2 DEER MANAGEMENT

Managing deer populations in support of caribou conservation is a challenge. Both can support predator populations that have negative effects on caribou (Latham et al. 2011c). Both can transmit diseases that could be catastrophic were they to spread to caribou populations (see above; Habib et al. 2011). Where mule deer and white-tail deer ranges overlap, mule deer tend to decline, perhaps also due to apparent competition (Robinson et al. 2002). In British Columbia, there is active management to increase mule deer populations through habitat protection (British Columbia Ministry of Environment 2017) and manage white-tailed deer populations through hunting regulations (British Columbia Ministry of Forests 2015). Neither are strictly regulated by either predators or food. White-tailed deer populations respond strongly to food availability as well as hunting or predation (Fryxell et al. 1991, Messier 1991, Dumont et al. 2000). Mule deer are similar, but tend to be more vulnerable to predation, food availability, severe weather and loss of native winter habitat (Pierce et al. 2012, Forrester and Wittmer 2013, Bergman et al. 2015). Indeed, regulating deer density using hunter tags must counter some difficult trends (declining number of hunters, increase prey refugia from hunters and increased use of residential areas by deer) to be successful (Brown et al. 2000). Managing deer populations to a lower density will require managing artificial food sources (hay, grain), and access to high quality habitats as well as increased hunting pressure.

Deer (white-tailed and mule) are present in the Barkerville caribou subpopulation range. Harvest statistics suggest that white-tailed deer populations are increasing across the Cariboo region (British Columbia Ministry of Forests 2015). Mule deer numbers across British Columbia have been relatively stable from 1994 to 2014 (Mitchell 2016), and this seems to also be the case in the Cariboo region (Davis 2010). Management actions are in place to support and increase mule deer numbers, and hunting regulations are in place to manage their densities.

4.4.3 OTHER

Elk, like moose and deer, are wolf prey and could potentially facilitate apparent competition with caribou (DeCesare et al. 2010b). Elk are present in the Barkerville caribou subpopulation range but are not being purposely managed.

4.5 POPULATION REINFORCEMENT

The International Union of Conserving Nations (IUCN) has established guidelines for reintroductions and related conservation translocations (IUCN Species Survival Commission 2012), of which population reinforcement is one tool. In this document, reinforcement is defined as an intentional movement and release of an organism into an existing population of conspecifics within its indigenous range. It differs from reintroduction in that the species has not been extirpated from that range (DeCesare et al. 2010a), but existing populations are being added to. The management tools described in this section are based on the assumption that caribou populations are being reinforced and not reintroduced.

4.5.1 MATERNITY PENNING

Maternity penning (sometimes called maternal penning) is a technique to increase calf recruitment by capturing and temporarily penning pregnant females to protect them from predators. These females are held through parturition and for up to six weeks after calves are born. By this time calves are large and strong enough to better avoid predators, improving their survival probability and population recruitment. Thus, if young-of-the-year predation is a contributing factor to unsustainable population decline, maternity penning can be an effective mitigation (Hayek et al. 2016). Maternity penning is an *in situ* method where the pen is constructed within their home range and animals are never moved outside of their home range.

There is no maternity penning operating or planned for the Barkerville caribou subpopulation region.

4.5.2 CAPTIVE BREEDING

Captive breeding is a conservation method that captures both male and female animals and moves them permanently to a facility where they are bred under controlled conditions (IUCN Species Survival Commission 2012). The objective is to create a surplus of female calves in the breeding facility that can then be translocated to ranges to reinforce small populations. To be effective, recipient populations should have low adult female survival that this action can reverse. This is a *ex situ* approach that takes animals away from their home range and returns animals to ranges that may not be where they originate (Harding and McCullum 1997). A number of factors, such as source animals, animal husbandry, genetic bottlenecks, gene mixing with destination herds, status of destination herds, disease transmission, fate of male calves among others must be considered in such an effort (Dolman et al. 2015, Hayek et al. 2016).

Captive breeding to reinforce the Barkerville caribou subpopulation is not being planned, although its population trajectory, low predator and primary prey densities make it a possible candidate herd. Although this subpopulation is increasing, it remains under 100 individuals and thus may not be considered as a source population for captive breeding programs.

4.5.3 TRANSLOCATION

Translocation is the reinforcement of small populations by moving animals directly from a sustainable population (Ray et al. 2015, Hayek et al. 2016). The goal is to rapidly increase the numbers of animals of all ages and sexes in the target population (Miller et al. 2007, Decesare et al. 2010c). Animals are captured in their home range, transported to the target range and either soft released in a temporary pen that offers an opportunity for individuals to adjust to their new surroundings, or hard released directly into the destination habitat.

Compared with other reinforcement methods, translocation is a relatively cost-effective approach to add animals to small populations. It has been tried successfully and unsuccessfully with caribou populations in Canada and British Columbia (Compton et al. 1995, Stronen et al. 2007, Hayek et al. 2016).

There have been no translocations to or from the Barkerville caribou subpopulation range.

4.5.4 OTHER

The proximate cause of caribou population declines is predation. While predator management is a direct way to manage this threat, an alternative solution is predator exclusion fencing (Hayek et al. 2016). In part, this approach is linked to direct predator management as any predators within an exclusion fence would be lethally removed, and it is linked to maternity penning as this is a form of small-scale, temporary predatory exclusion fencing. However, there are recent, and very large scale (thousands of hectares), proposals to erect predator exclusion fencing as a mitigation for caribou populations where habitat restoration is an unrealistic goal but the caribou population is critically low (Boutin and Merrill 2016, Cornwall 2016, Hebblewhite 2017, Proulx and Brook 2017).

To date, this conservation method has not been attempted anywhere, including in the range of the Barkerville caribou subpopulation (Antoniuk et al. 2016).

4.6 STEWARDSHIP/OUTREACH

Local communities and stewards are an essential part of caribou recovery. Management actions to recover very small populations are at times expensive, controversial and require the imposition of new and restrictive regulations (Hayek et al. 2016). Gaining the social licence to conduct management actions like predator management, translocation, captive breeding and access restrictions requires outreach. Effective outreach programs to local communities and regional populations must accompany planning for management actions (Antoniuk et al. 2015). This includes information to municipal and regional administrations, business stakeholders, recreational groups, conservation organizations, farming organizations, hunting clubs among others (see below). Outreach must be timely, targeted and inclusive to be effective (Wilkinson 2010).

Stewardship is the active participation by citizens or citizen groups in conservation and recovery programs. For caribou this can take a number of forms ranging from ambassador programs where citizen volunteers promote caribou conservation at community events, habitat protection through conservation offsets (Robichaud and Knopff 2015) to fund-raising and operating reinforcement activities such as maternity pens.

Prince George is an important hub for caribou research and conservation in central British Columbia. There are a number of caribou populations in the region, government offices focussed on caribou monitoring, Indigenous communities with cultural links to caribou and a university campus (University of Northern British Columbia) that conducts important, fundamental research on caribou and their habitat.

There is already a Community Working Groups for species at risk in Prince George; specifically, for White Sturgeon recovery. These are composed of First Nations, ENGO, Industry, Provincial and Federal Government representatives. A similar group could be established for caribou conservation. As well, the Spruce City Wildlife Association is a membership group of hunters, naturalists, anglers, trappers, guides and environmentalists conducting projects for wildland protection (SCWA 2017). Outreach to groups such as this to promote programs and education in caribou themes.

4.7 RESEARCH

Every caribou subpopulation in British Columbia requires some degree of management action; habitat protection or restoration, population reinforcement, alternative prey management or predator control. Yet few caribou subpopulations in British Columbia have sufficient, herd-specific information to enable confident management decisions. To fill these gaps, scientific research and traditional ecological knowledge must be gathered to fill critical gaps.

There have been decades of research into caribou biology and conservation. This body of work has informed scientists and policy makers of the key factors that contribute to caribou population dynamics, important threats and potential solutions. Key findings have been the proximate role of predation and apparent competition in caribou population fluctuations and the ultimate role of habitat destruction in caribou population declines. While their interactions are broadly understood, ongoing research to fine tune caribou responses to ecological stimuli and human disturbance including habitat fragmentation and primary prey density can improve our management.

The Barkerville caribou subpopulation, their habitat and predator-prey dynamics in the region, have long been studied by both university-based and government biologists. An understanding of caribou population variability, density of primary prey (moose and deer) and predator (wolf) dynamics has been gained (Seip 1998, Terry et al. 2000, Apps et al. 2001, Seip 2003, Wittmer et al. 2005a, Jones et al. 2007). An understanding of the cause and

effect of caribou population declines remains incompletely understood, however manipulations of predator populations in the 1990s and early 2000s have provided important insights (Roorda and Wright 2004, 2010). An understanding of the impact of mountain pine beetle infestation in this area has not been extensively studied, but is known from other regions (Willison and Cichowski 2006, Cichowski 2007).

4.8 MONITORING

Ecological, population and industrial footprint monitoring is an essential activity towards the conservation and recovery of woodland caribou. This provides the information that enables the detection of conservation threats, the effectiveness of management activities and the status of target populations. Although it cannot replace conservation action, it is an essential piece of the caribou recovery program.

The Government of British Columbia has committed resources to monitoring caribou and game species population density in the Barkerville caribou subpopulation range. Maintaining this information record so that links can be determined among habitat change, fragmentation, primary prey density, predator density, predation rates and caribou population dynamics.

5 IMPLICATIONS TO OTHER WILDLIFE

Changing population trends of woodland caribou will require manipulating the environment in ways that favour caribou ecology and life history at the expense of other wildlife. More old growth forest will benefit caribou but not moose or deer. Reducing adult female and calf mortality may require lethal wolf control. Maternity penning makes calves, common spring prey for black and grizzly bears, less vulnerable to these predators. None of these management actions can or will imperil other wildlife species but will precipitate changes to their population density and/or distribution.

Actions taken to protect and manage the Barkerville caribou subpopulation and their habitat may benefit or inhibit the protection of other species and their habitats (British Columbia Ministry of Environment 2013). Predator management directly affect wolves, who's populations have been intentionally reduced, and other ungulate species like moose, who's densities may also have to be held low to facilitate caribou conservation (Serrouya et al. 2017).

6 IMPLICATIONS TO OTHER VALUES

The recovery and protection of woodland caribou populations will affect a range of human values and activities across caribou range (Scarfe 2006). These include recreational / commercial activities such as camping, snowmobiling and backcountry skiing, commercial resource extraction activities such as forestry, mining and oil and gas development as well as non-commercial resource uses such as hunting. Research shows that none of these activities will have to be halted to protect woodland caribou (Kruse et al. 1998, Hebblewhite et al. 2006, Hebblewhite 2017). However, changes to operations, seasonal restrictions and area closures will be required, locally affecting some recreational and commercial activities (Government of Alberta 2016).

Already, recreational snowmobile use has been restricted in this area using legal closures, and the coverage of Wildlife Habitat Area protections restricts or prevents forestry over much of the subpopulation range. The last caribou hunt was in 1997 and the last caribou killed by a resident hunter was in 1991 (non-resident, guided hunters killed the last hunted caribou in the region in 1997).

7 PARTNERS / NEIGHBOURS

Partners are existing or potential groups that can contribute to woodland caribou management with expertise, funding, in-kind or moral support. Neighbours are groups within in the caribou subpopulation area that are currently not participating in caribou management but that could be affected by caribou management. Neighbours include local governments, industry tenure holders, and recreation groups. Neighbours could potentially become future partners.

Below is a list of communities in and adjacent to Barkerville range, organizations that have a clear interest in how this area is managed and businesses that have a commercial interest in the area. This may not be a complete list, particularly of distant organization with an inherent interest.

Communities: **First Nations:** Lheidli-T'enneh First Nation, ?Esdilagh First Nation (Alexandria Indian Band), T'exelc First Nation (Williams Lake Indian Band), Carrier Chilcotin Tribal Council (Red Bluff Indian Band (Lhtako Dene), Lhoosk'uz Dene' Government Administration) , Cariboo Tribal Council

Local: Quesnel, Dunkley, Wells, Sugarcane

Regional: Prince George (and outlying communities), Williams Lake

Organizations: **Recreation:** British Columbia Snowmobile Federation (Wells Snowmobile Club, Prince George Snowmobile Club, Williams Lake Powder Kings Snowmobile Club, Quesnel Snowmobile Club), Land Conservancy of British Columbia, Outdoor Recreation Council of British Columbia, Quad Riders Association of British Columbia, Prince George ATV Club, Quesnel Cross Country Motorcycle Association, Caledonia Ramblers Hiking Club, Prince George Horse Society, Prince George Off-Road Motorcycle Association, Williams Lake Off Road Motorcycle Association, Prince George Snowmobile Club, Northwest Brigade Canoe Club, Hickory Wing Ski Touring Club, Silvertip Heli-ski

Protection: Western Canada Wilderness Committee, BC Spaces for Nature, Yellowstone to Yukon Initiative

8 RECOMMENDED ACTIONS

8.1 SHORT TERM (WITHIN 6–12 MONTHS)

- Continue / resume predator management with a goal of maintaining wolf populations at a density of less than 6.5 wolves/1000 km² verified by periodic wolf population counts.
- Initiate a regional outreach program to foster support for management that will promote ongoing growth of the Barkerville caribou program.

8.2 MEDIUM TERM (WITHIN 12–24 MONTHS)

- Continue caribou population monitoring through annual or bi-annual aerial census or through non-invasive techniques such as scat mark-recapture (Ball et al. 2007).

8.3 LONG TERM (WITHIN 24–48 MONTHS)

- Maintain and enforce current population (no caribou hunt) and habitat (UWR, Wildlife Habitat Areas and Provincial Park) protection.
- Ensure a supply of habitat that supports a sustainable caribou population by allowing it to recover. This will be measured using remote sensing tools of aerial extent of undisturbed or recovering vegetation classes.
- Rehabilitate forestry road segments in the Barkerville caribou subpopulation range to prevent mechanized access and inhibit predator and primary prey (moose and deer) movement.
- Initiate research into mitigations for habitat loss due to Mountain Pine Beetle infestation.

9 LITERATURE CITED

- Abrams, P. A. 2002. Will small population sizes warn us of impending extinctions? . *The American Naturalist* **160**:293–305.
- Allison, B. A. 1998. The influence of wolves on the ecology of mountain caribou. University of British Columbia, Vancouver, BC.
- Anderson, R. C. 1972. The ecological relationships of meningeal worm and native cervids in North America. *Journal of Wildlife Diseases* **8**:304–310.
- Angelstam, P., S. Boutin, F. Schmiegelow, M.-A. Villard, P. Drapeau, G. Host, J. Innes, G. Isachenko, T. Kuuluvainen, M. Mönkkönen, J. Niemelä, G. Niemi, J.-M. Roberge, J. Spence, and D. Stone. 2004. Targets for Boreal Forest Biodiversity Conservation: A Rationale for Macroecological Research and Adaptive Management. *Ecological Bulletins* **51**:487–509.
- Antoniuk, T., E. Dzus, and J. Nishi. 2015. A methodological framework for caribou action planning in support of the Canadian Boreal Forest Agreement. The Science Committee and the National Working Group on Goals 2 and 3 of the Canadian Boreal Forest Agreement, Ottawa, ON.
- Antoniuk, T., J. Nishi, R. Harding, L. McNeil, and K. Manuel. 2016. Northeast Alberta caribou predator fencing pilot: Overview. Canada's Oil Sands Innovation Alliance (COSIA).
- Apps, C., and N. L. Dodd. 2017. Caribou habitat modeling and evaluation of forest disturbance influences across landscape scales in west-central British Columbia Ministry of Forests, Lands and Natural Resource Operations, Williams Lake, BC.
- Apps, C. D., and B. N. McLellan. 2006. Factors influencing the dispersion and fragmentation of endangered mountain caribou populations. *Biological Conservation* **130**:84–97.
- Apps, C. D., B. N. McLellan, T. A. Kinley, and J. P. Flaa. 2001. Scale-dependent habitat selection by mountain caribou, Columbia Mountains, British Columbia. *Journal of Wildlife Management* **65**:65–77.
- 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.
- Ball, M. C., R. Pither, M. Manseau, J. Clark, S. D. Petersen, S. Kingston, N. Morrill, and P. Wilson. 2007. Characterization of target nuclear DNA from faeces reduces technical issues associated with the assumptions of low-quality and quantity template. *Conservation Genetics* **8**:577–586.
- Beauchesne, D., J. A. G. Jaeger, and M.-H. St-Laurent. 2014. Thresholds in the capacity of boreal caribou to cope with cumulative disturbances: Evidence from space use patterns. *Biological Conservation* **172**:190–199.
- Bennett, V. J. 2017. Effects of road density and pattern on the conservation of species and biodiversity. *Current Landscape Ecology Reports* **2**:1–11.
- Bergerud, A. T. 1988. Caribou, wolves and man. *Trends in Ecology & Evolution* **3**:68–72.

Woodland Caribou Plan for the Barkerville Subpopulation

- Bergerud, A. T. 2000. Caribou. Pages pp, 658–693 in S. Demarais and P. R. Karusmann, editors. Ecology and Management of Large Mammals in North America. Prentice Hall, New Jersey.
- Bergerud, A. T. 2007. The need for the management of wolves — an open letter. *Rangifer* **17**:39–50.
- Bergerud, A. T., and J. P. Elliot. 1986. Dynamics of caribou and wolves in northern British Columbia. *Canadian Journal of Zoology* **64**:1515–1529.
- Bergman, E. J., P. F. Doherty, G. C. White, and A. A. Holland. 2015. Density dependence in mule deer: a review of evidence. *Wildlife Biology* **21**:18–29.
- Borthwick, R., and C. Mackay. 2008. 2008 – Cariboo Mountains (5-15c) winter moose inventory. 07-BC-0156, British Columbia Ministry of Environment, Williams Lake, BC.
- Boulet, M., S. Couturier, S. D. Côté, R. D. Otto, and L. Bernatchez. 2007. Integrative use of spatial, genetic, and demographic analyses for investigating genetic connectivity between migratory, montane, and sedentary caribou herds. *Molecular Ecology* **16**:4223–4240.
- Boutin, S., M. S. Boyce, M. Hebblewhite, D. Hervieux, K. H. Knopff, M. C. Latham, A. D. M. Latham, J. Nagy, D. Seip, and R. Serrouya. 2012. Why are caribou declining in the oil sands? *Frontiers in Ecology and the Environment* **10**:65–67.
- Boutin, S., and E. Merrill. 2016. A review of population-based management of Southern Mountain caribou in BC. University of Alberta, Edmonton, Canada.
- Bowden, G. K. 1985. Wildlife damage on private agricultural land in the east Kootenay. Ministry of Environment, Vancouver, BC.
- Bradshaw, C. J. A., S. Boutin, and D. M. Hebert. 1998. Energetic implications of disturbance caused by petroleum exploration to woodland caribou. *Canadian Journal of Zoology* **76**:1319–1324.
- British Columbia Conservation Data Centre. 2017. BC Species and Ecosystems Explorer. British Columbia Ministry of Environment, Victoria, BC.
- British Columbia Ministry of Environment. 2013. Implementation plan for the ongoing management of South Peace Northern Caribou (*Rangifer tarandus caribou* pop. 15) in British Columbia., Government of British Columbia, Victoria, BC.
- British Columbia Ministry of Environment. 2014. Science Update for the South Peace Northern Caribou (*Rangifer tarandus caribou* pop. 15) in British Columbia. Government of British Columbia, Victoria, BC.
- British Columbia Ministry of Environment. 2017. Regional Mule Deer Winter Range Strategy. Cariboo Region ESD. Government of British Columbia, Victoria, BC.
- British Columbia Ministry of Forests, Lands and Natural Resource Operations,. 2017. Current Allowable Annual Cut for Timber Supply Areas. Timber Supply Areas. Government of British Columbia, Victoria, BC.
- British Columbia Ministry of Forests, Lands and Natural Resource Operations, . 2015. White-tailed Deer: A Review of the 2010 Provincially Coordinated Hunting Regulation Government of British Columbia, Victoria, BC.
- Brook, R. K., M. Cattet, C. T. Darimont, P. C. Paquet, and G. Proulx. 2014. Maintaining ethical standards during conservation crisis. *Canadian Wildlife Biology and Management* **4**:72–79.
- Brown, G. S., L. Landriault, D. J. H. Sleep, and F. F. Mallory. 2007. Comment arising from a paper by Wittmer et al.: hypothesis testing for top-down and bottom-up effects in woodland caribou population dynamics. *Oecologia* **154**:485–492.
- Brown, T. L., D. J. Decker, S. J. Riley, J. W. Enck, T. B. Lauber, P. D. Curtis, and G. F. Mattfeld. 2000. The future of hunting as a mechanism to control white-tailed deer populations. *Wildlife Society Bulletin* **28**:797–807.
- Butler, E. A., W. F. Jensen, R. E. Johnson, and J. M. Scott. 2008. Grain overload and secondary effects as potential mortality factors of moose in North Dakota. *Alces: A Journal Devoted to the Biology and Management of Moose* **44**:73–79.
- Chubbs, T. E., L. B. Keith, S. P. Mahoney, and M. J. McGrath. 1993. Responses of woodland caribou (*Rangifer tarandus caribou*) to clear-cutting in east-central Newfoundland. *Canadian Journal of Zoology* **71**:487–493.
- Cichowski, D. B. 1989. Seasonal movements, habitat use, and winter feeding ecology of woodland caribou in west-central British Columbia. University of British Columbia, Vancouver, BC.

- Cichowski, D. B. 1996. Managing woodland caribou in west-central British Columbia. *Rangifer* **16**:119–126.
- Cichowski, D. B. 2007. Mountain pine beetle / lichen project quesnel timber supply area: Year 2. Experimental project number ep1208.01, Bulkley Valley Centre, Smithers, BC.
- Cichowski, D. B., and P. Williston. 2005. Mountain pine beetles and emerging issues in the management of woodland caribou in west-central British Columbia. *Rangifer* **16**:97–103.
- Compton, B. B., P. Zager, and G. Servheen. 1995. Survival and mortality of translocated woodland caribou. *Wildlife Society Bulletin* **23**:490–496.
- Cornwall, W. 2016. To save caribou, Alberta wants to fence them in. *Science* **353**:333–333.
- COSEWIC. 2011. Designatable Units for Caribou (*Rangifer tarandus*) in Canada. Ottawa.
- COSEWIC. 2015. Assessment and Status Report on the Caribou *Rangifer tarandus* Northern Mountain population, Central Mountain population, Southern Mountain population in Canada. Committee on the Status of Endangered Wildlife in Canada,, Ottawa, Canada.
- Côté, S. D., T. P. Rooney, J.-P. Tremblay, C. Dussault, and D. M. Waller. 2004. Ecological impacts of deer overabundance. *Annual Review of Ecology, Evolution, and Systematics* **35**:113–147.
- 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.
- Cringan, A. T. 1956. Some aspects of the biology of caribou and a study of the woodland caribou range of the Slate Islands, Lake Superior, Ontario. University of Toronto, Toronto, ON.
- Cumming, H. G. 1992. Woodland caribou: Facts for forest managers. *The Forestry Chronicle* **68**:481–491.
- Curatolo, J. A., and S. M. Murphy. 1986. The effects of pipelines, roads, and traffic on the movements of caribou, *Ragifer tarandus*. *Canadian Field-Naturalist* **100**:21 28–224.
- Davis, L. R. 2010. Assessment of mule deer population and habitat use on TFL 52 block B. . Davis Environmental Ltd. and West Fraser Mills Ltd., Williams Lake, BC.
- 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.
- Dawson, R., A. T. Werner, and T. Q. Murdock. 2008. Preliminary analysis of climate change in the Cariboo-Chilcotin Area of British Columbia. Pacific Climate Impacts Consortium, University of Victoria, Victoria, BC.
- DeCesare, N., J. Whittington, H. Robinson, M. Hebblewhite, M. Bradley, L. Neufeld, S. Cleveland, J. Goldberg, L. Greene, M. Hurley, C. Miller, W. Peters, J. Polfus, and M. Musiani. 2010a. Evaluating the reintroduction of southern mountain woodland caribou to restore small populations. Univeristy of Montana, Missoula, Montana.
- DeCesare, N. J., M. Hebblewhite, H. S. Robinson, and M. Musiani. 2010b. Endangered, apparently: the role of apparent competition in endangered species conservation. *Animal Conservation* **13**:353–362.
- Decesare, N. J., J. Whittington, M. Hebblewhite, H. Robinson, M. Bradley, L. Neufeld, and M. Musiani. 2010c. The role of translocation in recovery of woodland caribou populations. *Conservation Biology* **25**:365–373.
- DeMars, C. A., and S. Boutin. 2017. Nowhere to hide: Effects of linear features on predator-prey dynamics in a large mammal system. *Journal of Animal Ecology* **in press**.
- 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. Evaluating functional recovery of habitat for threatened woodland caribou. *Ecosphere* **8**:e01936–n/a.
- Dickie, M., R. Serrouya, R. S. McNay, and S. Boutin. 2016. Faster and farther: wolf movement on linear features and implications for hunting behaviour. *Journal of Applied Ecology* **54**:253–263.
- Dodd, N. L. 2017. Mountain caribou population status for the Wells Gray North, Barkerville and North Cariboo Mountains-Bowron sub-populations, Cariboo region, 2015-2016. British Columbia Ministry of Environment, Victoria, BC.

Woodland Caribou Plan for the Barkerville Subpopulation

- Dolman, P. M., N. J. Collar, K. M. Scotland, and R. J. Burnside. 2015. Ark or park: the need to predict relative effectiveness of *ex situ* and *in situ* conservation before attempting captive breeding. *Journal of Applied Ecology* **52**:841–850.
- Dumont, A., M. Crête, J.-P. Ouellet, J. Huot, and J. Lamoureux. 2000. Population dynamics of northern white-tailed deer during mild winters: evidence of regulation by food competition. *Canadian Journal of Zoology* **78**:764–776.
- Dussault, C., V. Pinard, J.-P. Ouellet, R. Courtois, and D. Fortin. 2012. Avoidance of roads and selection for recent cutovers by threatened caribou: fitness-rewarding or maladaptive behaviour? *Proceedings of the Royal Society B: Biological Sciences* **279**:4481.
- 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.
- Dyer, S. J., J. P. O'Neill, S. M. Wasel, and S. Boutin. 2002. Quantifying barrier effects of roads and seismic lines on movements of female woodland caribou in northeastern Alberta. *Canadian Journal of Zoology* **80**:839–845.
- Edmonds, E. J., and M. Bloomfield. 1984. A study of woodland caribou (*Rangifer tarandus caribou*) in west-central Alberta, 1979 to 1983. Unpublished report AFW-84-045, Alberta Energy and Natural Resources Fish and Wildlife Division.
- Environment and Climate Change Canada. 2016. Range Plan Guidance for Woodland Caribou, Boreal Population. Page 26p. *in* Environment and Climate Change Canada, editor., Ottawa, ON.
- Environment Canada. 2012a. Management Plan for the Northern Mountain Population of Woodland Caribou (*Rangifer tarandus caribou*) in Canada. Page vii + 79 pp *in* E. Canada, editor., Ottawa, Canada.
- Environment Canada. 2012b. Recovery Strategy for the Woodland Caribou, Boreal population (*Rangifer tarandus caribou*) in Canada Page vi + 55 pp *in* E. Canada, editor. Environment Canada, Ottawa, Ottawa, Canada.
- Environment Canada. 2014. Recovery Strategy for the Woodland Caribou Southern Mountain population (*Rangifer tarandus caribou*) in Canada. . Page viii + 103 pp. *in* Environment Canada, editor., Ottawa, Canada.
- exploreBC. 2017. Cariboo Chilcotin Coast. Backcountry Skiing. Government of British Columbia, Victoria, BC.
- Forrester, T. D., and H. U. Wittmer. 2013. A review of the population dynamics of mule deer and black-tailed deer *Odocoileus hemionus* in North America. *Mammal Review* **43**:292–308.
- Fryxell, J. M., D. J. T. Jussell, A. B. Lambert, and P. C. Smith. 1991. Time lags and population fluctuations in white-tailed deer. *Journal of Wildlife Management* **55**:377–385.
- Gillett, N. P., A. J. Weaver, F. W. Zwiers, and M. D. Flannigan. 2004. Detecting the effect of climate change on Canadian forest fires. *Geophysical Research Letters* **31**:n/a–n/a.
- Gilpin, M. E. 1990. Extinction of finite metapopulations in correlated environments. Pages 177–186 *in* B. Shorrocks and I. R. Swingland, editors. *Living in a Patchy Environment*. Oxford Scientific, Oxford.
- Glover, G. J., M. Swendrowski, and R. J. Cawthorn. 1990. An epizootic of Besnoitiosis in captive caribou (*Rangifer tarandus caribou*), reindeer (*Rangifer tarandus tarandus*) and mule deer (*Odocoileus hemionus hemionus*). *Journal of Wildlife Diseases* **26**:186–195.
- Government of Alberta. 2016. Little Smoky and A La Pêche Caribou Range Plan. *in* Ministry of Environment and Parks, editor., Edmonton, Canada.
- Government of British Columbia. 1996a. Park Act. *in* Province of British Columbia, editor. RSBC 1996. Queen's Printer, Victoria, BC.
- Government of British Columbia. 1996b. Park Act: Park, Conservancy and Recreation Area Regulation. *in* Province of British Columbia, editor. B.C. Reg. 180/90. Queen's Printer, Victoria, BC.
- Government of British Columbia. 2017a. Caribou. Species & Ecosystems at Risk. British Columbia Ministry of Environment, Victoria, BC.
- Government of British Columbia. 2017b. Hunting & Trapping Regulations Synopsis. Victoria, BC.
- Government of British Columbia. 2017c. Southern Mountain Caribou. Wildlife Conservation. BC Ministry of Forests, Lands and Natural Resource Operations., Victoria, BC.
- Griesbauer, H. P., and D. S. Green. 2010. Regional and ecological patterns in interior Douglas-fir climate–growth relationships in British Columbia, Canada. *Canadian Journal of Forest Research* **40**:308–321.

- Gustine, D. D., K. L. Parker, R. J. Lay, M. P. Gillingham, and D. C. Heard. 2006. Interpreting resource selection at different scales for woodland caribou in winter. *Journal of Wildlife Management* **70**:1601–1614.
- Habib, T. J., E. H. Merrill, M. J. Pybus, and D. W. Coltman. 2011. Modelling landscape effects on density–contact rate relationships of deer in eastern Alberta: Implications for chronic wasting disease. *Ecological Modelling* **222**:2722–2732.
- Harding, L. E., and E. McCullum. 1997. Ecosystem response to climate change in British Columbia and Yukon: threats and opportunities for biodiversity. Pages 1–22 *in* E. Taylor and B. Taylor, editors. Responding to global climate change in British Columbia and Yukon. Environment Canada, Vancouver, BC.
- Hatter, I. W., P. Dielman, and G. W. Kuzyk. 2017. An integrated modeling approach for assessing management objectives for mule deer in central British Columbia. *Wildlife Society Bulletin* **41**:508–515.
- Hayek, T., N. Lloyd, M. R. Stanley-Price, A. Saxena, and A. Moehrenschrager. 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, Alberta, Canada.
- 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., M. Musiani, N. J. deCesare, S. Hazenberg, W. Peters, H. Robinson, and B. V. Weckworth. 2010a. Linear features, forestry and wolf predation of caribou and other prey in west central Alberta. University of Montana.
- Hebblewhite, M., C. White, and M. Musiani. 2010b. Revisiting Extinction in National Parks: Mountain Caribou in Banff. *Conservation Biology* **24**:341–344.
- Hebblewhite, M., J. Whittington, M. Bradley, G. Skinner, A. Dibb, and C. White. 2007. Conditions for caribou persistence in the wolf-elk-caribou systems of the Canadian Rockies. *Rangifer Special Issue* **17**:79–90.
- Hebblewhite, M., J. Whittington, M. Bradley, G. Skinner, A. Dibb, and C. A. White. 2006. Conditions for caribou persistence in the wolf-elk-caribou systems of the Canadian Rockies. The Eleventh North American Caribou Workshop, 24–27 April, 2006., Jasper, Alberta, Canada.
- Hebda, R. J. 1997. Impact of climate change on biogeoclimatic zones of British Columbia and Yukon. Pages 31–31 – 13–15 *in* E. Taylor and B. Taylor, editors. Responding to global climate change in British Columbia and Yukon. British Columbia Ministry of Environment, Lands and Parks, Victoria, BC.
- 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*:1029–1037.
- Herzog, F., A. Lausch, E. Müller, H.-H. Thulke, U. Steinhardt, and S. Lehmann. 2001. Landscape metrics for assessment of landscape destruction and rehabilitation. *Environmental Management* **27**:91–107.
- Holt, R. D. 1977. Predation, apparent competition, and the structure of prey communities. *Theoretical Population Biology* **12**:197–229.
- Houghton, J. T., Y. Ding, D. J. Griggs, M. Noguer, P. J. v. d. Linden, and D. Xiaosu, editors. 2001. Climate change 2001: the scientific basis. Cambridge University Press, New York, NY.
- IUCN Species Survival Commission. 2012. IUCN Guidelines for Reintroductions and Other Conservation Translocations. Page 16 pp. International Union of Conserving Nations, Gland, Switzerland.
- James, A., and A. Stuart-Smith. 2000a. Distribution of caribou and wolves in relation to linear corridors *Journal of Wildlife Management* **64**:154–159.
- James, A. R. C., 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.
- James, A. R. C., and A. K. Stuart-Smith. 2000b. Distribution of caribou and wolves in relation to linear corridors. *Journal of Wildlife Management* **64**:154–159.

Woodland Caribou Plan for the Barkerville Subpopulation

- Johnson, C. J., L. P. W. Ehlers, and D. R. Seip. 2015. Witnessing extinction – Cumulative impacts across landscapes and the future loss of an evolutionarily significant unit of woodland caribou in Canada. *Biological Conservation* **186**:176–186.
- Johnson, C. J., K. L. Parker, and D. C. Heard. 2000. Feeding site selection by woodland caribou in north-central British Columbia. *Rangifer* **20**:158–172.
- Johnson, C. J., K. L. Parker, D. C. Heard, and D. S. Seip. 2004. Movements, foraging habits, and habitat use strategies of northern woodland caribou during winter: Implications for forest practices in British Columbia. 2004.
- Johnson, D. R. 1985. Man-caused deaths of mountain caribou, *Rangifer tarandus* in southeastern British Columbia. *Canadian Field-Naturalist* **99**:542–544.
- Johnson, D. R., and M. C. Todd. 1977. Summer use of a highway crossing by mountain caribou. *Canadian Field-Naturalist* **91**:312–314.
- Jones, E. S., M. P. Gillingham, D. R. Seip, and D. C. Heard. 2007. Comparison of seasonal habitat selection between threatened woodland caribou ecotypes in central British Columbia. *Rangifer* **27**:111–128.
- Jones, S. 2014. Facts about Brucellosis. In *Animal and Plant Health Inspection Service*, editor. Brucellosis Disease Information. United States Department of Agriculture, Washington, DC.
- Kinley, T. A. 2003. Snowmobile–mountain caribou interactions: a summary of perceptions and an analysis of trends in caribou distribution., British Columbia Ministry of Water, Land and Air Protection, Victoria, BC.
- Klaczek, M., and D. Heard. 2016. Population Assessment of Southern Mountain Caribou (*Rangifer tarandus*) in the Prince George Forest District. BC Ministry of Forests, Lands and Natural Resource Operations, Prince George, BC.
- Kruse, J., D. Klein, S. Braund, L. Moorehead, and B. Simeone. 1998. Co-management of natural resources: A comparison of two caribou management systems. *Human Organization* **57**:447–458.
- Laikre, L., N. Ryman, and N. G. Lundh. 1997. Estimated inbreeding in a small, wild muskox *Ovibos moschatus* population and its possible effects on population reproduction. *Biological Conservation* **79**:197–204.
- Latham, A. D. M., M. C. Latham, and M. S. Boyce. 2011a. Habitat selection and spatial relationships of black bears (*Ursus americanus*) with woodland caribou (*Rangifer tarandus caribou*) in northeastern Alberta. *Canadian Journal of Zoology* **89**:267–277.
- Latham, A. D. M., M. C. Latham, M. S. Boyce, and S. Boutin. 2011b. Movement responses by wolves to industrial linear features and their effect on woodland caribou in northeastern Alberta. *Ecological Applications* **21**:2854–2865.
- Latham, A. D. M., M. C. Latham, N. A. McCutchen, and S. Boutin. 2011c. Invading white-tailed deer change wolf-caribou dynamics in northeastern Alberta. *Journal of Wildlife Management* **75**:204–212.
- Lessard, R., S. Martell, C. Walters, T. Essington, and J. Kitchell. 2005. Should ecosystem management involve active control of species abundances? *Ecology and Society* **10**:1:online.
- MacNearney, D., K. E. Pigeon, J. Cranston, G. Stenhouse, and L. Finnegan. 2016. Towards stable caribou populations in Alberta: Considering resource selection by wolves, grizzly bears, and caribou to prioritize restoration of legacy seismic lines. *PeerJ Preprints* **4**:e1972v1971.
- Mahoney, S. P., K. Mawhinney, C. McCarthy, D. Anions, and S. Taylor. 2001. Caribou reactions to provocation by snowmachines in Newfoundland. *Rangifer* **21**:35–43.
- McClung, D. M. 2001. Characteristics of terrain, snow supply and forest cover for avalanche initiation caused by logging. *Annals of Glaciology* **32**:223–229.
- McDevitt, A. D., S. Mariani, M. Hebblewhite, N. J. DeCesare, L. Morgantini, D. Seip, B. V. Weckworth, and M. Musiani. 2009. Survival in the rockies of an endangered hybrid swarm from diverged caribou (*Rangifer tarandus*) lineages *Molecular Ecology* **18**:665–679.
- McKay, T. L. 2007. Woodland caribou response to encounters with people in Jasper National Park. Royal Roads University, Victoria, BC.
- McLellan, B. N., R. Serrouya, H. U. Wittmer, and S. Boutin. 2010. Predator-mediated Allee effects in multi-prey systems. *Ecology* **91**:286–292.

Woodland Caribou Plan for the Barkerville Subpopulation

- McNay, R. S., D. C. Heard, R. Sulyma, and R. Ellis. 2008. A recovery action plan for northern caribou herds in north-central British Columbia. Forrex Forest Research Extension Society, Kamloops, B.C., Canada.
- McNay, R. S., G. Sutherland, R. K. McCann, and V. Brumovsky. 2013. Re-evaluation of trends in moose populations in the cariboo region 1985-2012. Wildlife Infometrics Inc., Mackenzie, BC.
- Messier, F. 1991. The significance of limiting and regulating factors on the demography of moose and white-tailed deer. *Journal of Animal Ecology* **60**:377–393.
- Messier, F. 1994. Ungulate population models with predation: a case study with the North American moose. *Ecology* **75**:478–488.
- Messier, F., and D. O. Joly. 2000. Comment: Regulation of moose populations by wolf predation. *Canadian Journal of Zoology* **78**:506–510.
- Miller, F. L., S. J. Barry, W. A. Calvert, and K. A. Zittlau. 2007. Rethinking the basic conservation unit and associated protocol for augmentation of an ‘endangered’ caribou population: An opinion. *Rangifer Special Issue No. 17*:13–24.
- Miller, M. J. R., R. D. Dawson, and H. Schwantje. 2014a. Besnoitiosis. *Manual of Common Diseases and Parasites of Wildlife in Northern British Columbia*. University of Northern British Columbia, Prince George, BC.
- Miller, M. J. R., R. D. Dawson, and H. Schwantje. 2014b. *Manual of Common Diseases and Parasites of Wildlife in Northern British Columbia*. University of Northern British Columbia, Prince George, BC.
- Mitchell, M. 2016. Range-wide Status of Black-tailed Deer and Mule Deer ~ 2016., Western Association of Fish and Wildlife Agencies, Boise, ID.
- Moose Management Technical Team. 2015. Provincial Framework for Moose Management in British Columbia. Page 44 pp in M. o. F. Fish and Wildlife Branch, Lands and Natural Resource Operations, editor. Government of British Columbia, Victoria, British Columbia.
- Neiland, K. A., J. A. King, B. E. Huntley, and R. O. Skoog. 1968. The diseases and parasites of Alaskan wildlife populations, part i. Some observations on brucellosis in caribou. *Bulletin of the Wildlife Disease Association* **4**:27–36.
- Nellemann, C., I. Vistnes, P. Jordhøy, O. Strand, and A. Newton. 2003. Progressive impact of piecemeal infrastructure development on wild reindeer. *Biological Conservation* **113**:307–317.
- Nitschke, C. R. 2008. The cumulative effects of resource development on biodiversity and ecological integrity in the Peace-Moberly region of Northeast British Columbia, Canada. *Biodiversity and Conservation* **17**:1715–1740.
- O’Brien, D., M. Manseau, A. Fall, and M.-J. Fortin. 2006. Testing the importance of spatial configuration of winter habitat for woodland caribou: An application of graph theory. *Biological Conservation* **130**:70–83.
- Oberg, P. R. 2001. Responses of mountain caribou to linear features in a west-central Alberta landscape. University of Alberta, Edmonton, AB.
- Parker, K. L., P. S. Barboza, and M. P. Gillingham. 2009. Nutrition integrates environmental responses of ungulates. *Functional Ecology* **23**:57–69.
- Parker, K. L., P. S. Barboza, and T. R. Stephenson. 2005. Protein conservation in female caribou (*Rangifer tarandus*): Effects of decreasing diet quality during winter. *Journal of Mammalogy* **86**:610–622.
- Pierce, B. M., V. C. Bleich, K. L. Monteith, and R. T. Bowyer. 2012. Top-down versus bottom-up forcing: evidence from mountain lions and mule deer. *Journal of Mammalogy* **93**:977–988.
- Pigeon, K. E., M. Anderson, D. MacNearney, J. Cranston, G. Stenhouse, and L. Finnegan. 2016. Toward the restoration of caribou habitat: Understanding factors associated with human motorized use of legacy seismic lines. *Environmental Management* **58**:821–832.
- Plummer, D. A., D. Caya, A. Frigon, H. Côté, M. Giguère, D. Paquin, S. Biner, R. Harvey, and R. d. Elia. 2006. Climate and climate change over north america as simulated by the Canadian RCM. *Journal of Climate* **19**:3112–3132.
- Polfus, J., M. Hebblewhite, and K. Heinemeyer. 2011. Identifying indirect habitat loss and avoidance of human infrastructure by northern mountain woodland caribou. *Biological Conservation* **144**:2637–2646.
- Polfus, J. L. 2010. Assessing cumulative human impacts on northern woodland caribou with traditional ecological knowledge and resource selection functions. Dissertation. The University of Montana, Missoula, MT.

Woodland Caribou Plan for the Barkerville Subpopulation

- Poole, K. G., D. C. Heard, and G. Mowat. 2000. Habitat use by woodland caribou near Takla Lake in central British Columbia. *Canadian Journal of Zoology* **78**:1552–1561.
- Price, G., and L. Roorda. 2006. Four year summary of the Quesnel Highland snowmobile-mountain caribou monitoring project, Cariboo Region British Columbia Ministry of Environment, Environmental Stewardship Division Cariboo Region, Prince George, BC.
- Proulx, G., and R. Brook. 2017. Fencing large predator-free and competitor-free landscapes for the recovery of woodland caribou in western Alberta: An ineffective conservation option. *Animals* **7**:2.
- Racey, G. D. 2005. Climate change and woodland caribou in Northwestern Ontario: a risk analysis. *Rangifer* **25**:123–136.
- 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**:49–80.
- Robichaud, C. B., and K. H. Knopff. 2015. Biodiversity offsets and caribou conservation in Alberta: opportunities and challenges. *Rangifer* **35**:99–122.
- Robinson, H. S., M. Hebblewhite, N. J. DeCesare, J. Whittington, L. Neufeld, M. Bradley, and M. Musiani. 2012. The effect of fire on spatial separation between wolves and caribou. *Rangifer* **32**:277–294.
- Robinson, H. S., R. B. Wielgus, and J. C. Gwilliam. 2002. Cougar predation and population growth of sympatric mule deer and white-tailed deer. *Canadian Journal of Zoology* **80**:556–568.
- Roorda, L., and R. Wright. 2004. Quesnel Highland wolf project progress report: July 1, 2001 – March 31, 2004. Wildlife Branch Ministry of Water, Air and Land Protection Cariboo Region, Prince George, BC.
- Roorda, L., and R. Wright. 2010. Quesnel Highland wolf project progress report: November 2005 – March 2010. Wildlife Branch Ministry of Water, Air and Land Protection Cariboo Region, Prince George, BC.
- Rytwinski, T., and L. Fahrig. 2012. Do species life history traits explain population responses to roads? A meta-analysis. *Biological Conservation* **147**:87–98.
- Sachs, D. L., P. Sollins, and W. B. Cohen. 1998. Detecting landscape changes in the interior of British Columbia from 1975 to 1992 using satellite imagery. *Canadian Journal of Forest Research* **28**:23–36.
- Scarfe, B. L. 2006. Socio-economic and environmental impact assessment for the Peace Moberly Tract: The base case BriMar Consultants Ltd, Victoria, BC.
- Schneider, R. R., G. Hauer, W. L. Adamowicz, and S. Boutin. 2010. Triage for conserving populations of threatened species: The case of woodland caribou in Alberta. *Biological Conservation* **143**:1603–1611.
- Schwantje, H. 2015. Chronic Wasting Disease. *Wildlife Diseases*. Government of British Columbia, Victoria, BC.
- SCWA. 2017. Spruce City Wildlife Association. in S. Hamilton, editor., Prince George, BC.
- Seip, D. 2003. Winter distribution and abundance of mountain caribou in relation to habitat management zones in the Robson Valley. *BC Journal of Ecosystems and Management* **4**:1–9.
- Seip, D. R. 1990. Ecology of woodland caribou in Wells Gray Provincial Park. No. B-68, British Columbia Ministry of Environment and Parks, Victoria, BC.
- Seip, D. R. 1992a. 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. 1992b. Habitat use and population status of woodland caribou in the Quesnel Highlands, British Columbia. *Wildlife Bulletin* No. B-71. British Columbia Ministry of Environment, Victoria, BC.
- Seip, D. R. 1998. Ecosystem management and the conservation of caribou habitat in British Columbia. *Rangifer* **18**:203–211.
- Seip, D. R. 2008. Mountain caribou interactions with wolves and moose in central British Columbia. *Alces* **44**:1–5.
- Seip, D. R., and D. B. Cichowski. 1996. Population ecology of caribou in British Columbia. *Rangifer* **16**:73–80.
- Seip, D. R., C. J. Johnson, and G. S. Watts. 2007. Displacement of mountain caribou from winter habitat by snowmobiles. *Journal of Wildlife Management* **71**:1539–1544.
- Seip, D. R., and E. Jones. 2010. Response of woodland caribou to partial retention logging of winter ranges attacked by mountain pine beetle British Columbia Ministry of Environment, Prince George, BC.
- Serrouya, R., B. N. McLellan, H. van Oort, G. Mowat, and S. Boutin. 2017. Experimental moose reduction lowers wolf density and stops decline of endangered caribou. *PeerJ* **5**:e3736.

Woodland Caribou Plan for the Barkerville Subpopulation

- Sifton, E. 2001. Disease risk assessment for an experimental captive breeding program of Mountain Caribou in British Columbia. final, Wildlife Branch BC Ministry of Environment, Lands and Parks, Nelson, British Columbia.
- Simpson, K. 1987a. The effects of snowmobiling on winter range use of mountain caribou. Ministry of Environment and Parks, Wildlife Branch, Nelson, BC.
- Simpson, K. 1987b. Impacts of hydro-electric reservoir on populations of caribou and grizzly bear in southern British Columbia. BCEP--WR-24, British Columbia Ministry of Environment and Parks, Victoria, BC.
- Simpson, K., and E. Terry. 2000. Impacts of backcountry recreation activities on mountain caribou. Wildlife Working Report No. WR-99, Ministry of Environment, Lands and Parks Wildlife Branch, Victoria, BC.
- Simpson, K., and G. P. Woods. 1987. Movements and Habitats of caribou in the mountains of southern British Columbia. No. B-57, British Columbia Ministry of Environment and Parks, Victoria, BC.
- Sinclair, A. R. E., R. P. Pech, C. R. Dickman, D. Hik, P. Mahon, and A. E. Newsome. 1998. Predicting effects of predation on conservation of endangered prey. *Conservation Biology* **12**:564–575.
- Smith, K. G. 2004. Woodland caribou demography and persistence relative to landscape change in west-central Alberta. University of Alberta, Edmonton, AB.
- Smith, K. G., E. J. Ficht, D. Hobson, T. C. Sorensen, and D. Hervieux. 2000. Winter distribution of woodland caribou in relation to clear-cut logging in west-central Alberta. *Canadian Journal of Zoology* **78**:1433–1440.
- 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. 1994. Cougar in British Columbia. British Columbia Fish and Wildlife Branch, Information and Education Section, Victoria, BC.
- Stevenson, S. K. 1990. Managing second-growth forests as caribou habitat. *Rangifer Special Issue No. 3*:139–144.
- Stevenson, S. K. 1991. Forestry and caribou in British Columbia. *Rangifer* **11**:124–129.
- Stevenson, S. K., and D. F. Hatler. 1985. Woodland caribou and their habitat in southern and central British Columbia. British Columbia Ministry of Forests, Victoria, BC.
- Stronen, A. V., P. Paquet, S. Herrero, S. Sharpe, and N. Waters. 2007. Translocation and recovery efforts for the Telkwa caribou, *Rangifer tarandus caribou*, herd in westcentral British Columbia, 1997–2005. *The Canadian Field-Naturalist* **121**:155–163.
- Swift, K., and S. Ran. 2012. Successional responses to natural disturbance, forest management and climate change in British Columbia forests. 2012 **13**.
- Terry, E. L., B. N. McLellan, and G. S. Watts. 2000. Winter habitat ecology of mountain caribou in relation to forest management. *Journal of Applied Ecology* **37**:589–602.
- The Mountain Caribou Technical Advisory Committee. 2002. A Strategy for the Recovery of Mountain Caribou in British Columbia. British Columbia Ministry of Water, Land and Air Protection, Victoria, BC.
- Trainer, D. O. 1973. Caribou mortality due to the meningeal worm. *Journal of Wildlife Diseases* **9**:376–378.
- Vors, L. S., and M. S. Boyce. 2009. Global declines of caribou and reindeer. *Global Change Biology* **15**:2626–2633.
- Walden, H. S., S. A. L. Ness, L. D. Mittel, T. J. Divers, K. van Laaren, and D. C. Sellon. 2014. Chapter 60 - Miscellaneous Parasitic Diseases. Pages 505–514. *Equine Infectious Diseases* (Second Edition). W.B. Saunders, St. Louis.
- Weckworth, B. V., M. Musiani, A. McDevitt, M. Hebblewhite, and S. Mariani. 2012. Reconstruction of caribou evolutionary history in western North America and its implications for conservation. *Molecular Ecology* **21**:3610–3624.
- Whittington, J., M. Hebblewhite, N. J. DeCesare, L. Neufeld, M. Bradley, J. F. 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.
- Wilkinson, C. J. A. 2010. An analysis of government actions for the protection and recovery of forest-dwelling woodland caribou (*Rangifer tarandus caribou*) in Ontario, Canada. *Rangifer* **30**:67–77.

Woodland Caribou Plan for the Barkerville Subpopulation

- Willison, P., and D. Cichowski. 2006. The response of caribou terrestrial forage lichens to mountain pine beetles and forest harvesting in the East Ootsa and Entiako areas. Final Report – 2005 – Year 5, Bulkley Valley Centre and BC Parks, Smithers, BC.
- Wilson, S. F. 2009. Recommendations for predator-prey management to benefit the recovery of mountain caribou in British Columbia BC Ministry of Environment, Victoria
- Wilson, S. F., and D. Hamilton. 2003. Cumulative effects of habitat change and backcountry recreation on mountain caribou in the Central Selkirk mountains Final Report, BC Ministry of Sustainable Resource Management, Nelson, Canadian Mountain Holidays, Banff AB, Pope & Talbot Ltd., Nakusp BC
- Wittmer, H. U., B. N. McLellan, D. R. Seip, J. A. Young, T. A. Kinley, G. S. Watts, and D. Hamilton. 2005a. Population dynamics of the endangered mountain ecotype of woodland caribou (*Rangifer tarandus caribou*) in British Columbia, Canada. Canadian Journal of Zoology **83**:407–418.
- Wittmer, H. U., B. N. McLellan, R. Serrouya, and C. D. Apps. 2007. Changes in landscape composition influence the decline of a threatened woodland caribou population. Journal of Animal Ecology **76**:568–579.
- Wittmer, H. U., R. Serrouya, L. M. Elbroch, and A. J. Marshall. 2013. Conservation strategies for species affected by apparent competition. Conservation Biology **27**:254–260.
- Wittmer, H. U., A. R. E. Sinclair, and B. N. McLellan. 2005b. The role of predation in the decline and extirpation of woodland caribou. Oecologia **144**:257–267.
- Wobeser, G. 1976. Besnoitiosis in a woodland caribou. Journal of Wildlife Diseases **12**:566–571.
- Wolfe, S. A., B. Griffith, and C. A. G. Wolfe. 2000. Response of reindeer and caribou to human activities. Polar Research **19**:63–73.
- Young, J. A., and N. L. Freeman. 2003. Mountain caribou population status and trends: Summary of Mountain Caribou Surveys within the Quesnel Highland and Cariboo Mountains, Cariboo Region, up to and including 2002. Progress Report, Fish and Wildlife Science and Allocation Section, Environmental Stewardship Division, Ministry of Water, Land and Air Protection, Cariboo Region, Prince George, BC.