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

Graham

Subpopulation

Graham

Local Population Unit

BRITISH COLUMBIA

Recommended Citation:

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EXECUTIVE SUMMARY

TABLE OF CONTENTS

1 BACKGROUND

1.1 INTRODUCTION TO THE PROGRAM

2 POPULATION DESCRIPTION

Graham caribou are a subpopulation of southern mountain (SM) caribou, an ecotype of woodland caribou that is federally designated as *Threatened* under the *Species at Risk Act*. SM caribou currently occur in 38 subpopulations that are distributed across the southern two-thirds of British Columbia and west-central Alberta with one subpopulation extending into the northern portions of Idaho and Washington (Environment Canada 2014). Within Canada, this distribution coincides with the Southern Mountain National Ecological Area (COSEWIC 2002, Environment Canada 2014). Subpopulations of SM caribou have been further organized into 24 Local Population Units (LPUs), which reflect subpopulations that were historically contiguous. The Graham subpopulation forms its own LPU and these animals are considered part of the Northern group of SM caribou (Designatable Unit 7; COSEWIC 2011). The three groups of SM caribou – Northern, Central and Southern – are differentiated by their winter foraging behaviour and seasonal range use (Environment Canada 2014). Caribou in the Northern group, which are considered the "northern" ecotype in British Columbia (Heard and Vagt 1998), reside in mountainous areas with relatively shallow snow where they predominantly feed on terrestrial lichens within old-growth conifer forests or wind-swept alpine areas during winter. Within British Columbia, the Northern group is currently *Blue-listed* with a conservation status of S2/S3 due to threats from industrial activities and sustained declines in some subpopulations.

2.1 DISTRIBUTION

The range of the Graham subpopulation is situated within the southern portion of the Northern Rocky Mountains approximately 100-km northwest of Fort St. John in the north-central part of the province (Fig. 1). The 9291 km^2 range, which is at the northern limit of SM caribou distribution, lies predominantly within the Sub-boreal Interior eco-province with its eastern and northern boundaries extending slightly into the Boreal Plains and Northern Boreal Mountain ecoprovinces, respectively. The range's eastern extent is bounded by the Halfway River and the agricultural areas near the community of Hudson's Hope. The upper watershed of the Halfway River also constitutes the range's northern boundary. To the west, the range is bounded by the Ospika River watershed and the range's southern extent terminates at the Peace Reach of the Williston Reservoir. Topography within the range is typified by north-south oriented ridges, with alpine tundra and parkland forests occurring above 1400-m and conifer forests (Engelmann Spruce – Supalpine Fir; Boreal White and Black Spruce) occurring in lower-elevation valleys (Backmeyer 2000, Culling and Culling 2016). The range encompasses Graham-Laurier and Butler Ridge Provincial Parks and its north-central portion lies within the Muskwa-Kechika Management Area

2.2 HABITAT AND BEHAVIOUR

Most mountain-dwelling subpopulations of caribou undertake seasonal migrations with respect to elevation (Bergerud 1978, Heard and Vagt 1998). Radio-collaring studies conducted over the past 20 years have suggested that the Graham subpopulation is partially migratory (Backmeyer 2000, Culling et al. 2005). In early winter, both migrant and resident caribou occupy alpine tundra and subalpine parkland forests located within the eastern foothills of the Rocky Mountains (Culling et al. 2005, Williamson-Ehlers 2012). These areas continue to be used in late winter with females also using old-growth pine forests and males showing increased use of lower-elevation black spruce wetland complexes (Culling et al. 2005). In the last decade, use of lower-elevation boreal forests located in the eastern portion of the range appears to have declined (Seip and Jones 2013, Price 2018). In spring (April – May), migratory caribou leave the eastern foothills and move westward to higher elevation areas in the Rocky Mountains (Backmeyer 2000, Culling et al. 2005). During the late spring, summer and early fall, Graham

caribou are maximally dispersed throughout their range and occur in alpine tundra and subalpine parkland complexes. In mid to late fall, migratory caribou begin returning to their winter ranges in the eastern foothills.

Calving occurs from mid-late May to early June with females showing relative fidelity to calving areas (Culling et al. 2005). During calving, females appear to disperse as individuals before forming post-calving aggregations of up to 40 individuals later in the summer. Calving sites are not restricted to a particular habitat type, with females using high-elevation open and dense conifer forests, subalpine parklands and alpine tundra (Culling et al. 2005).

2.3 Population Size and Trend

Over the last four decades, the Graham subpopulation has received periodic surveys to estimate population size. In the late 1970s, Bergerud (1978) conducted some of the first aerial surveys to estimate caribou numbers within the boundaries of the current Graham range. For the 'Graham River herd', Bergerud (1978) estimated 250 caribou with most animals observed on or near Butler Ridge and Hackney Hills, which are located in the southeastern portion of the current range. In an area between Cypress Creek and the Halfway River, which constitutes the northern portion of the current range, Bergerud estimated 125 caribou.

More formal surveys to estimate caribou population size within the Graham range began in 1989 (Table 1). In the intervening years between Bergerud's (1978) survey and 1989, expert opinion suggested a population size of 530 (Harper 1988). In the winter of 1988 – 1989, three aerial surveys were conducted in various portions of the range (Backmeyer 1990). The largest of these surveys covered an area from Williston Lake to Cypress Creek and recorded 587 caribou, which included only three of ten animals previously radio-collared. Adjusting for these marked but unseen animals, Backmeyer (1990) suggested the population size could be as high as 1672-1761 caribou.

In the winters of 2002 and 2003, Culling et al. (2005) surveyed the eastern foothills from Williston Lake north to the Chowade River as part of a GPS radio-collaring study. Using the collared animals in a mark-resight framework, the 2002 survey recorded 113 caribou and estimated the population size to be 282 (95% CI: 177-609). A repeat survey in 2003 was attempted but poor snow conditions resulted in many caribou remaining below treeline, which limited sightability. This survey recorded 46 caribou with a mark-resight estimate of 107 (95% CI: 61-348). Culling et al. (2005) cautioned that because of poor snow conditions, the 2003 estimate is not likely an accurate depiction of the range's true population size.

The Graham range was surveyed again in the winter of 2009 (Culling and Culling 2009). This survey also focused on the core winter range in the eastern foothills but it had a larger extent than previous surveys, extending north of the Chowade River to the upper Halfway River. This survey recorded 190 caribou with a mark-resight estimate of 708 (95% CI: 311-1558). Culling and Culling (2009) cautioned that this estimate may be biased high due to suspected ingress from Pink Mountain caribou and a low number of resights (3 of 20), potentially due to suboptimal snow conditions causing many animals to remain below treeline. Culling and Culling (2009) also derived an estimate of 301 caribou (95% CI: 132-662) for areas south of the Chowade River to facilitate comparisons to previous surveys.

The most recent surveys of the Graham range were completed in 2015, 2016 and 2017 (Culling and Culling 2015, 2016, Seip and Jones 2017). In 2015, 215 caribou were observed, which included 11 of 21 previously collared females. The mark-resight estimate for the range was 347 (95% CI: 207-660). For the area south of the Chowade River, the mark-resight estimate was 114 (95% CI: 78-185). The survey was repeated in 2016 when 76 caribou

were recorded (six of 20 collared animals observed), yielding a mark-resight estimates of 230 (95% CI: 116-447) for the core winter range and 74 (95% CI: 41-216) for the area south of the Chowade River. Culling and Culling (2016) suggested that these estimates be viewed cautiously because of the low number of resights (i.e. < 7). To account for the 23% of collared animals being subsequently located outside of the survey blocks, Culling and Culling (2016) estimated the population size for the entire range to be 298. In 2017, a late winter survey to estimate juvenile recruitment recorded 86 caribou (Seip and Jones 2017).

Estimates of juvenile recruitment and adult female survival, two demographic parameters with high influence on caribou population dynamics (DeCesare et al. 2012), have also been recorded for the Graham subpopulation. Juvenile recruitment can be expressed as the percentage of ~9-10 month old calves in the population or as ratio of the number of ~9-10 month old calves per 100 adult females. In 1989, Backmeyer (1990) estimated calves to be 15.6% of the population, which was slightly above thresholds associated with population stability (15%; Bergerud 1996). All subsequent estimates have been below 15%, ranging from 4.5% in 2003 (Culling et al. 2005; Table 2) to 13% in 2015 (Culling and Culling 2015). Estimates of adult female survival are confined to more recent studies. For radio-collared females monitored by provincial biologists from 2008-2009, Culling and Culling (2009) reported survival to be 85% (sample size of radio-collared animals was not reported). For 28 females monitored from 2015-2016, Culling and Culling (2016) estimated survival to be 93% (95% CI: 84-100%). In the subsequent year (March 2016 – March 2017), however, survival had decreased to 81% (n = 26 females monitored; Seip and Jones 2017).

Over the last two decades, estimates of population size and demographic parameters suggest that the Graham subpopulation has been declining. Estimates of population size south of the Chowade River, an area that has been consistently surveyed, have decreased from ~ 500 animals in 1989 to 114 by 2015 (Culling and Culling 2009, Culling and Culling 2015; Table 3). While some estimates may have been affected by suboptimal weather conditions and low sightability, demographic data support this decline. Adult female survival has been variable with some years being < 85% and juvenile recruitment has been consistently below 15%, which has been generally insufficient to compensate for lost females (Seip and Jones 2017; D. Seip, *personal communication*). Note that the federal recovery strategy released in 2014 considered the Graham subpopulation to be stable but this assessment only considered survey data up to 2009 (Environment Canada 2014).

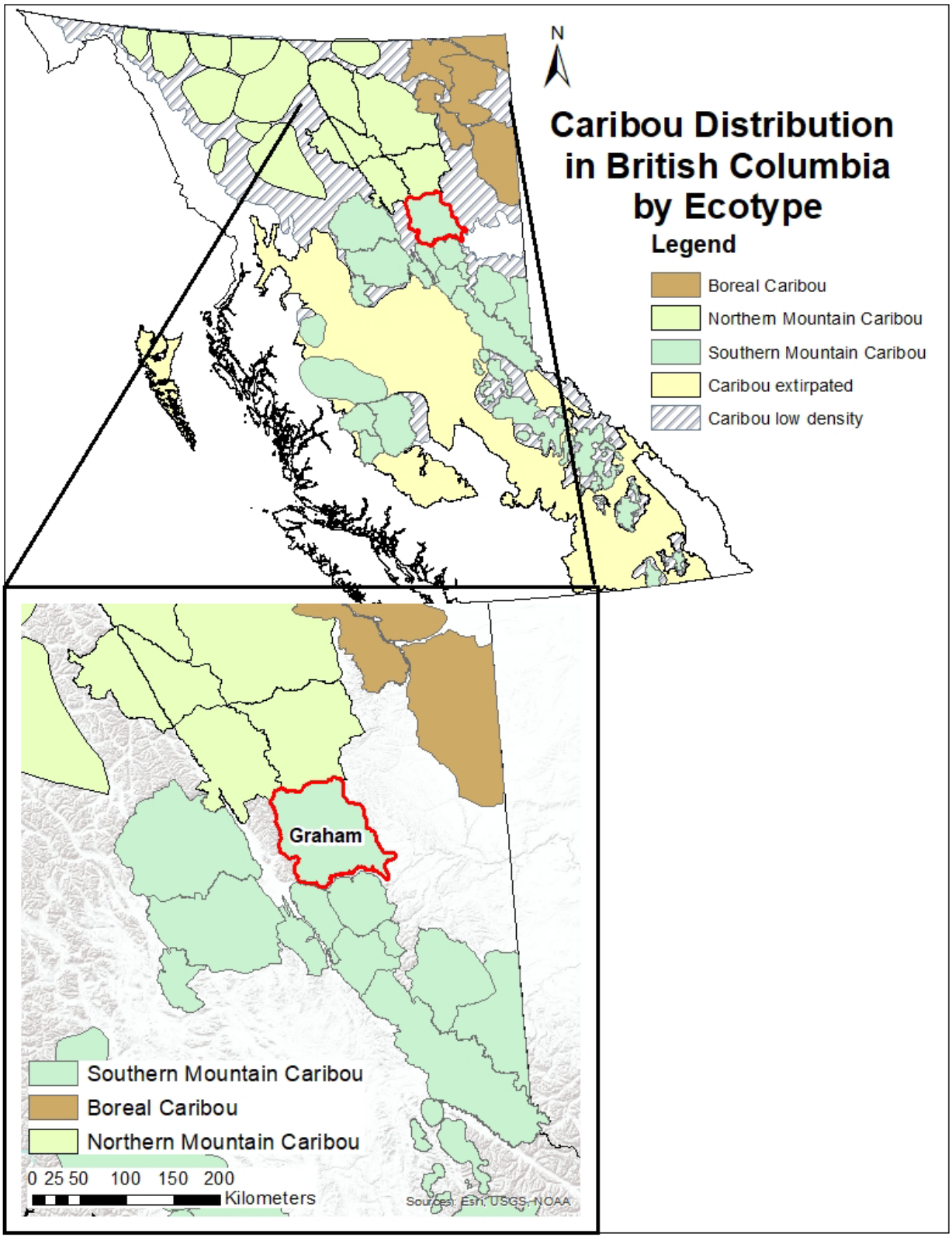

Figure 1: The geographical location of the Graham subpopulation of southern mountain caribou. The 9291 km^2 range (inset: red outline) is situated ~ 100 km northwest of Fort St. John in north-central British Columbia.

Table 1: Estimates of population size by year for the Graham subpopulation of southern mountain caribou in north-central British Columbia.

Year	Estimate	Method	Survey Timing	Reference
1978	375[1]	minimum count	winter	Bergerud 1978
1988	530	expert opinion	NA	Harper 1988
1989	587[2] (1672-1761)	minimum count (mark-resight estimate)	March	Backmeyer 1990
1998	800	expert opinion	NA	Heard and Vagt 1998
2002	282 (107-609)	mark-resight estimate (95% CI)		Culling et al. 2005
2002	300	unknown	NA	COSEWIC 2002
2003	107[3] (61-348)	mark-resight estimate (95% CI)	March	Culling et al. 2005
2009[4]	708 (311-1558)	mark-resight estimate (95% CI)	March	Culling and Culling 2009
2015	347 (207-660)	mark-resight estimate (95% CI)	March	Culling and Culling 2015
2016	230[5] (116-447)	mark-resight estimate (95% CI)	March	Culling and Culling 2016
2017	86	minimum count	March	Seip and Jones 2017

[1] Combined minimum counts from aerial surveys conducted over the Graham River area and over an area between Cypress Creek and Halfway River.
[2] Survey extent was slightly smaller than the current range boundaries with the northern extent of the survey ending at Cypress Creek.
[3] This survey was only partially completed due to low sightability from minimal snow cover and a large proportion of caribou staying below treeline.
[4] Surveys after 2009 had a larger spatial extent than previous surveys with these later surveys extending north of the Chowade River to the upper Halfway River. All surveys from 2009 and beyond focused on the core winter range located in the eastern foothills.
[5] Culling and Culling (2016) derived an estimate of 298 for the entire range. The 230 estimate is confined to the core winter range.

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

Year	Calves: 100 Females	% Calves	Survey Timing	Reference
1989	-	15.6	March	Backmeyer 1990
2002	15	9.2	March	Culling et al. 2005
2003	7	4.5	March	Culling et al. 2005
2009	14	10	March	Culling and Culling 2009
2015	21	13	March	Culling and Culling 2015
2016	17	12	March	Culling and Culling 2016
2017	-	12.8	March	Seip and Jones 2017

3 THREATS AND LIMITING FACTORS

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

The federal *Recovery Strategy* for SM caribou (Environment Canada 2014) identified a number of threats potentially affecting caribou populations and their habitat. These threats, in descending order of importance, included: predation, industrial activities, roads and other linear features, recreational activities, natural disturbances (e.g. fire), hunting, climate change and parasites and diseases. This section follows a similar approach, discussing these threats – and others – though their order does not reflect their relative importance to a specific population. Note that while threats are discussed individually, they are not mutually exclusive as they may interact and their effects on caribou population dynamics are likely cumulative (Sorensen et al. 2008, Johnson et al. 2015).

3.1 PREDATION

Increasing rates of predation are the primary proximate cause of population decline in most woodland caribou herds (McLoughlin et al. 2003, Wittmer et al. 2005*b*, Apps et al. 2013). Increasing predation has been attributed to changes in the abundances and distributions of predators and alternate prey in response to human-mediated landscape alteration and climate change (Seip 1992, Latham et al. 2011*b*, Apps et al. 2013, DeMars and Boutin 2018). Hypothesized mechanisms relating increased predation to landscape alteration and climate change are detailed under *Section 3.3 Human Activities* and *Section 3.6 Climate Change*.

Predation has been identified as the primary cause of mortality among caribou subpopulations within the South Peace region, including the Graham subpopulation (BC Ministry of Environment 2014, Seip and Jones 2017, Price 2018). A number of predators may prey on caribou including wolves, bears, wolverine, and lynx. Wolves are likely the primary predator of South Peace caribou, as evidenced by field investigations of mortality sites of radio-collared caribou and ongoing results from an adaptive management experiment assessing the effects of wolf control within the South Peace region (Culling et al. 2005, Seip and Jones 2016, 2017, Price 2018). In this latter project, the Graham subpopulation currently serves as a "control" with its demographic parameters (adult female survival, juvenile recruitment and population trend) being compared to those of other nearby subpopulations where wolf control is currently being implemented (Quintette, Kennedy Siding, and Klinse-za; Seip and Jones 2016, 2017). In the first two years of the program, the Graham subpopulation has continued to experience high rates of adult mortality (e.g. 19% from March 2016 to March 2017) and low rates of calf recruitment, suggesting that the population is continuing to decline, whereas subpopulations in the wolf control zone have stabilized or

increased (Seip and Jones 2017). These results suggest that wolf predation is likely a primary factor driving suspected recent declines in the Graham subpopulation.

3.2 Food Limitation

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

For SM caribou, including the Graham subpopulation, evidence to date suggests that food limitation is not a primary factor in recent populations declines (Wittmer et al. 2005*b*, McLellan et al. 2012). Such evidence, however, does not preclude any food limitation effect. In 2014 and 2015, measures of body fat were estimated for 22 females captured within the Graham range (Cook and Cook 2015). These measurements were, on average, lower than measurements recorded within nearby boreal caribou ranges, suggesting that caribou residing in montane environments may be food limited, particularly on summer / late fall ranges. Heard and Zimmerman (2017) reported similar findings of potential food limitation in the nearby Kennedy Siding subpopulation. They reported that 37% of females appeared to be undernourished when first arriving at experimental feeding stations in early winter. Heard and Zimmerman (2017) suggested that this effect could result if increased predation risk limits food intake and/or restricts traditional migratory movements causing caribou to overgraze seasonal ranges.

Cook and Cook (2015) suggested that lower body fat levels from food limitation could affect caribou populations by lowering pregnancy rates. Food limitations may also result in smaller calves, which could have increased predation risk (Adams et al. 1995). Determining the magnitude of food limitation effects, however, is difficult in a high predation environment because predation may occur before effects on body condition become evident (Boutin and Merrill 2016).

3.3 Human Activities

Human activities within and adjacent to caribou range are believed to be a primary driver of current declines in woodland caribou populations (Wittmer et al. 2007, Environment Canada 2008, Sorensen et al. 2008, Johnson et al. 2015) . Such activities can impact caribou populations through multiple mechanisms including direct habitat loss, displacement from preferred habitats (Seip et al. 2007) and indirectly increasing predation (Apps et al. 2013, DeMars and Boutin 2018). This section focuses on impacts associated with industrial activities, recreational activities and other activities such as agriculture and roads.

3.3.1 Industrial

Industrial activities include forestry, mining, oil & gas development and clean energy. Since the early 1990s, the cumulative impacts from industrial activities have significantly altered many areas within caribou ranges of north-central British Columbia, including the Graham range. Across South Peace caribou ranges, industrial impacts have resulted in the loss of 53% of high quality caribou habitat (Johnson et al. 2015, Price 2018).

3.3.1.1 FORESTRY

Woodland caribou are an old-growth forest dependent species (Bergerud 2000) and are therefore affected by forestry practices. Logging of old-growth forests can result in direct habitat loss and an increase in the extent of early seral (or young) forest, which can increase the abundance and alter the distribution of other ungulates (e.g. moose) and their predators, potentially leading to increased caribou predation (Serrouya et al. 2011, 2015). Cutblocks can further increase predation risk for caribou if behavioural avoidance of these areas causes caribou to become more clumped in their distribution (Schaefer and Mahoney 2007, Fortin et al. 2013).

Within the South Peace region and the range of the Graham subpopulation, large-scale forest harvesting began in the 1970s with the largest impacts occurring from 2000 – 2009 (BC Ministry of Environment 2014). During this decade of high impact, the amount of land change due to forestry was 13% within the Graham range. The majority of forest harvesting has taken place in low-elevation conifer forests, which are often used by caribou for at least part of the winter (Seip 1998). This pattern of harvest is evident within the Graham range. Using cutblock GIS data spanning 1989 - 2015, the majority of cutblocks are confined to the perimeter of the range and are situated in low-elevation valleys. The intensity of cutblocks does increase outside of the range boundary, particularly to the east and southeast.

3.3.1.2 MINING

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

The Graham range has a number of mine tenures situated within its borders (Price 2018). The largest of these is the Aley project, which is a proposed 433 km^2 open-pit niobium mine covering 104 mineral claims situated in the eastern portion of the range near the eastern border of Graham-Laurier Provincial Park (https://www.tasekomines.com/properties/aley). This project is still in the provincial environmental assessment process. The majority of the other mine tenures within the Graham range are located along the southern and eastern borders. Using GIS data of mine tenures from the BC Data Catalogue (accessed May 2017), mine tenures comprise ~ 7% of the range's area.

3.3.1.3 OIL AND GAS

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

The Graham range has been impacted by oil and gas development, particularly along and adjacent to its eastern border (Price 2018). Such disturbances include polygonal features such as well sites and camps as well as linear disturbances such as seismic lines, pipe lines and roads. For the former, GIS data available from the BC Oil and

Gas Commission up to 2016 suggests that there are ~ 186 active, completed or abandoned wells within the Graham range. Natural gas tenures comprise ~ 14% of the range's area.

3.3.1.4 CLEAN ENERGY

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

The Peace Reach of the Williston Reservoir forms the southern boundary of the Graham range. This arm of the reservoir is formed by the Gordon M. Shrum hydroelectric dam. A second dam, the Peace Canyon dam, is located further downstream near the community of Hudson's Hope.

To date, there are no wind power developments within the Graham range. There are, however, multiple tenures for potential wind power developments situated along the eastern foothills within core winter range for Graham caribou (BC Ministry of Environment 2014, Price 2018). In 2014, the extent of these tenures was estimated to be ~ 32,000 ha with 40% situated within core high-elevation winter range (BC Ministry of Environment 2014).

3.3.1.5 OTHER

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

3.3.2 RECREATION

Recreational activities conducted within caribou range can impact caribou populations by displacing individuals into sub-optimal habitats (Seip et al. 2007), increasing stress levels (Freeman 2008) and / or facilitating predator movement into caribou habitat (Whittington et al. 2011). This section considers impacts related to snowmobiling and backcountry skiing as well as other activities such as hiking and mountain biking.

3.3.2.1 SNOWMOBILE

Among winter recreational activities, snowmobiling appears to have the highest impact on caribou, in part because the preferred areas for this activity overlap with the preferred winter habitat of caribou (Simpson and Terry 2000). Snowmobiling has been shown to displace caribou from preferred areas and the intensity of displacement – both in space and time – can depend on the intensity of snowmobile use (Simpson and Terry 2000, Seip et al. 2007). Snowmobiling may further induce physiological stress, potentially affecting individual fitness and population dynamics (Freeman 2008). Compacted trails from snowmobiles may also facilitate movement of predators into winter habitats of caribou, thereby increasing predation risk (Droghini and Boutin 2017).

Snowmobiling does take place within the Graham range, though its intensity of use within core winter ranges has not been quantified during aerial surveys (e.g., Culling et al. 2005, Culling and Culling 2016). An established network of snowmobile trails exists within Butler Ridge Provincial Park. Butler Ridge is considered part of the core winter range of Graham caribou and late-winter use of Butler Ridge by caribou was documented during aerial surveys in 1989 and 2002 (Backmeyer 2000, Culling et al. 2005). Aerial surveys conducted since 2002,

however, have not found caribou using this area. It is not known whether snowmobiling has resulted in the displacement of caribou from Butler Ridge but this linkage has been documented in the Hart Ranges immediately to the south of the Graham range (Seip et al. 2007).

3.3.2.2 Heli-ski / Cat-ski

Heli- and cat-skiing can have similar mechanistic effects on caribou populations as snowmobiling though the degree of impacts is considered to be lower, primarily because skiing generally occurs on slopes steeper than those preferred by caribou (Simpson and Terry 2000). In 2008, best management practices for ski operators were implemented to reduce conflicts with caribou (Hamilton and Pasztor 2009). These practices, such as skiing at least 500-m away from observed caribou, may reduce caribou-skier encounters (Huebel 2012) although lack of compliance with these practices remains an issue (L. DeGroot, *personal communication*).

In 2001, a heli-ski tenure was issued for areas encompassed by the Graham range. This tenure, granted to Peace Reach Heli Ski, covered over 8,000 km^2 and included over 200 developed runs. The heli-ski company is no longer operational and it is not known the degree to which heli-skiing impacted caribou use of winter range.

3.3.2.3 Summer Recreation

Recreational activities in the snow-free seasons can also impact caribou populations. Trails associated with off-road vehicles, hiking, mountain biking and horseback riding may facilitate predator movements into summer habitats used by caribou, potentially increasing predation risk (Whittington et al. 2011). Human presence on hiking trails may also induce physiological stress, though this response may attenuate if humans are not perceived as a predation threat (Lesmerises et al. 2017).

Hiking, mountain biking, horseback riding, and off-road vehicle use all occur within the Graham range though the extent of these trails and their intensity of use has not been explicitly quantified. The Chowade River Trail and the Cypress Creek Trail are designated all-terrain vehicle routes for accessing the Muskwa-Kechika Management Area and Graham-Laurier Provincial Park. The Royal Northwest Mounted Police Trail runs adjacent to the Cypress Creek Trail and is restricted to equestrian use.

3.3.2.4 Other

Graham caribou may also be impacted by backcountry skiing (i.e. ski touring). Simpson and Terry (2000) rated this activity's threat to caribou as low because of its non-motorized nature. However, as with other activities, its degree of impact is related to its intensity of use and the popularity of this sport has increased significantly in the last decade. Backcountry skiing is known to take place within Butler Ridge Provincial Park (http://www.env.gov.bc.ca/bcparks/explore/parkpgs/butler_ridge/#WinterRecreation).

3.3.3 Other

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

3.3.3.1 Agriculture

Agriculture can impact caribou populations through a number of mechanisms. First, conversion of forested areas to agriculture can result in direct habitat loss and avoidance behaviours by caribou may increase the extent of loss beyond the physical footprint (Vistnes and Nellemann 2008). Second, agricultural areas are generally favourable to alternate prey (e.g. deer and elk), potentially increasing their populations and those of predators, which ultimately may increase predation rates of caribou. Third, agriculture could increase the likelihood of disease and

parasite transmission among domesticated animals, alternate prey and caribou although such links have not been established within British Columbia caribou herds (Vors and Boyce 2009, Martin et al. 2011).

There are minimal impacts from agricultural within the Graham caribou range. The few agricultural areas present are along the range's southeastern border near the community of Hudson's Hope.

3.3.3.2 Major Highway Corridors

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

There are no major highways within the Graham range.

3.3.3.3 Linear Features

Industrial activities within forested systems are often accompanied by the creation of linear features such as roads, railways, power lines, pipe lines and seismic lines. Such features are thought to increase predation of caribou by increasing predator hunting efficiency (McKenzie et al. 2012, Dickie et al. 2017*b*) and facilitating predator movement into caribou range (Whittington et al. 2011, DeMars and Boutin 2018). Linear features may further contribute to caribou-predator spatial overlap if such features facilitate the movement of alternate prey into caribou range (Dawe and Boutin 2016, Fisher et al. 2017).

Linear features associated with forestry and oil and gas development are present within the Graham range. The vast majority of these features are situated in the range's eastern foothills and low elevation forests. The high density of linear features (estimated length = 7948 km; density = 0.86 km/km^2; data sources (https://catalogue.data.gov.bc.ca/dataset/forest-tenure-road-segment-lines; https://data-bcogc.opendata.arcgis.com/) within this area likely constitutes an increased predation risk for Graham caribou, particularly during winter when individuals are likely to use lower elevation forests. Note that the age, width and state of regeneration on linear features within the Graham range are largely unknown and that these attributes likely play a significant role in determining predator use of – and movement efficiency on – a given linear feature (Dickie et al. 2017*a*).

3.3.3.4 Hunting

Historical records indicate that SM caribou have long been hunted by First Nations (Spalding 2000). Following Euro-American settlement of the region in the late 1800s and early 1900s and the subsequent arrival of firearms, excessive harvest was likely a primary factor in suspected province-wide population declines of caribou during the early 20th century (Bergerud 1978, Spalding 2000). Since the 1940s, guided hunting has also occurred within the Northern Rocky Mountains (Spalding 2000).

Licensed hunting for caribou still occurs within portions of the Graham range. Six Wildlife Management Units (WMUs) overlap the range: 7-35, 7-36, 7-37, 7-43, 7-57, and 7-58. Within WMUs 7-35, 7-36, and 7-43, hunting for caribou has been closed for at least a decade. Within WMUs 7-37 and 7-57, there are eight- and six-week general hunting seasons, respectively, for 5-point or larger bulls. From the mid- 1970s to 2010, harvest has averaged five caribou per year within each of these WMUs (BC Ministry of Environment 2014). Currently,

hunting within WMU 7-57 is restricted to north of the Halfway River to protect Graham caribou. Movement of Graham caribou into the Pink Mountain range, however, has been documented (Culling and Culling 2016) and this areal closure does not entirely eliminate exposure of Graham caribou to hunting within this WMU. In WMU 7-58, which occurs in the extreme northeastern corner of the range, hunting is restricted to a 4-week bow only season for 5 point or larger bulls. Since 2008, harvest records indicate only three bulls have been harvested in WMUs 7-57 and 7-58 (J. Strong, BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development, *unpublished data*).

3.3.3.5 POACHING

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

3.4 NATURAL DISTURBANCE

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

Within the boreal forests of north-central British Columbia, the median return interval for forest fires is ~ 100 years (Johnstone et al. 2010). Using forest fire data available to 2015, the extent of areas burned < 50 years ago constitutes < 4% of the Graham range with the majority of these fires situated in the eastern foothills and along the range's northern perimeter. Within the last 50 years, the largest fire occurred in 1965 (11,960 ha burned) and was situated on the range's northern boundary.

The Graham range has been affected by the mountain pine beetle with most infestations confined to lower elevation forests (https://www.for.gov.bc.ca/hre/bcmpb/year13.htm). Projections into the year 2024 do not suggest an expansion in the current spatial extent of infestations, although the intensity of infestation may increase in some lower elevation forests situated along the range's eastern boundary.

3.5 PARASITES AND DISEASES

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

deer into caribou range may increase the prevalence of meningeal worm in caribou, a parasite that is highly pathogenic to caribou and whose usual host is white-tailed deer (Anderson 1972).

Evidence to date, however, suggests that mortality from natural causes (i.e. diseases and nutrition) is low (McLellan et al. 2012, Apps et al. 2013) and diseases and parasites are not thought to be a major driver of current declines in populations of SM caribou (Environment Canada 2014). For the Graham subpopulation, impacts from parasites and disease appear to be low based on observations from captured individuals. Among 22 animals captured in 2001 – 2002, 21 were classified as being in good condition with the other individual being an older bull (> 10 years old) that had a relatively high infestation of warble flies (Culling et al. 2005). For animals captured in 2015 (n = 30), none had winter ticks nor did any have evidence of parasite-related hair loss (Culling and Culling 2015). Warble fly larvae, however, were observed on 10 individuals.

3.6 Climate Change

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

Impacts of climate change on the Graham range have not been well studied. The negative impacts of the northward expansion white-tailed deer have been documented in ranges of boreal caribou (Latham et al. 2011*b*, Dawe and Boutin 2016) but whether white-tailed deer have impacted caribou ranges in British Columbia's northern mountain remains unclear.

Recent analyses using demographic data from boreal caribou subpopulations in northeast British Columbia have suggested that woodland caribou may be impacted from effects of climate change other than those related to alterations in predator-prey communities. Specifically, juvenile recruitment was negatively affected by increasing mean winter temperatures while adult female survival was positively associated with the timing of spring (i.e., later onset of spring growing conditions equated to increased survival; DeMars et al. 2017). Collectively, these relationships suggest that warmer winter temperatures and lowered snowfall may have a negative effect on caribou population dynamics. It is unknown whether the Graham subpopulation has been specifically impacted by these predicted effects of climate change.

3.7 Small Population Size Effects

Caribou subpopulations that are small and isolated may be subject to negative demographic effects that can occur as a result of their small size (Caughley 1994). Such effects include inbreeding depression, genetic isolation from population fragmentation (Serrouya et al. 2012), demographic stochasticity (e.g. all offspring produced are of one sex), environmental stochasticity (e.g. the population is extirpated by a random natural disturbance such as an avalanche; Hebblewhite et al. 2010), and Allee effects (e.g. lowered demographic performance with decreasing

population size; Courchamp et al. 1999). For group-living ungulates such as caribou, McLellan et al. (2010) documented a predation-mediated Allee effect where the predation rate may increase with declining population size because group size declines at a faster rate than the number of groups in the population and the number of groups dictates the rate of caribou-predator encounters.

With a current population size estimated to be > 200 caribou (see 2.3 *Population Size and Trend*), the Graham subpopulation is likely to be minimally affected by potential negative effects associated with small population size. This subpopulation, however, could become subject to small population size effects in the near future if abundances continue to decline as they have over the past decade.

4 MANAGEMENT HISTORY

Over the past 15 years, a number of different entities have proposed management actions aimed at recovering SM caribou populations in British Columbia. For the most part, many of these recommendations were focused on mountain caribou residing in the deep snow mountains, which British Columbia recognized as "mountain caribou", and were not developed specifically for more northern subpopulations such as the Graham, which are considered the "northern" ecotype provincially. Nevertheless, these recommendations are reviewed here because they are broadly applicable and have been incorporated into more recent management strategies.

In 2002, the Mountain Caribou Technical Advisory Committee outlined a strategy that emphasized identifying and protecting critical habitat, monitoring the size and movement of caribou populations, managing predators and managing the populations of other ungulate species (Mountain Caribou Technical Advisory Committee 2002). In 2004, an independent panel reviewing recovery of mountain caribou in the South Columbia Mountains suggested an adaptive management approach emphasizing protection of old-growth forests, population monitoring of caribou, reducing populations of predators and other ungulates, and limiting recreational activities in caribou range (Messier et al. 2004). The Mountain Caribou Science Team issued similar recommendations in 2006 and further suggested potentially augmenting small subpopulations and that habitat protection should promote connectivity among subpopulations (Mountain Caribou Science Team 2006). In 2008, McNay et al. (2008) issued recommendations specific to caribou herds in the province's north-central mountains. These recommendations included protecting large patches of old-growth forest, managing human-mediated disturbance so that total disturbance (human-mediated + natural) is within the range of natural variability, managing recreation access, and managing alternate prey and predators. One year later, Wilson (2009) outlined actions for managing predators and other ungulates within and adjacent to caribou range, including species-specific density targets. In 2013, the *Implementation Plan for the Ongoing Management of South Peace Northern Caribou* was developed, which had four main implementation objectives: *i)* protect 90% of high-elevation winter range; *ii*) conduct predator and prey population management; *iii*) manage and reduce the industrial footprint; and *iv*) monitor management actions and modify accordingly (BC Ministry of Environment 2013).

While these documents have collectively added to the understanding of caribou population dynamics and potential recovery actions, they are unified in their recommendations for the following three management actions:

i. Protecting and restoring sufficient habitat for caribou to carry out life history processes and reduce predation risk thereby ensuring long-term population persistence. Habitat protection generally has included managing recreational activities (e.g. snowmobiling and heli-sking) within caribou range.

ii. Managing the populations of other ungulate species.

iii. Managing predator populations.

These actions are also key components in the 2014 federal *Recovery Strategy* and in more recent reviews on management strategies for recovering populations of SM caribou (Environment Canada 2014, Boutin and Merrill 2016, Serrouya and McLellan 2016). Because of continued declines in most subpopulations and their current small population sizes, more direct measures for reinforcing populations – such as maternal penning – have been further suggested (Boutin and Merrill 2016, Serrouya and McLellan 2016). This section reviews management actions undertaken for the Graham subpopulation under these four broad categories: habitat management, predator management, alternate prey management, and population reinforcement.

4.1 HABITAT

Protecting and restoring sufficient habitat for caribou to carry out essential life processes and reduce predation risk is fundamental to achieving self-sustaining populations (Environment Canada 2014, Ray et al. 2015). SM caribou require large tracts of undisturbed habitat and have evolved to inhabit old-growth forests, which separates them – both in terms of elevation and horizontal space – from other ungulates and their generalist predators (Seip 1992, Rettie and Messier 2000, Apps et al. 2001). Spatial requirements for SM caribou also extend beyond areas of high use (i.e. habitat cores) and can include "matrix" habitat, of which there are two types (Environment Canada 2014). Type 1 matrix range are areas of relatively low use and such areas may include those used during migration. Type 2 matrix range are areas surrounding seasonal cores where predator-prey dynamics still affect caribou populations.

Impacts to caribou habitat are generally assessed at the range scale in a cumulative effects framework (Environment Canada 2008, 2014). The 2014 federal *Recovery Strategy* suggests that caribou populations have a higher probability of being self-sustaining when their range contains at least 65% undisturbed habitat (Environment Canada 2014).

4.1.1 PROTECTION

A primary action recommended in the *Implementation Plan for the Ongoing Management of South Peace Northern Caribou* was to identify and protect caribou habitat from impacts associated with industrial development (BC Ministry of Environment 2013). Over the last five years, spatially-explicit modelling has been completed to identify core summer and winter ranges and matrix habitat within the Graham range (Williamson-Ehlers 2012, Seip and Jones 2013, Seip and Jones 2015*a, b*). For winter range, the *Implementation Plan* recommended the protection of at least > 90% of core winter habitat. Using this threshold, Seip and Jones (2014) analysed core winter habitat within the Graham range and identified areas where industrial development could occur and the corresponding areas that should be protected. Areas identified for industrial development contained < 1% of winter GPS locations collected from radio-collared caribou up to that time.

Approximately 34% of the Graham range lies within the Muskwa-Kechika Management Area, which is managed to maintain wilderness values. Provincial Parks and Protected Areas encompass 11% of the range's area – with most situated within the Muskwa-Kechika Management Area – and these areas provide even stronger protections as no industrial development is permitted. The range also contains zones designated as Ungulate Winter Range (UWR; 42% of range area) and Wildlife Habitat Areas (WHAs; 25% of range area) where logging is prohibited or severely restricted. UWR and WHAs do overlap within the Graham range and collectively they cover ~ 54% of the range's area. A small portion (407 ha) of high-elevation winter range lies within an Old Growth

Management Area, which are legal Crown designations established under the *Land Act* to retain patches of old-growth forest (BC Ministry of Environment 2014).

4.1.2 Enhancement and Restoration

To date, there have been no management actions to enhance or restore caribou habitat within the Graham range.

4.2 Recreation and Access Management

Compared to SM caribou subpopulations located further south, the Graham subpopulation has been less impacted by recreational activities and therefore there are minimal management actions focused on recreation and access.

4.2.1 Snowmobile

Because of the negative impacts that snowmobiling can have on SM caribou, the provincial government closed many areas to snowmobiling within SM caribou ranges beginning in 2009. To date, these closures have not extended into the Graham range (http://www.env.gov.bc.ca/fw/wildlife/snowmobile-closures/).

4.2.2 Heli-ski / Cat-ski

The *Mountain Caribou Recovery Implementation Plan* recommended the development of best management practices for commercial backcountry ski operators. These practices, which include maintaining a distance of at least 500-m from observed caribou, were implemented in 2008 (Hamilton and Pasztor 2009).

Currently, there are no heli- or cat-ski companies operating within the Graham range and thus it is not subjected to impacts from these activities.

4.2.3 Summer Recreation

Currently, there no regulations on summer activities (e.g. hiking, mountain biking) within the Graham caribou range.

4.2.4 Other

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

4.3 Predators

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

4.3.1 Wolf Management

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

1960s (Bergerud 1978, Spalding 2000) though the specific effects of wolf control on the Graham subpopulation is unknown.

Since the cessation of province-wide wolf control, northeastern British Columbia has had a few periods of wolf removals. From 1978 – 1980, 71 wolves were removed from the Horseranch Mountains and an unknown number of wolves were removed from the Muskwa range by local guide outfitters (Bergerud and Elliott 1998). In the 1980s, wolf removal experiments were conducted in northeastern British Columbia to test the effects of wolf predation on recruitment rates – and consequently population growth rates – of four ungulate species (Bergerud and Elliott 1998). Within the Muskwa study area, wolves were removed in 1984 (60% reduction over a 6775 km^2 area), 1985 (77% reduction over 13,570 km^2) and in 1987 (62% reduction over 10,000 km^2). Within the Kechika study area, which included the Horseranch Mountains, wolves were removed in 1982 (85% reduction over 3833 km^2), 1983 (83% reduction over 7123 km^2), 1984 (76% reduction over 9961 km^2) and 1985 (65% reduction over 18,400 km^2). These removals resulted in high recruitment rates and probable population growth in caribou populations in the two study. Effects of the wolf removal program, however, were short-term as recruitment rates in the Muskwa study area had lowered from 30.4 calves per 100 females in the last year of wolf removal to 17.5 calves per 100 females three years later.

In the winter of 2015, wolf reductions were also initiated in caribou ranges in north-central BC, specifically the Klinse-Za, Kennedy Siding and Quintette ranges (Seip and Jones 2015*c*). Across these ranges, 57 wolves were removed in 2015, 201 in 2016 and 93 in 2017. Since the reductions began, all three subpopulations have had increases in adult survival, calf recruitment and population size while the Graham subpopulation, which served as a control, continued to decline (Seip and Jones 2017).

Currently, in WMUs 7-35, 7-36, 7-43, 7-57, and 7-58, there is a year-round general hunting season for wolves in areas < 1100 m elevation; above this elevation, there is a 10.5 month general hunting season. The annual bag limit is three. In WMU 7-37, there is an eleven month general hunting season for wolves with no bag limit.

4.3.2 Cougar Management

Being situated at the northern edge of cougar distribution within western North America, the Graham range likely has a low density of cougars (Culling and Culling 2016), though their population has not been explicitly enumerated. To date, there have been no documented reports of caribou predation by cougars within the Graham range. Because of their likely low impact on the population dynamics of Graham caribou, cougars have not been subject to management actions in the context of caribou conservation. Within WMUs 7-35, 7-36, 7-43, 7-57, and 7-58, there is a 7 month general hunting seasons for cougar with a bag limit of one. WMU 7-37 is closed to cougar hunting.

4.3.3 Other

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

4.4 Alternate Prey

Declines in many populations of woodland caribou have been attributed to apparent competition, an indirect interaction between two or more prey species and a shared predator (Holt 1977, DeCesare et al. 2010, Hebblewhite 2017). In this process, increased abundances of other ungulate species – stemming from an increase in favourable habitat following landscape alteration – has led to higher populations of predators, resulting in

unsustainable predation of caribou. Because of these linkages, recommended strategies for recovering caribou populations includes reducing the abundances of primary prey (McNay et al. 2008, Wittmer et al. 2013, Serrouya et al. 2015, Boutin and Merrill 2016).

4.4.1 Moose Management

Surveys to estimate moose abundance or density have not been conducted within the Graham range or within any of the WMUs that overlap it (Poole and DeMars 2015). The closest WMU where moose density has been estimated is in 7-42, which overlaps the Pink Mountain range (Poole and DeMars 2015). Since 1989, this WMU has received four surveys with the most recent occurring in 2015. Using information from this WMU and others with empirical survey data in the Peace region, Poole and DeMars (2015) estimated moose densities for all WMUs within the Game Management Zone 7Pc, which encompasses the Graham range. Estimated densities ranged from 0.15 moose/km^2 (WMU 7-57) to 0.67 moose/km^2 (WMU 7-58). For perspective, Bergerud (1996) has suggested that caribou populations will decline when moose densities exceed 0.2 – 0.3 / km^2.

To date, there has been no active management of moose in the context of caribou conservation within the Graham range. Within WMUs overlapping the Graham range, there are general hunting seasons for bull moose. In WMUs 7-36, 7-43, 7-57, and 7-58, there is a 2-week season for any bull moose followed by a 10-week season where harvest is restricted to spike-fork bulls, tripalm bulls and bulls with ≥ 10 points. In WMU 7-35, there is a 6-week season for spike-fork bulls, tripalm bulls and bulls with ≥ 10 points. In WMU 7-37, there is a 10.5 general season for spike-fork bulls only. The impact of First Nations hunting on moose populations is unknown.

4.4.2 Deer Management

White-tailed deer and mule deer are present within the Graham caribou range (Culling and Culling 2016). Mule deer are likely more abundant (Kline 2013), although the northern distribution and abundance of white-tailed are likely increasing (Latham et al. 2011*b*, Dawe and Boutin 2016) . There are general hunting seasons for both mule deer and white-tailed deer within WMUs overlapping the Graham range. Within WMUs 7-35, 7-36, 7-43, 7-57 and 7-58, there are general 12-week hunting season for mule deer bucks 4-points or larger. In WMU 7-37, there is an initial 3-week season for mule deer bucks 4-points or larger followed by a 4-week season for bucks of any size. Across WMUs overlapping the Graham range, there are 12-week seasons for white-tailed deer bucks and within 7-35 there is a 3.5-week anterless season. The bag limit for each species is one.

To date, there have been no management actions targeted toward deer in the context of caribou conservation in the Graham range.

4.4.3 Other

Elk (*Cervus elaphus*), mountain goat (*Oreamnos americanus*) and Stone's sheep (*Ovis dalli stonei*) are also present within the Graham caribou range (Culling and Culling 2016). For elk, there are general hunting seasons for bulls with six points or larger in WMUs 7-36, 7-37, and 7-57 while WMUs 7-35, 7-43, and 7-58 have general seasons for bulls with three points or larger and, in some portions of these WMUs, 6-week antlerless seasons. For Stone's sheep, there are general hunting seasons for full curl rams in WMUs 7-36, 7-37, 7-43 and 7-57 (7-35 and 7-58 are closed). In these same WMUs, there are also general hunting seasons for mountain goat. The bag limit for each species is one. None of these species have been subject to management actions in the context of caribou conservation.

4.5 Population Reinforcement

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

4.5.1 Maternal Penning

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

Maternal penning has not t been used within the Graham caribou range.

4.5.2 Captive Breeding

Captive breeding is defined by Hayek et al. (2016) as "keeping and selectively breeding caribou in captivity, usually at an ex-situ facility, over a relatively long period of time with the purpose of releasing individuals back into the wild". To date, captive breeding of caribou has not been implemented as a management tool for conserving wild caribou populations.

There have been no captive breeding efforts undertaken for the Graham subpopulation.

4.5.3 Translocation

Translocation refers to the movement of individuals from one population (or subpopulation) to another (Hayek et al. 2016). Numerous translocation efforts for caribou have taken place across South America and are reviewed in Bergerud and Mercer (1989) and Hayek et al. (2016).

There have been no translocations of other caribou into the Graham subpopulation.

4.5.4 Other

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

4.6 Stewardship/Outreach

[NO IDEA WHAT TO PUT HERE....]

4.7 Research

Most subpopulations of mountain-dwelling caribou in the northern part of British Columbia are relatively little studied, perhaps because they are a lower management priority due to being less threatened than subpopulations found further south (Environment Canada 2012). Within British Columbia, one of the first research efforts aimed at evaluating caribou ecology and behaviour in the province's northern region began in the late 1970s with Bergerud's (1978) surveys of various subpopulations to estimate size, juvenile recruitment and population trend. Since then, numerous studies have been conducted within the region's caribou ranges, with research focusing on predator-prey dynamics (Bergerud and Elliot 1986, Bergerud and Elliott 1998, Gustine et al. 2006*b*), estimating

vital rates (Parker and Gustine 2007, McNay et al. 2014), spatial behaviours (Bergerud et al. 1984, Bergerud and Page 1987), habitat selection (Wood 1996, Gustine and Parker 2008, Polfus et al. 2014), responses to disturbance impacts (Polfus et al. 2011), pregnancy rates (McNay et al. 2014), diet (Denryter et al. 2017) and nutritional condition (Parker and Gustine 2007). These studies have collectively informed broad strategies aimed at managing and recovering caribou populations (e.g. (McNay et al. 2008, Environment Canada 2012, 2014), though further herd-specific research will likely be necessary to develop effective strategies for individual subpopulations (Environment Canada 2012, 2014).

For the Graham subpopulation, Bergerud (1978) provided some of the first insights into herd abundance, distribution and seasonal movements. The first focused study of caribou ecology in the Graham range began in 1988 (Hiebert 1989, Backmeyer 1990, 2000). Primary objectives of this planned four-year study were to identify seasonal ranges and movement patterns of Graham caribou and to provide basic information on their life history and productivity. During the course of the study, 11 VHF radio-collars were deployed on nine females and one male. Due to a discontinuity of funding, caribou were monitored from 1988-1989 and 1991-1994 (Backmeyer 2000). Upon completion, the study provided the first estimates of population size, herd composition and habitat use by caribou within the Graham range.

The next period of research focusing on the Graham subpopulation occurred in the early-2000s when a three-year GPS radio-collaring project was initiated (Culling et al. 2005). Similar to the Backmeyer (2000) study, this project sought to describe seasonal movements and habitat use and to identify migration corridors. Between 2001 and 2003, 22 caribou (14 females, 8 males) were monitored with GPS radio-collars. This study yielded inferences on pregnancy rate (91%), migration timing, calving behaviour and timing, seasonal space use, and habitat selection. Importantly for management, this study identified core areas highly used by caribou seasonally and, for a proportion of the population, year-round. The study also highlighted the importance of alpine tundra and subalpine parklands to Graham caribou.

Radio-collaring of Graham caribou continued through the late-2000s. Williamson-Ehlers (2012) used data from 36 Graham caribou to assess seasonal patterns of habitat selection and to generate predictive maps of space use. This research again showed selection of alpine tundra and subalpine parklands by Graham caribou during both summer and winter. Radio-collared animals were also used in a mark-resight framework to derive estimates of population size (Culling and Culling 2009).

More recently, the Graham subpopulation has been used as a 'control' herd in an adaptive management experiment initiated in 2015 to evaluate the effects of wolf control on caribou population dynamics (Seip and Jones 2016). VHF radio-collars (n = 30) deployed in 2015 (Culling and Culling 2015) are being used to estimate adult female survival and late-winter aerial surveys are being conducted to estimate juvenile recruitment. These two parameters, which are also used to calculate population trend (Hatter and Bergerud 1991, Hervieux et al. 2013), are being compared to those estimated in the Klinse-Za, Kennedy Siding and Quintette ranges where wolf control is being conducted (see also *4.3.1 Wolf Management*). Preliminary findings suggest caribou subpopulations are responding positively (i.e. increasing) within the wolf control area (Seip and Jones 2017).

4.8 MONITORING

Compared to other caribou subpopulations in northeastern BC, the Graham subpopulation has been monitored on a relatively consistent basis. In the late 1980s, the first radio-collars were deployed on caribou (n = 11) in the Graham range and aerial surveys were conducted in 1988 and 1989 to estimate population size and herd

composition (Hiebert 1989, Backmeyer 1990, 2000). Monitoring of these radio-collared individuals continued until 1994 (Backmeyer 2000).

Monitoring of Graham caribou resumed in 2001 when 22 individuals were captured and fitted with GPS radio-collars (Culling et al. 2005). These individuals were monitored for three years during which time two aerial surveys were conducted to estimate population size. Subsequent aerial surveys to estimate population size were conducted in 2009, 2015 and 2016 (Culling and Culling 2009, 2015, 2016). Radio-collars have continued to be deployed on Graham caribou to assist in monitoring, with collars being deployed in 2008 (cited in Culling and Culling 2015) and 2015 (n = 30; Culling and Culling 2015).

Since 2015, the Graham subpopulation has been monitored annually to estimate adult female survival, juvenile recruitment, and population trend as part of an ongoing adaptive management study evaluating caribou population response to wolf control (Seip and Jones 2015*c*, 2016, 2017). Adult female survival has been monitored and estimated using data from the 30 VHF collars deployed on females during the winter of 2015 (Culling and Culling 2015). As of March 2017, 21 radio-collared females remain alive (Seip and Jones 2017).

5 IMPLICATIONS TO OTHER WILDLIFE

Management actions focused on conserving caribou will necessarily have impacts on other wildlife species. Caribou require landscapes where densities of other ungulates and predators are low; thus, management actions undertaken for caribou may result in population sizes of moose, deer, and wolf that are much lower than those currently experienced (Serrouya et al. 2015, 2017*c*). Reducing the populations of these species may occur from either direct management actions (e.g. lethal control) or through environmental changes (e.g. habitat restoration for caribou) that lowers the extent of suitable habitat.

Conserving caribou will likely benefit a myriad of other species co-occurring within old-growth forests. In this context, caribou may be considered an "umbrella" species (Bichet et al. 2016). Such species generally have large spatial requirements and are sensitive to environmental changes, both attributes associated with caribou. Meeting the habitat requirements of caribou will therefore result in the habitat needs of many other species also being met.

6 IMPLICATIONS TO OTHER VALUES

Enacting measures to conserve caribou will likely have impacts on social, political and economic values. Most woodland caribou populations occur in working landscapes managed for natural resource extraction. Conserving caribou in these landscapes will require limits on these activities, which will invoke socioeconomic costs (Schneider et al. 2011). Limiting recreational activities such as snowmobiling and skiing within caribou range will likely create further socioeconomic costs. To effectively mitigate these impacts while conserving caribou in multi-use landscapes, conservation planning will need to incorporate both economic costs and the biological needs of caribou in a spatially-explicit modelling framework (Schneider et al. 2011, 2012).

In many caribou ranges, reducing the current densities of other ungulate species will be fundamental to conserving caribou (Serrouya et al. 2015). Lowered populations of big-game species such as moose and white-tailed deer will result in reduced hunting opportunities. While incorporating hunters in the initial lowering of these populations can be advantageous and seen as a "win-win" (Serrouya et al. 2015), the long-term suppression of these populations will likely require support from the regional hunting community.

Caribou have evolved a life history strategy that is dependent on large landscapes of intact wilderness (Bergerud 2000). For many, such landscapes have inherent and intangible value. Intact wilderness also has economic benefits, including climate regulation, sedimentation control and nutrient cycling (Balmford et al. 2002).

Caribou conservation can also elicit ethical issues. For many small and rapidly declining populations, management actions may include direct control of predators and other ungulates (Hervieux et al. 2014). Such actions can elicit considerable controversy and, consequently, require substantial scientific support and justification for their implementation (Boertje et al. 2010).

7 PARTNERS / NEIGHBOURS

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Partners are bodies, currently existing or with strong future potential, that can assist in some aspect of management, such as expertise, financial contribution, in-kind support or moral support.

Neighbours are bodies within in the caribou subpopulation area that are currently not participating in caribou management that could be affected by caribou management, such as local governments, industry tenure holders, and recreation groups. These neighbours could potentially become future partners.

8 RECOMMENDED ACTIONS

In the past five years, two management plans governing the Graham subpopulation have been released. In 2013, the provincial government released the *Implementation Plan for the Ongoing Management of South Peace Northern Caribou (Rangifer tarandus caribou pop. 15) in British Columbia*. This document outlined actions to manage caribou subpopulations in the South Peace region, which includes the Graham subpopulation. To guide management efforts, the *Implementation Plan* had one overarching goal: to increase the population of South Peace caribou to ≥ 1200 animals within 21 years across their range. To achieve this goal, four objectives were set out:

1. Protect 90% of identified high elevation winter habitat across the range of South Peace caribou:
    a. Protect ≥ 90% of identified high elevation winter habitat in the Graham, Moberly, Burnt Pine, Scott, Kennedy Siding, and Narraway herd ranges; and
    b. Protect ≥ 80% of identified high elevation winter habitat in the Quintette herd range.
2. Conduct South Peace caribou population management to address non-habitat related threats (e.g., predation) to certain South Peace caribou herds.
3. In all ranges, manage the industrial footprint in identified high and low elevation habitats by requiring standardized industry management practices across all industry sectors to reduce or prohibit surface disturbance and habitat alteration, and support long-term sustainable caribou habitat conditions.
4. In all ranges, monitor the compliance and effectiveness of management actions and modify actions accordingly to ensure the population and distribution goal is being achieved.

To meet these objectives, a number of actions have been implemented within in the South Peace region. For the Graham subpopulation specifically, seasonal ranges and habitat cores have been mapped (Seip and Jones 2013, 2015*a*, *b*, Price 2018) and low risk areas for industrial development have been identified (Seip and Jones 2014). For the latter, these areas cumulatively equate to < 10% of high-elevation winter range and are clustered to decrease potential negative effects if developments were dispersed (McNay et al. 2008). To further meet habitat objectives, caribou mitigation and monitoring plans are required for developments within high-elevation winter range (BC Ministry of Forests, Lands, Natural Resource Operation, and Rural Development 2017) and standardized industrial management practices have been developed (BC Ministry of Forests, Lands and Natural Resource Operations 2016).

In 2014, the federal *Recovery Strategy* for SM caribou was released to outline objectives and strategies for recovering and managing subpopulations of SM caribou across their distribution (Environment Canada 2014). The primary goal of the *Recovery Strategy* is to "achieve self-sustaining populations in all LPUs within their current distribution". Many of the objectives set out in the *Recovery Strategy* mirrored those contained in the province's *Implementation Plan* and each document emphasized the importance of habitat protection and restoration. Objectives in the federal *Recovery Strategy* included:

i. Evaluating and monitoring population size and trend
ii. Protecting and restoring suitable caribou habitat. Such habitat includes high- and low-elevation seasonal ranges and matrix habitat, which collectively allow caribou sufficient space and resources to carry out life processes.
iii. Evaluating disturbance impacts in a cumulative affects framework
iv. Understanding and managing predator-prey dynamics
v. Assessing risks from climate change to caribou
vi. Assessing health risks (e.g. parasites and disease) to caribou
vii. Where appropriate, managing harvest for sustainable use with priority access given to First Nations
viii. Fostering multi-stakeholder stewardship and developing knowledge sharing programs

Objectives outlined in both the federal and provincial are necessarily broad-based and recovery actions needed for a specific subpopulation will vary depending on local conditions. Below, recommended management actions are outlined for the Graham subpopulation. Following the framework of the federal *Recovery Strategy*, actions are grouped under six headings – Mortality and Population Management, Landscape Level Planning, Habitat Management, Managing Recreational Activities, Population Monitoring, and Communication and Involvement.

Recommended Actions for the Graham Subpopulation

1. *Mortality and Population Management*

    - *Manage predators and alternate prey*

      Caribou population dynamics are sensitive to the abundance and distribution of predators and alternate prey. For example, caribou populations are less likely to persist when wolf densities exceed 6.5 wolves / 1000 km^2 (Bergerud and Elliot 1986) and such densities are generally supported by high densities of moose (e.g. > 0.3 moose / km^2; Bergerud 1996). Recent and ongoing monitoring of the Graham subpopulation suggests that caribou abundance is declining due to high rates of predation by wolves, yet estimates of wolf and moose densities within the range are lacking. Although high predation rates are ultimately linked to landscape alteration, periodic monitoring and management of predators and/or alternate prey may be necessary to maintain caribou numbers until the effects of habitat restoration are realized.

2. *Landscape Level Planning*

    - *Maintain a spatial inventory of natural and anthropogenic disturbances within caribou range*

      Substantial evidence demonstrates a negative relationship between caribou population growth rates and the amount of disturbance within caribou range (Environment Canada 2008, 2014). Analyses from these populations suggest that the spatial extent of buffered (500-m) disturbances should not exceed 35% of caribou range.

    - *Manage current and future anthropogenic disturbances in a cumulative effects framework*

      Because caribou ranges like the Graham reside in multi-use landscapes, coordination among governments, industry and First Nations will be required to ensure that the cumulative disturbance footprint does not exceed levels associated with caribou population declines. McNay et al. (2008) further suggested that anthropogenic disturbances such as logging be clustered rather than dispersed throughout the range. The recent identification of low risk areas for industrial development should provide a sound framework for guiding future developments. All potential developments within high-elevation winter range should be restricted to these low risk areas (Price 2018).

    - *Maintain functional connectivity between important season ranges*

      Identify frequently used migration corridors and avoid disturbances within or adjacent to these routes (McNay et al. 2008).

3. *Habitat Management*

    - *Identify then ensure protection of core habitat areas*

      Habitat protections such as UWRs and Wildlife Habitat Areas should be re-visited to ensure protection of > 90% of high-quality winter and summer ranges and calving areas (Price 2018).

    - *Monitor caribou to detect changes in seasonal distribution*

      Caribou may adjust seasonal ranges in response to changes in forage availability, predation risk, and disturbance. Consequently, habitat protection measures may need to be re-visited periodically and adjusted when appropriate.

    - *Habitat restoration*

      Within the eastern portion of the Graham range, industrial activities have altered a large areas of low-elevation winter range, likely increasing predation risk for caribou using these areas. Restoration measures should be enacted to reduce predation risk in these low-elevation forests to improve habitat quality for caribou.

4. *Managing Recreational Activities*

    - Recreational activities have the potential to displace caribou from core habitats and trails associated with these activities may increase predation risk for caribou. Area closures to recreational activities should be considered within core caribou habitats.

5. *Population Monitoring*

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

Effectively managing wildlife populations requires estimates of population size and trend. Population size should be estimated at regular intervals (e.g. every 3-5 years) using a consistent survey design (see Wittmer et al. 2005*a*, Serrouya et al. 2014, 2017*a* for examples and discussion). In the absence of consistent estimates of population size, trend can be monitored indirectly using Hatter and Bergerud's (1991) "R/M" equation, which estimates the population growth rate (λ) by relating annual adult female survival (S) to juvenile recruitment (R) ($\lambda = S / (1 - R)$; DeCesare et al. 2012, Serrouya et al. 2017*a*). This indirect approach requires a sample of radio-collared females to estimate S and late-winter composition surveys to estimate R. An advantage to the indirect approach is that by maintaining a sample of radio-collared animals, information on mortality causes can also be collected, which can provide insights into mechanisms influencing population declines. If an indirect approach is used, periodic surveys should still be done to validate trend estimates (Serrouya et al. 2017*a*).

6. *Communication and Involvement*

   - *Facilitate shared stewardship with all relevant stakeholders, including guide outfitters and First Nations*

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

8.1 Short Term (Within 6-12 Months)

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8.2 Medium Term (Within 12-24 Months)

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8.3 Long Term (Within 24-48 Months)

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