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

Tsenaglode
Subpopulation

Northern Mountain Caribou

BRITISH COLUMBIA

Recommended Citation:

Photo credit: Doug Heard

EXECUTIVE SUMMARY

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1 BACKGROUND

1.1 INTRODUCTION TO THE PROGRAM

The Tsenaglode subpopulation is the northern mountain ecotype of woodland caribou (*Rangifer tarandus caribou*), designatable unit seven (DU 7), and is within the Northern Mountain National Ecological Area (NMNEA). These herds are listed as *Threatened* by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2002)and appear on Schedule 1 of the Federal Species at Risk Act (SARA). They are blue-listed in British Columbia and are included in the Provincial Identified Wildlife Management Strategy (British Columbia Ministry of Water, Land and Air Protection 2004).

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 Tsenaglode subpopulation is blue-listed in BC, and current monitoring indicates that they are increasing (Grant 2017).

This document spans the divide between these disparate designations in British Columbia and Canada, compiling past research, knowledge and management actions into guidance for the management and recovery of the Tsenaglode Northern Mountain caribou subpopulation.

2 POPULATION DESCRIPTION

Relative to other western mountain caribou (DU 8 and 9), members of DU 7 are found in dry sub-boreal montane ecosystems and use pine-dominated habitats during winter. Most populations of Northern Mountain caribou are relatively small and sedentary, with individuals wintering in small groups. They generally use a calving strategy of moving to high elevations on open sub-alpine ridges, spacing away from conspecifics and predators (COSEWIC 2011).

2.1 DISTRIBUTION

The Tsenaglode subpopulation range area is small, roughly 2500 square kilometres, north of the Stikine River and encompasses the McBride River system to the east. The western boundary skirts Hluey Lakes to the north, and curves around southeast along the Stikine River.

The most recent population estimate for the Tsenaglode subpopulation is 639 individuals, last censused in 2015 with a population of 200 (British Columbia Ministry of Environment 2010). The population trend is currently increasing (Grant 2017) (note that this document has an error for this herd in Table 1. It states the population at 2000, but it was 200 (British Columbia Ministry of Environment 2010)).

Information on ecology and habitat use specific to Tsenaglode caribou is limited. Available information indicates that seasonal movements of Tsenaglode caribou are dependent on snow conditions, though in general, they spend the summer in high elevation alpine and subalpine habitats and move to lower elevation coniferous forests during the winter (COSEWIC 2002). Winter forage consists primarily of terrestrial lichen (COSEWIC 2002).

Four biogeoclimatic (BEC) zones (Meidinger and Pojar 1991) occur in the range area. These BEC zones are generally described as follows:

- Boreal Altai Fescue Alpine (BAFA) is dominated mostly by rock, ice and snow with vegetation limited to shrubs, herbs, mosses, lichens and dwarf trees.
- Spruce Willow Birch (SWB) occurs at mid-elevations below the BAFA. The SWB supports open forests of predominantly white spruce, subalpine fir and deciduous shrubs.
- Engelmann Spruce – Subalpine Fir (ESSF) is a forested mid-elevation zone occurring below the BAFA. Spruce and fir are the dominant species although lodgepole pine occurs on drier sites.
- Boreal White and Black Spruce (BWBS) zone is found in the lower elevations. Frequent fires have resulted in extensive successional forests of lodgepole pine and trembling aspen. On gentle terrain, stands of white spruce and trembling aspen are interspersed with black spruce bogs (Brumovsky and McNay 2015).

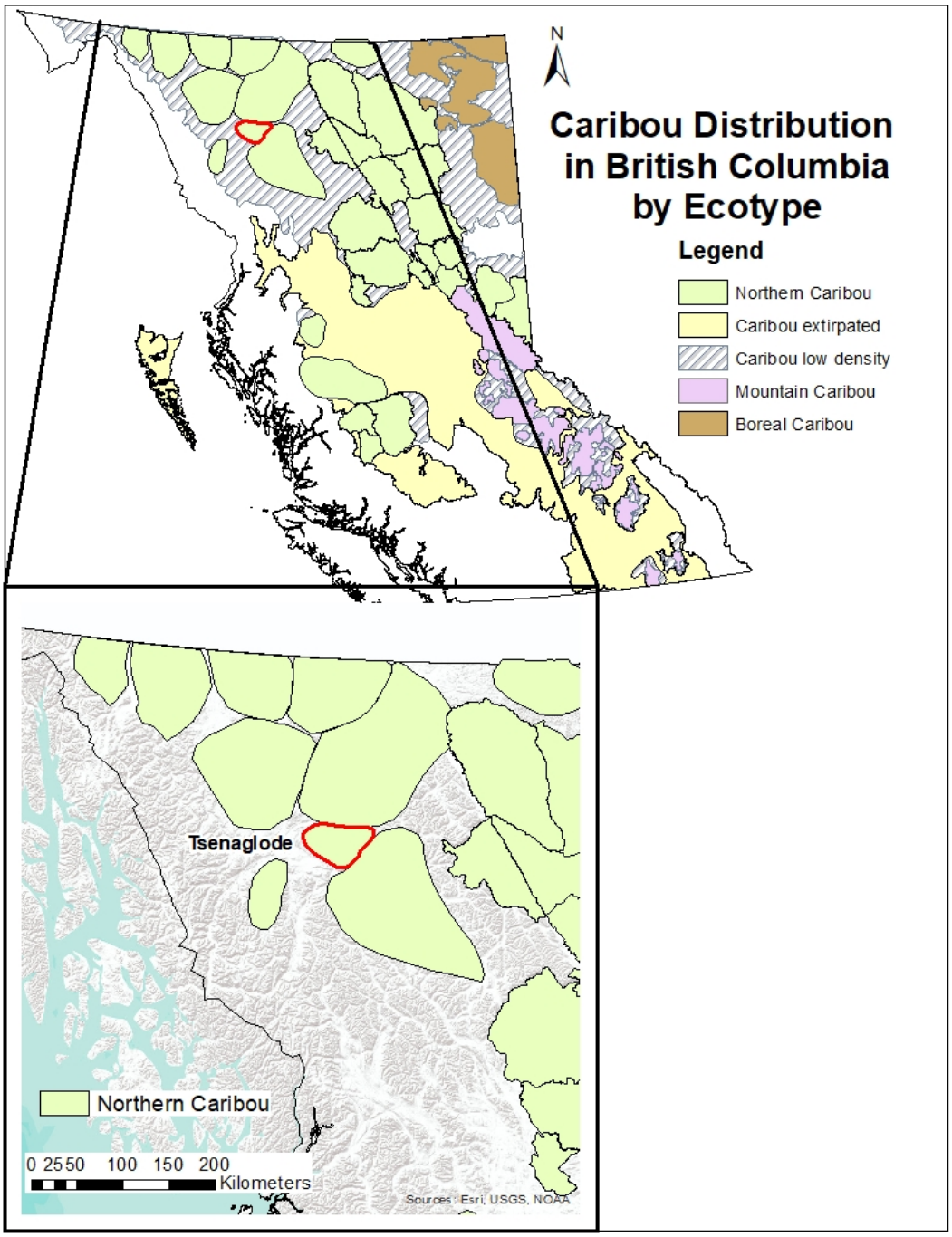

Figure 1: The location of the Tsenaglode subpopulation of woodland caribou. The 2500 km^2 range (inset: red outline) is within the Skeena Region.

2.2 Habitat and Behaviour

The Tsenaglode caribou subpopulation lives in the western extent of the Stikine Range and the Three Sisters Range of the Cassiar Mountains. It straddles the Southern Boreal Plain and Stikine Plateau ecosections.

The Tsenaglode caribou subpopulation select lowland spruce-willow-birch and upland boreal Altai fescue alpine equally with transitional use of boreal white and black spruce (McNay 2011). They are considered a shallow snow subpopulation (Serrouya et al. 2012) meaning that they spend winters in low-lying habitats, cratering through shallow snow to feed on terrestrial lichens and move to spend summers in alpine habitats (Grant 2018). Detailed information on their movements and seasonal habitat use has not been reported.

2.3 Population Size and Trend

There are few population counts for the Tsenaglode caribou subpopulation, with only two years of reliable estimates (Figure 2) and no information on recruitment (Environment Canada 2012a).

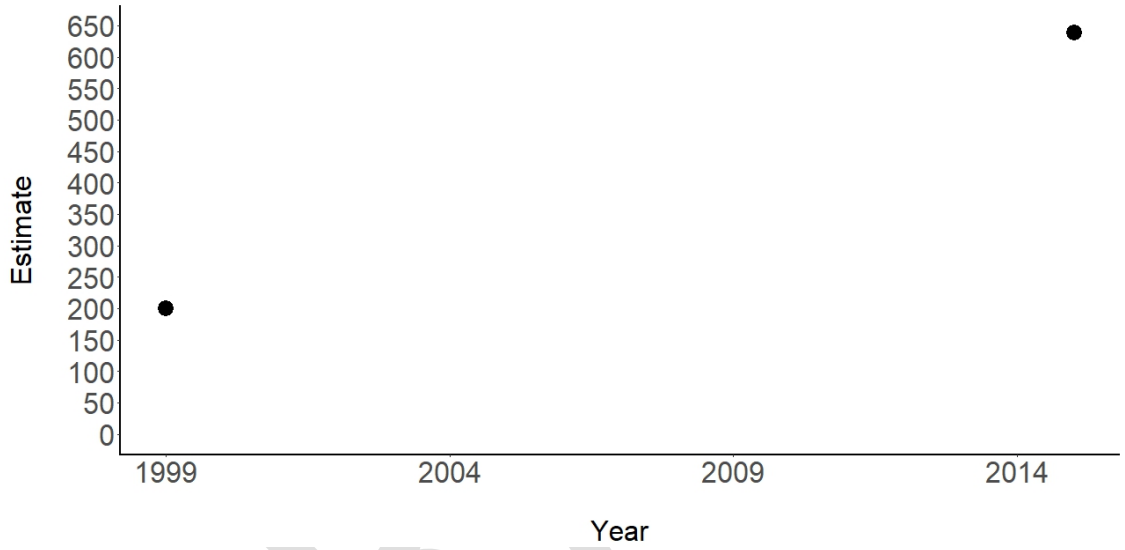

Figure 2: Caribou estimates for the Tsenaglode sub-population (Grant 2017).

Caribou recruitment, measured as percent of calves in the population observed during a spring census (Bergerud and Elliot 1986), has not been estimated for the Tsenaglode caribou subpopulation.

3 Threats and Limiting Factors

Primary threats to caribou and their habitat have been noted by McNay et al. (2008), COSEWIC (2014) 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). In this review, threats are treated in isolation, but this does not discount the likelihood that they interact. Cumulative 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 affect 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
    8. Small population size effects

3.1 PREDATION

GPS collar and radio telemetry studies indicate 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 abundance (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 (Hayhurst 1983, Latham et al. 2011b). More generally, Bergerud (2007) has calculated that wolf densities greater than 6.5 wolves/1000 km^2 will result in woodland caribou declines. More recently, the federal recovery strategy identifies 3 wolves/1000 km^2 as a target (Environment Canada 2014).

There are no predation rates or mortality sources for the Tsenaglode caribou subpopulation.

3.2 FOOD LIMITATION

Woodland caribou are herbivores and rare among large mammals 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 an individual's nutritional needs (Newsome et al. 2000, 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).

Tsenaglode caribou are among British Columbia's shallow snow caribou, selecting abundant, lowland habitats in the winter with low snow loads to access terrestrial lichen. Their density is estimated at 6.6 / 100 km^2 which is relatively low for northern caribou (COSEWIC 2002). Although there have been no studies of nutrition or food limitation on the Tsenaglode caribou subpopulation, this information suggests that they are unlikely 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 presence of physical infrastructure 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 regrowth (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 forest cutblocks can have a significant influence on caribou habitat availability.

The Tsenaglode caribou subpopulation is within the Cassiar timber supply area (TSA), and it falls within the Timber Management and Timber Harvesting Land Base (LM Forest Resource Solutions 2007, Nicholls 2015). But there has been no forestry in its range.

3.3.1.2 MINING

Mine sites deter caribou both for the activities that occur there when they are active as well a 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).

The Red Chris Mine is just south of the Tsenaglode caribou subpopulation range (and at the edge of the Spatsizi subpopulation range). Although there are no active mines (although there are gravel pits along Highway 37) in the Tsenaglode ranges, there is mineral exploration in the winter range (Environment Canada 2012a).

3.3.1.3 OIL AND GAS

Oil and gas development threatens 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 oil and gas developments (well sites, access roads, pipelines, seismic lines) and the range of activities that take place in caribou habitat cumulative effects of this combined with other activities (e.g. forestry, hydroelectric) also play a large role in threatening resident caribou herds (Nitschke 2008). A study of the 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 are no oil and gas tenures or exploration in the Tsenaglode 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 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 large-scale wind or solar energy projects in the Tsenaglode caribou subpopulation range. There is an independent power project with hydroelectric dams on the Hluey Lakes and Sitsa Lake in their range (Government of British Columbia 2012).

3.3.1.5 OTHER

There are no other major developments in the Tsenaglode caribou subpopulation range.

3.3.2 RECREATION

Recreational use of caribou habitat refers largely to fall and winter activities, including snowmobiling, commercial heli-skiing, commercial snowcat-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 wildlife generally and woodland caribou in particular avoid mechanized winter activities to varying degrees (Simpson 1987a, Simpson and Terry 2000, Mahoney et al. 2001, Wilson and Hamilton 2003, Borkowski et al. 2006, Seip et al. 2007, Kinley 2008, Harris et al. 2014). Despite records of displacement, no study has been able to draw a direct link between winter recreational use and woodland caribou population decline, largely because effects are chronic and be time-lagged.

3.3.2.1 SNOWMOBILE

Snowmobile use in caribou habitat can result in their displacement (Simpson 1987a, Webster 1997, Apps et al. 2001, Brade 2003, Kinley 2008). 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). Mechanisms of displacement include caribou avoiding or fleeing snowmobiles while they are in use, or avoidance of snowmobile packed trails that facilitate access to caribou winter habitat by human hunters and natural predators (Bergerud 1988, James and Stuart-Smith 2000, Oberg 2001, Powell 2004, Polfus 2010, Whittington et al. 2011). A study of stress using hormone profiles in free-ranging caribou demonstrated that elevated fecal glucocorticoids in animals as far as 10 km from snowmobile activity, suggesting that caribou perceive snowmobiles in their habitat as a stressor (Freeman 2008).

Much of the Tsenaglode caribou subpopulation range is considered mid and backcountry area for recreational use, including snowmobiles (Government of British Columbia 2012). Although recreational snowmobiling is popular in the nearby Dease Lake area, lack of trail development and general access has limited this activity in the area.

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 helicat ski operations and minimize

operational impacts. Concentrations of glucocorticoid stress hormones are higher in caribou that live where commercial heli-skiing operates than in areas without heli-skiing (Freeman 2008).

There are no helicopter or snowcat ski tenures in the Tsenaglode caribou subpopulation range, but Last Frontier Heliskiing operates in the region, south of the Tsenaglode range.

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).

Stikine River Provincial Park runs along the southern boundary of the Tsenaglode caribou subpopulation range and provides backcountry access (albeit without facilities) to this area. Several air charter companies operate in this area that can also provide backcountry access (Skeena Region Environmental Stewardship Division 2003, BC Parks 2018).

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 2000, 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 directly 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) and indirectly their predators like bears and wolves. These, in turn, predate caribou, putting downward pressure on caribou populations (apparent competition).

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).

There is no agriculture in the Tsenaglode caribou subpopulation range.

3.3.3.2 MAJOR HIGHWAY CORRIDORS

Where they occur in caribou habitat, highways have strong, negative effects on caribou populations (Curatolo and Murphy 1986, Apps and McLellan 2006, McFarlane et al. 2009). 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 (Dyer et al. 2002, Rytwinski and Fahrig 2012). Habitat and population fragmentation results as populations

are unable to move between ranges. Highways and roadways can also give people access 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 37 (the Dease Lake Highway and Stewart-Cassiar Highway) traverses the Tsenaglode caribou subpopulation range. Although road density is low, vehicle collisions are a concern for the Tsenaglode subpopulation due to this highway (COSEWIC 2014). This range falls within Highway District 10 (Bulkley-Stikine). From 1988 to 2007, 19 caribou were killed on this district's highways, but it is not clear how many of these were on highway 37 or within the Tsenaglode range (Sielecki 2010).

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 (Oberg 2001, 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 2018).

Highway 37 is paralleled by an abandoned railroad track for the length that it traverses the Tsenaglode caribou subpopulation range. The Tsenaglode range is at risk to be affected by pipelines (COSEWIC 2014), although there are no current pipelines or pipeline applications.

3.3.3.4 *Hunting*

The Tsenaglode caribou subpopulation overlaps with three wildlife management units; 6-19 and 6-22 (Skeena) and 7-52 (Omineca). There is an annual caribou hunt in wildlife management units 6-19, 6-22 (5-point bulls only), some areas only to limited entry. From November to March the herd is accessible along Highway 37 and all-terrain vehicles are accessing alpine areas which facilitates hunting (Environment Canada 2012a). Prior to 2012, there were an average of 6 caribou hunted in the Tsenaglode range each year (Environment Canada 2012a). From 1976 to 2013, 1387 caribou were killed in 6-19 and 6-22, but not all in the Tsenaglode range.

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) resulting in population declines.

There are no confirmed poaching incidents in the Tsenaglode caribou subpopulation range. But the use of all-terrain vehicles to hunt in the area (Environment Canada 2012a), enables poaching.

3.4 Natural Disturbance

Fire as a natural disturbance can have large-scale and long-lasting impacts on woodland caribou (Environment Canada 2014). Fire can kill individuals, destroy habitats and change 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).

There have been very few natural disturbances in the Tsenaglode caribou subpopulation range. Only about 7 km^2 has burned since records were begun in the 1920s (a lightning strike fire in 1958, south of Tsenaglode Lake), and no forests affected by mountain pine beetle have been reported.

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 tenius*) 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 Tsenaglode 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 limit 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).

Climate change effects on part of the range of the Tsenaglobe caribou subpopulation range has been modeled as part of the Muskwa-Kechika Management Area Biodiversity Conservation and Climate Change Assessment (Kehm 2011). This model predicts low levels of "upheaval" for caribou connectivity in this area and few areas sensitive to fragmentation and conversion. The model also predicts that the Stikine Ranges will lose 49.2% of their alpine area due to climate change (Kehm 2011) and be considerably fragmented. Kehm's models project a 3^{o}C temperature increase from 1960 to 2050 resulting in a 400 – 500 m upward shift in climate zones (Kehm 2011).

3.7 Small Population Size Effects

Small population effects include several threats to caribou that are unique to small (approximately less that 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 Tsenaglode caribou subpopulation is relatively large and growing (Figure 2). Although difficult to verify as there are no collared animals in this subpopulation, the close proximity of the Tsenaglode caribou subpopulation to other herds (Level Kawdy, Horseranch, Spatsizi, Edziza), the Tsenaglode subpopulation is unlikely to suffer geographic isolation effects (Environment Canada 2012a).

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, Serrouya et al. 2012, Weckworth et al. 2012).

The Tsenaglode caribou subpopulation clusters genetically with many other northern caribou and it is unlikely that it has undergone a strong genetic bottleneck.

4 Management History

4.1 Habitat

Habitat management in this area is overseen by the provincial government and implemented by the forestry industry through application of their allowable annual cut. Active restoration takes place in the form of cutblock replanting that accelerates seedling establishment (Cichowski 1989, 1996). For their part, forestry regulations prescribe practices to manage resource use and protect forests that are caribou habitat (Seip 1998).

There is no forestry in the range of the Tsenaglode caribou subpopulation and limited habitat disturbance in this area.

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) (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 1996a) but are not relevant in this subpopulation range.

Protected areas in the Tsenaglode caribou subpopulation range include the Stikine River Provincial Park, 118 km^2 of which overlaps with the range, and proposed ungulate winter range (UWR), established to protect thinhorn sheep (u-6-041) and overlapping with approximately 900 km^2 of the Tsenaglode caribou range. Habitat, particularly high elevation range, is protected by the provincial park and UWR (proposed), but caribou hunting is permitted in both.

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 2018). 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.

An abandoned railway line parallels Highway 37 in the north-south direction through the Tsenaglode caribou subpopulation range. It has not been restored. Mineral exploration has occurred in the area with roads and small cleared sites. It is unclear whether there are plans to restore these sites.

4.2 RECREATION AND ACCESS MANAGEMENT

Road access to woodland caribou habitat elevates conservation threats including conflicts with motor vehicles, 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 to 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).

A limited network of roads developed for mine exploration and access to hydroelectric sites provide access from highway 37 into caribou habitat. Including highway 37, there are approximately 200 km of roadway in the Tsenaglode caribou subpopulation range (0.08 km/km^2).

4.2.1 SNOWMOBILE

There are no snowmobile management areas or snowmobile management trails in the Tsenaglode caribou subpopulation range. Snowmobiling is generally prohibited in the Stikine River Provincial Park with the exception of members of the Tahltan First Nation who are permitted to use snowmobiles throughout their traditional territory (Skeena Region Environmental Stewardship Division 2003). Trapline holders are also

permitted snowmobile access to Stikine River Provincial Park (Skeena Region Environmental Stewardship Division 2003), but not for recreational use.

4.2.2 HELI-SKI / CAT-SKI

There are no helicopter or snowcat ski tenures in the range of the Tsenaglode caribou subpopulation range, but there is heliskiing in the region.

See section 3.3.2.2 for general threat information.

4.2.3 OTHER

Recreational access for off highway vehicles (or all terrain vehicles) is identified as a threat, particularly with respect to hunting access (Environment Canada 2012a). There are no management actions directed at off road vehicle use in this region specific to caribou habitat protection.

4.3 PREDATORS

Unsustainable predation is acknowledged as a key, proximal mechanism of woodland caribou declines across Canada (Bergerud and Elliot 1986, Bergerud 1988, Environment Canada 2012b, 2014). 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 bring them into closer proximity to alternative prey species that can sustain higher predator populations (Seip 1992, Apps et al. 2013). Road and seismic line clearing and winter trail packing makes travel for predators into caribou critical habitats more efficient, elevating 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).

While habitat changes facilitate unsustainable predation, habitat regrowth and restoration occur 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 9–10/1000km^2 but increased at wolf densities from 1–4/1000km^2 (Bergerud and Elliot 1986). For this reason, target wolf densities that would enable caribou recovery are set to 6.5/1000km^2. 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.

It is legal to hunt wolves in the Tsenaglode caribou subpopulation range and from 1978 to 2015, 289 wolves were killed by resident and non-resident hunters (mean = 8.8 / year) in the Skeena wildlife management units with

which their range overlaps. There is no government program to manage wolves to protect the caribou population in this area.

4.3.2 Cougar Management

Cougars are likely present in the range of the Tsenaglode caribou subpopulation range but at very low densities. There is no hunting season for them in the wildlife management units with which their range overlaps. There are no management actions dedicated to their management with respect to caribou recovery.

4.3.3 Other

Grizzly bears, black bears and wolverines are also woodland caribou predators (Seip 1992, 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 bears and black bears are present in the Tsenaglode caribou subpopulation range and have been managed through hunting regulations. The grizzly bear hunt was stopped throughout British Columbia in 2017 (Bellringer 2017, McLellan et al. 2017), but prior to that, on average 7 grizzly bears were killed by hunters annually. Hunters kill, on average, 6 bears per year in the Skeena wildlife management units overlapping the Tsenaglode caribou subpopulation range.

In 2012, the grizzly bear population estimate for the Spatsizi was 666 animals (Ministry of Forests, Lands and Natural Resource Operations 2012). There is no published estimate of black bear population size in this region.

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 access 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 caribou 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.

The South Skeena Caribou Management Plan suggest that moose should be managed to a density of < 0.3 / km^2. The current density in Game Management Zone 6e (Stikine) is estimated to be 0.305 / km^2 and stable or slightly decreasing and GMZ 7Pd (Liard) estimated to be 0.316 / km^2 and decreasing (Gerald Kuzyk, unpublished data). Serrouya et al. (2017) reported for southern British Columbia that moose densities of 0.2 / km^2 lowered caribou mortality (mediated through wolf predation), while moose densities of 0.43 / km^2 did not. The Tsenaglode area is between these two measures and could be lowered to benefit caribou recovery. Moose are hunted in this region with an average of 97 animals reported killed by resident and non-resident hunters each year (data for between 1976 and 2015). No other actions to manage moose are being undertaken in the Edziza caribou subpopulation range.

4.4.2 Deer Management

Managing deer populations in support of caribou conservation is a challenge. Both mule and white-tailed deer 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, Lands and Natural Resource Operations 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.

White-tailed deer are either absent or at very low densities in this area, and mule deer are at very low densities. There are no hunting seasons for either deer species in the WMUs overlapping with the Tsenaglode caribou subpopulation range.

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 either absent or at very low densities in this area. There are no hunting seasons for elk in the WMUs overlapping with the Tsenaglode caribou subpopulation range.

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. 2016a). 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 reinforcement program that will affect the Tsenaglode caribou subpopulation.

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. 2016a).

There is currently no captive breeding program being undertaken anywhere for woodland caribou in British Columbia or Alberta. The Tsenaglode caribou subpopulation's relatively large size and apparent recent increase make it a potential candidate to contribute to a captive breeding effort.

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. 2016a). 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. 2016a).

Translocation has been used as a tool several times in British Columbia (South Purcell and Telkwa), but not with the Tsenaglode caribou subpopulation (Hayek et al. 2016b).

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. 2016a). 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 Tsenaglode 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. 2016a). 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. Local environmental stewardship has recently been defined in detail as "… the actions taken by individuals, groups or networks of actors, with various motivations and levels of capacity, to protect, care for or responsibly use the environment in pursuit of environmental and/or social outcomes in diverse social-ecological contexts" (Bennett et al. 2018). They identify actors, motivations and capacity as the key elements of effective local environmental stewardship.

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.

The Tsenaglode caribou subpopulation presents an ideal opportunity for meaningful stewardship activities. It is one of the few caribou populations in British Columbia that is secure and increasing, so non-consumptive (and properly managed consumptive) interactions with this group do not put the population at risk. It is connected to several other subpopulations (Edziza, Level Kawdy, Horseranch, Spatsizi), so stewardship efforts can have multiplier effects. It is within the traditional territory of the Tahltan First Nation who have strong ties to caribou and this landscape and are active in regional stewardship. It is remote, but close to several regional centres including Dease Lake with easy access with highway 37. And there is a variety of value groups including hunters, backcountry enthusiasts and wildlife viewers who would benefit from participating in their stewardship. While motivation will vary among groups and are complex, the outcome, a sustainable caribou herd that persists without the need for intensive management, is commonly shared.

Stewardship themes include monitoring and discouraging poaching, managing access into sensitive habitats, ensuring the continuity of local oral traditions and the values and responsibilities of hunting a population of a species that is declining in most areas.

It is important to consider that local stewardship can be undermined or supported by actions in other places (Robichaud and Knopff 2015, Bennett et al. 2018). Being careful stewards of the Tsenaglode caribou subpopulation, but not providing similar outreach and participation opportunities for its neighbourhood herds will undo gains. Nevertheless, it is a strength to include opportunities and activities for 5 herds all in close proximity. Hence, stewardship planned for the Tsenaglode caribou subpopulation should include the other, nearby subpopulations.

Key to successful stewardship is motivating the identified actors with resources and capacity. This means committing money, facilities and experts to guide activities and communications with stewardship partners.

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 North Skeena caribou 3-year management plan identifies key research topics for herds in this region (Grant 2017). Research priorities listed in this plan for the Tsenaglode subpopulation include to identify critical habitat, delineate home range spatial boundaries, assess baseline health biomarkers and compare these among regional herds and finally assess genetic diversity and develop baseline understanding of genetic exchange among herds. In addition, an estimate of sources of caribou mortality in this region will be key to developing regional conservation actions, including evaluating this herd as a potential captive breeding donor.

4.8 MONITORING

Ecological, population and industrial footprint monitoring is an essential activity for the conservation and recovery of woodland caribou. This work provides the information to enable 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 North Skeena caribou 3-year management plan identifies key monitoring topics for herds in this region (Grant 2017). Identified for the Tsenaglode caribou subpopulation are fall rut counts to determine population size and trend, assess intensity and extent of recreational use to aid in developing recreation management strategies, and monitor harvest using Traditional Ecological Knowledge (TEK), Local Ecological Knowledge (LEK), and compulsory inspection information.

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.

The relatively intact habitat and wildlife populations in the Tsenaglode caribou subpopulation range suggest that caribou management should have few implications for other wildlife. Moose, thinhorn (Dall's) sheep and mountain goats are the most common ungulates in this range. Moose populations are already near their target management density. Large areas of the Tsenaglode range are already proposed to be part of a UWR order to protect sheep and, by extension, mountain goat habitat.

The size of the wolf population in this area has not been reported but may have to be managed to a lower density to facilitate caribou recovery (Bergerud 2007). This would directly affect wolf populations and indirectly affect moose populations.

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).

The management and recovery of the Edziza caribou subpopulation should have few negative implications on other values, but several positive implications. Habitat protections, such as a provincial park and UWR (albeit to protect thinhorn sheep) already restrict resource extraction in this region. Caribou hunting is permitted, but rare and were it to be prohibited would impact few hunters or guide operators. Research, monitoring and recovery efforts should greatly benefit the Tahltan First Nation and their values. Stewardship of the Tsenaglode caribou subpopulation will provide a variety of ecotourism opportunities in this remote part of British Columbia.

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. They 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 Tsenaglode subpopulation 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**: Tahltan, Kaska Dena, Treaty 8, Iskut First Nation, Dease River Band

Local: Dease Lake, Tatogga

Regional: Watson Lake, Smithers

Organizations: **Recreation**: British Columbia Snowmobile Federation, Land Conservancy of British Columbia, Outdoor Recreation Council of British Columbia, Alpine Lakes Air

Protection: Tahltan Central Council, BC Ministry of Environment

Commercial: **Hunting and Trapping**: **Accommodation and Guiding**: Kawdy Outfitters, Little Dease Ventures, Tahlan Outfitters, BC Safaris, Lehman Creek Outfitters, Last Frontier Heliskiing, BlueStone Guiding and Adventures

Forestry *(Active licences to cut)*: none

Forestry *(Woodlots)*: none

Agriculture: none

8 Recommended Actions

8.1 Short Term (Within 6–12 Months)

- Plan and execute a fall rut count
- Plan and execute a calf recruitment survey

8.2 Medium Term (Within 12–24 Months)

- Plan and execute a predator (wolf) survey
- Conduct a moose survey
- Plan a ground and GIS study to measure caribou critical habitat

8.3 Long Term (Within 24–48 Months)

- Develop and implement a stewardship program including regional actors and interconnected herds.
- Develop research programs in partnership with universities to achieve stated research goals.

9 LITERATURE CITED

Abrams, P. A. 2002. Will small population sizes warn us of impending extinctions? The American Naturalist **160**:293–305.

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). Calgary, AB.

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. Journal of Wildlife Management **77**:1409–1419.

BC Parks. 2018. Stikine River Provincial Park. Government of British Columbia, Victoria, BC. http://www.env.gov.bc.ca/bcparks/explore/parkpgs/stikine/. Accessed July 31, 2018.

Bellringer, C. 2017. An independent audit of grizzly bear management. Office of the Auditor General of British Columbia, Government of British Columbia, Victoria, BC.

Bennett, N. J., T. S. Whitty, E. Finkbeiner, J. Pittman, H. Bassett, S. Gelcich, and E. H. Allison. 2018. Environmental stewardship: A conceptual review and analytical framework. Environmental Management **61**:597-614.

Bergerud, A. T. 1988. Caribou, wolves and man. Trends in Ecology & Evolution **3**:68–72.

Bergerud, A. T. 2000. Caribou. Pages 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.

Borkowski, J. J., P. J. White, R. A. Garrott, T. Davis, A. R. Hardy, and D. J. Reinhart. 2006. Behavioral responses of bison and elk in Yellowstone to snowmobiles and snow coaches. Ecological Applications **16**:1911–1925.

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, AB.

Bowden, G. K. 1985. Wildlife damage on private agricultural land in the east Kootenay. Ministry of Environment, Vancouver, BC.

Brade, B. 2003. Management of motorized access in high elevation mountain caribou habitat Ministry of Water, Land and Air Protection, Government of British Columbia, Omineca Region, 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 Ministry of Environment. 2010. Caribou Distribution in British Columbia by Ecotype (Map). Government of British Columbia, Victoria, BC. http://www.env.gov.bc.ca/wld/speciesconservation/caribou_by_ecotype.html#_. Accessed July 30, 2018.

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. In: Cariboo Region, Environmental Stewardship Division. Government of British Columbia, Victoria, BC. http://www.env.gov.bc.ca/cariboo/env_stewardship/ecosystems/mdwr_strat/mgmtplan.html. Accessed November 27, 2017.

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. http://www.env.gov.bc.ca/fw/wildlife/management-issues/docs/white_tailed_deer_prov_review.pdf. Accessed Noember 2, 2017.

British Columbia Ministry of Water, Land and Air Protection. 2004. Procedures for Managing Identified Wildlife B.C. Ministry of Water, Land and Air Protection, 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.

Brumovsky, V. J., and R. S. McNay. 2015. Recommendations for wildlife habitat area designations for caribou in the Finlay/Akie, Chase, and Wolverine herds of north-central British Columbia. Wildlife Infometrics Inc., Mackenzie, BC.

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 **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., 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. 2002. COSEWIC assessment and update status report on the woodland caribou *Rangifer tarandus caribou* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON.

COSEWIC. 2011. Designatable Units for Caribou (*Rangifer tarandus*) in Canada. Ottawa, ON.

COSEWIC. 2014. 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. Unviersity 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, *Rangifer tarandus*. Canadian Field-Naturalist **100**:218–224.

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, MT.

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. 2018. Nowhere to hide: Effects of linear features on predator-prey dynamics in a large mammal system. Journal of Animal Ecology **87**:274–284.

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.

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.

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**:4481–4488.

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 – 1983. Unpublished report AFW-84-045, Alberta Energy and Natural Resources Fish and Wildlife Division, Edmonton, AB.

Environment and Climate Change Canada. 2016. Species at Risk Public Registry - Species Profile for Woodland Caribou Southern Mountain population. ed. Canadian Wildlife Service. Government of Canada, Ottawa, ON. http://sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=638#ot10. Accessed 16 May 2018.

Environment Canada. 2012a. Management Plan for the Northern Mountain Population of Woodland Caribou (*Rangifer tarandus caribou*) in Canada. Page vii + 79 Environment Canada, Ottawa, Canada.

Environment Canada. 2012b. Recovery Strategy for the Woodland Caribou, Boreal population (*Rangifer tarandus caribou*) in Canada Environment Canada, Government of Canada, Ottawa. Canada.

Environment Canada. 2014. Recovery Strategy for the Woodland Caribou Southern Mountain population (*Rangifer tarandus caribou*) in Canada. Page viii + 103 pp. Environment Canada, Ottawa, Canada.

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.

Freeman, N. L. 2008. Motorized backcountry recreation and stress response in mountain caribou (*Rangifer tarandus caribou*). MSc Thesis. University of British Columbia, Vancouver, BC.

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**:L18211.

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, UK.

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 Peche Caribou Range Plan. Ministry of Environment and Parks, Edmonton, AB.

Government of British Columbia. 1996a. Park Act. RSBC 1996. Queen's Printer, Province of British Columbia, 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. 2012. Dease-Liard sustainable resource management plan. Ministry of Forests, Lands and Natural Resource Operations, Government of British Columbia, Smithers, BC.

Grant, L. 2017. North Skeena Caribou 3-year Management Plan British Columbia Ministry of Forests, Lands and Natural Resource Operations, Smithers, BC.

Grant, L. 2018. Edziza Hodzih (Caribou) Rut Count: October 2017. Ministry of Forests, Lands, and Natural Resource Operations, Smithers, 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.

Harris, G., R. M. Nielson, T. Rinaldi, and T. Lohuis. 2014. Effects of winter recreation on northern ungulates with focus on moose (*Alces alces*) and snowmobiles. European Journal of Wildlife Research **60**:45–58.

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. Moehrenschlager. 2016a. 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.

Hayek, T., M. R. Stanley-Price, J. G. Ewen, N. Lloyd, A. Saxena, and A. Moehrenschlager. 2016b. 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.

Hayhurst, K. 1983. Reintroducing caribou to Caribou Mountain, B.C.: in defence of remnant populations. Unpublished.

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, Petroleum Technology Alliance of Canada, Canadian Association of Petroleum Producers, Missoula, MT.

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**:79–91.

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 1–15 (Chapter 13) *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 **92**:1029–1037.

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. van der 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. Pages 1–16. International Union of Conserving Nations, Gland, Switzerland.

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. 2000. Distribution of caribou and wolves in relation to linear corridors. Journal of Wildlife Management **64**:154–159.

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. BC Journal of Ecosystems and Management **5**:22–35.

Johnson, D. R. 1985. Man-caused deaths of mountain caribou, *Rangifer tarandus* in southeastern British Columbia. Canadian Field-Naturalist **99**:542–544.

Jones, S. 2014. Facts about Brucellosis In: Brucellosis Disease Information, ed. Animal and Plant Health Inspection Service. United States Department of Agriculture, Washington, DC. https://www.aphis.usda.gov/animal_health/animal_diseases/brucellosis/downloads/bruc-facts.pdf. Accessed September 18, 2017.

Kehm, G. 2011. Muskwa-Kechika Management Area Biodiversity Conservation and Climate Change Assessment. Yellowstone to Yukon Conservation Initiative, Vancouver, BC.

Kinley, T. A. 2008. Snowmobile - mountain caribou interactions: Perceptions and trends in caribou displacement British Columbia Ministry of Environment, Victoria, 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**:http://www.ecologyandsociety.org/vol10/iss12/art11/.

LM Forest Resource Solutions. 2007. Cassiar Timber Supply Area: Vegetation resources inventory strategic inventory plan. British Columbia Ministry of Forests and Range, Smithers, BC.

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.

McFarlane, K. A., A. Gunn, and C. Strobeck, editors. 2009. Proceedings from the caribou genetics and relationships workshop. Department of Natural Resources and Environment, Government of the Northwest Territories, , Edmonton, AB and Yellowknife, NT.

McKay, T. L. 2007. Woodland caribou response to encounters with people in Jasper National Park. Royal Roads University, Victoria, BC.

McLellan, B. N., G. Mowat, T. Hamilton, and I. Hatter. 2017. Sustainability of the grizzly bear hunt in British Columbia, Canada. Journal of Wildlife Management **81**:218–229.

McLellan, B. N., R. Serrouya, H. U. Wittmer, and S. Boutin. 2010. Predator-mediated Allee effects in multi-prey systems. Ecology **91**:286–292.

McNay, R. S. 2011. Silviculture options for use in ranges designated for the conservation of northern caribou in British Columbia. Forrex, Kamloops, BC.

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, BC.

Meidinger, D., and J. Pojar. 1991. Ecosystems of British Columbia. Ministry of Forests, Government of British Columbia, Victoria, 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. In: Manual of Common Diseases and Parasites of Wildlife in Northern British Columbia. University of Northern British Columbia, Prince George, BC. http://wildlifedisease.unbc.ca/besnoitia.htm. Accessed September 18, 2017.

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.

Ministry of Forests, Lands and Natural Resource Operations. 2012. British Columbia Grizzly Bear Population Estimate for 2012. Ministry of Forests, Lands and Natural Resource Operations, Victoria, BC.

Moose Management Technical Team. 2015. Provincial Framework for Moose Management in British Columbia. Pages 1–44 Fish and Wildlife Branch, Ministry of Forests, Lands and Natural Resource Operations, Government of British Columbia, Victoria, BC.

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.

Newsome, T. A., H. M. Armleder, M. J. Waterhouse, and O. A. Steen. 2000. Fifth year results from group selection harvesting in the ESSFwc3 on windthrow, artificial and natural regeneration. British Columbia Ministry of Forests, Williams Lake, BC.

Nicholls, D. 2015. Cassiar timber supply area: Rationale for allowable annual cut (AAC) determination. Ministry of Forests, Lands and Natural Resource Operations, Government of British Columbia, Victoria, BC.

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.

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. de Elia. 2006. Climate and climate change over North America as simulated by the Canadian RCM. Journal of Climate **19**:3112–3132.

Polfus, J. L. 2010. Assessing cumulative human impacts on northern woodland caribou with traditional ecological knowledge and resource selection functions. MSc Thesis. University of Montana, Missoula, MT.

Polfus, J. L., M. Hebblewhite, and K. Heinemeyer. 2011. Identifying indirect habitat loss and avoidance of human infrastructure by northern mountain woodland caribou. Biological Conservation **144**:2637–2646.

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.

Powell, T. 2004. Réponse comportementale des caribous des bois au harcèlement par les motoneiges. Université de Sherbrooke, Sherbrooke, QC.

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**:10.3390/ani7010002.

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.

Rytwinski, T., and L. Fahrig. 2012. Do species life history traits explain population responses to roads? A meta-analysis. Biological Conservation **147**:87–98.

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. In: Wildlife Diseases. Government of British Columbia, Victoria, BC. http://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-health/wildlife-diseases/chronic-wasting-disease. Accessed September 18, 2017.

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. 1992. Factors limiting woodland caribou populations and their interrelationships with wolves and moose in southeastern British Columbia. Canadian Journal of Zoology **70**:1494–1503.

Seip, D. R. 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.

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.

Serrouya, R., D. Paetkau, B. N. McLellan, S. Boutin, M. Campbell, and D. A. Jenkins. 2012. Population size and major valleys explain microsatellite variation better than taxonomic units for caribou in western Canada. Molecular Ecology **21**:2588–2601.

Sielecki, L. E. 2010. Wildlife accident monitoring and mitigation in British Columbia British Columbia Ministry of Transportation and Infrastructure, Victoria, BC.

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, BC.

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.

Skeena Region Environmental Stewardship Division. 2003. Management Plan for Stikine Country Protected Areas. BC Parks, Government of British Columbia, Smithers, BC.

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.

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.

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. 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. BC Journal of Ecosystems and Management **13**:1–23.

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, MO.

Webster, L. 1997. The effects of human related harassment on caribou (*Rangifer tarandus*). Ministry of the Environment, Government of British Columbia, Williams Lake, BC.

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.

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

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, Canadian Mountain Holidays, Pope & Talbot Ltd., Nelson, BC, Banff, AB and 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.