Appendix 1. Description and rationale for BRAT framework Threats, Barriers, and risk quantification

1.0 Threat 1: General Predation (Wolf, Bear, Human)

Predation by wolf and bear is widely considered to be the key proximate (top-down) factor controlling population dynamics of caribou by directly causing mortality (Seip 1991, Bergerud 1996, Wittmer *et al.* 2005a, Wittmer *et al.* 2005b). Moreover, predation is ranked as a threat of 'high concern' in Canada's Woodland Caribou (boreal population) recovery strategy (Environment Canada 2012). We therefore included general predation as a primary threat potentially leading to our top event.

Environment Canada (2008) lists the adult female survival of the Chinchaga herd of Northeastern British Columbia as 87%; alternatively the mortality of adult females would be 13%. We assume that 90% of this mortality is due to general predation (11.7% or 0.117; main text Figure 6; main text Table 3) because it is deemed the dominant driver (Bergerud 1988, Mcloughlin *et al.* 2003, Hervieux *et al.* 2014).

1.1 Barrier: Predator avoidance efforts by females post-calving (habitat selection)

Efforts by adult female caribou to avoid predators can functionally reduce predation levels at a coarse spatial and temporal scale by selecting habitats with lower predator densities (Rettie and Messier 2000), spatial overlap, and predator access (Serrouya et al. 2019b). Additionally, predator avoidance will only partially mitigate predation events as some predation is compensatory (i.e., prey that would have died from alternate causes). We populated this barrier using data derived from broad-scale landscape experiments (as called for in Serrouya *et al.* 2019a); effects due to compensatory mortality were not considered. We utilized a published wolf-cull manipulation to identify known responses of wolf predation on both adult female survival, and juvenile recruitment. Hervieux et al. (2014) demonstrated population change can vary from 4.6% to 14% under a 50% wolf cull rate, and that the majority of the effect was on juveniles; we averaged this rate (9.3%) and extrapolated it to a 100% wolf cull rate to obtain the partial λ effect of a complete wolf cull (18.6 % of λ, translating to the wolf cull mitigation factor; 0.814 λ). We assume that 1) the effectiveness of wolf culls as reported in Hervieux et al. (2014) is a linear relationship that can be scaled to 100% and 2) wolf populations will be replenished within caribou herds through reproduction and landscape-scale source-sink dynamics. We consider this "wolf cull effect" to be an indicator of additive (i.e., non-compensatory) predation; even if the direct estimates of predation rates are higher than this, we know that many of those mortality events would have occurred anyway. We then back-calculated from this wolf cull effect to populate the barrier. We partitioned the wolf cull so that 10% of the effect was on adult females; the majority of Woodland caribou predation by wolves occurs on juveniles rather than adults (Wittmer et al. 2005b, Wittmer et al. 2007, Hervieux 2014). This resulted in a partial λ effect of 0.019 for direct predator avoidance efforts by adult females (1 – 0.814/10). Any remaining effects of predation are therefore "compensatory" because the wolf cull did not remove more than this. To determine the overall mortality due to predation (both additive and compensatory), we assumed a consistent ratio of additive to compensatory predation on both juveniles and adults to determine that 0.021 λ was due to compensatory predation on adult females. We utilized these values to solve for the barrier LOPA factor for total predation on adult females, 1.716 (main text Figure 6; main text Table 3). We calculated the effectiveness of wolf predation by dividing the calculated value for predator avoidance effort (0.019 λ) by the value for total predator avoidance efforts (additive + compensatory; 0.039 λ; main text Table 3).

1.2 Barrier: Restoration of seismic traces to reduce access

Deliberate linear disturbances (roads, pipelines, seismic lines, hydroelectric lines) allow wolves to move two to three times faster in caribou habitat (Dickie *et al.* 2017). At the same time, caribou avoid linear features at a minimum distance of 250m (Dyer *et al.* 2001). Canada's Woodland Caribou (boreal population) recovery strategy considers the need for habitat management to be urgent; concerted efforts to restore linear features are listed as one of the interventions needed to meet caribou requirements (Environment Canada 2012). The restoration of linear features at landscape levels is currently being explored in British Columbia (Golder Associates 2017) and Alberta (Tattersall *et al.* 2019, Keim *et al*. 2019); with linear features being in various conditions, the restoration efforts focus on the proportion of linear features requiring restoration. However, none of the described efforts currently occur within our specific study areas. Moreover, the extensive amount of linear features in our study areas (Figures 2-4) create a highly disturbed landscape and an incipient increase over the natural threat incidence. Caribou-wolf encounters increase near linear features (Whittington *et al.* 2011, McKenzie *et al*. 2012), and wolf-use of these linear features may increase predation risk for caribou also near these features (Latham *et al.* 2011). We assumed that doubled rates of wolf access over linear features (McKenzie *et al*. 2012, minimum per Dickie *et al*. 2017) may increase predation over natural levels by up to 40%; we therefore assigned a LOPA factor of 1.4 for this barrier (main text Figure 5; main text Table 3). However, it is possible that caribou learn to avoid areas of high linear feature density in efforts to avoid predation; this scenario would reduce the LOPA factor.

1.2.1 Escalator: Ongoing creation of linear disturbances

Because ongoing creation of linear disturbances could jeopardize any gains made through restoration, we have included this as a potential risk escalator for this barrier. However, the occurrence of one partial Resource Review Area (Cichowski *et al*. 2012) and several parks in our study areas suggests that this escalator is possible to regulate.

1.3 Barrier: Wolf trapping and hunting

We consider hunting of predators by the general public to be an indirect type of intervention appropriate for threat prevention (but see Section 5.1.1). The resulting limits to predation are both functional and numeric. Decreased hunting and trapping pressure for wolves has resulted in higher populations than those observed through most of the 20th Century, when fur prices were higher and wolf control was widespread and aggressive (BCMFLNRO 2014). The Management Plan for the Grey Wolf (*Canis lupus*) in British Columbia indicates that hunting removed ca. 350 wolves in the Peace Region during 2010, where the wolf population was estimated (in 2014) to range from 1,300 to 3,000 (BCMFLNRO 2014). A conservative (minimum) estimate of the wolf population would therefore provide an estimated removal rate of 27% (350 wolves/1,300 wolves). Assuming that ca. 80% wolf eradication is needed for successful suppression of the predation threat (BCMFLFNRO 2014, Hervieux *et al.* 2014), a 34% effectiveness is implied for this barrier (0.27/0.80). LOPA is measured in units of *failure*, the inverse of effectiveness. The

LOPA value for this barrier is therefore 0.66 (1-0.34), which we rounded to a LOPA failure probability of 0.65 (main text Figure 6; main text Table 3). Appendix 2 (A1) uses this barrier as an example of calculating the LOPA barrier values from data, and translating them to partial λ effects. This rationale is consistent for all barriers.

1.3.1 Escalator: Social acceptance

From a sociological perspective, wolf hunting can be controversial (BCMFLNRO 2014). This is particularly the case in northeastern B.C., where communities are in conflict over conservation of wolves vs. caribou (Tanner, 2010). We therefore include lack of social acceptance as a potential escalation factor for this barrier, wherein perceptions of successful caribou conservation might be countered.

1.4 Barrier: Management of early seral stage forests for cover to reduce access

Habitat disturbances can exacerbate predation levels when forest clearings facilitate predator mobility and access to prey (Wittmer *et al*. 2007, Serrouya *et al.* 2015, 2019a; 2019b). Fire, for example, is a major natural disturbance promoting early seral stages. In nearby Alberta, the landscape affected by wildfire in the past fifty years, combined with the anthropogenic footprint, reportedly accounts for 96% of variability in λ in caribou populations in one model (Sorensen *et al.* 2008). Early seral stages are also caused by forestry practices and can favor moose and deer populations that help to support predator populations (Fisher and Wilkinson 2005), reducing caribou survival (Wittmer *et al*. 2005b, 2007, Serrouya *et al.* 2015, 2019a). Canada's Woodland caribou (boreal population) recovery strategy considers the need for habitat management, including, for example, habitat protection, forest fire management, and recovery of key areas altered by human activities (e.g. forestry), to be a strategic direction for recovery (Environment Canada 2012). Examining data relating to disturbance in our study areas (Figures 2-4), minor to trace amounts of deforestation, fire disturbance, and timber harvest continue to add to the major amount of disturbed habitat outlined in Section 1.2. Considering the massive scope of this disturbance, and its ongoing accumulation, we estimated the overall LOPA factor to be 1.5 for this barrier (i.e. risks here are reinforced; main text Figure 6; main text Table 3). Appendix 2 (A1) uses this barrier as an example of calculating the LOPA barrier values from inference, and translating them to partial λ effects. This rationale is consistent for all barriers.

1.4.1 Escalator/De-escalator: Ongoing disturbances forming early seral stages

Because ongoing disturbance rates (Section 6.0) could continue to exceed rates of habitat recovery, we have included this as a potential escalator of risk for this barrier. However, limiting the formation of early seral stages is a priority listed in the B.C. Boreal Caribou Recovery Implementation Plan (BCME/BCMFLNRO 2017); de-escalation of risk for this barrier would occur through such a strategy.

1.4.2 Escalator: Climate Change

Climate change is considered a threat of moderate concern in Canada's Woodland caribou (boreal population) recovery strategy (Environment Canada 2012). In the context of our framework, we show it as a second potential risk escalator for this barrier to predation. As climate change proceeds, increased fire frequency is expected to reduce the proportion of old growth forest (Price *et al.* 2013), and therefore availability of forest cover. Climate change is also expected to exacerbate drought conditions, causing an increase in fire incidence and area burned in western portions of Canada's boreal forest by the 2070s (Boulanger *et al.* 2014).

1.5 Barrier: Caribou hunting moratorium

Management of predation by humans (hunting) is considered a moderate priority in Canada's Woodland Caribou (boreal population) recovery strategy (Environment Canada 2012). In this context, B.C. First Nations have enacted a voluntary moratorium on hunting caribou (Environment and Climate Change Canada 2017). We have indicated this as a barrier to predation in our framework but set the LOPA value to 1.0 (indicating uncertain risk; main text Figure 6; main text Table 3), because the precise rates of human hunting versus other predation are unknown prior to the current era and were likely complicated by compensatory interactions.

1.5.1 Escalator: Maintenance of caribou for food

We have included the maintenance of caribou for food as a potential risk escalator for this barrier. First Nations have relied on caribou as food source in the past (David Suzuki Foundation 2013); the current moratorium therefore does not diminish expectations for a resumed hunt.

1.6 Barrier: Hunting of alternate prey (deer, moose) supporting predator populations

Apparent competition can increase predation (Wittmer *et al*. 2005b, 2007). When caribou and moose ranges overlap, wolves that prey on moose also prey on caribou (Serrouya *et al*. 2017; 2019b). This can lead to depensatory (inverse density-dependent; Serrouya 2013) predation potentially resulting in caribou extirpation (Rettie and Messier 2000, Serrouya *et al*. 2017). Canada's Woodland caribou (boreal population) recovery strategy also regards management of alternate prey as a high level concern (Environment Canada 2012). Licensed and unlicensed hunting of one alternate prey species, moose (*Alces alces*), is reported to be a minor (18%) cause of moose mortality; however, in some areas there are concerns that these levels need to be reduced due to increasing wolf predation and a declining moose population (GOABC 2016). Wolf culls have been observed to result in population increases for moose (GOABC 2016), but we did not locate specific data on the amount of wolf predation that would occur on moose without hunting. We conservatively estimated the LOPA factor of failure for this barrier to be 0.9 (less than a complete failure to prevent risk, but greater than the current rate of harvest; main text Figure 6; main text Table 3).

1.6.1 Escalator: Climate change

Models predict that northern moose populations in Ontario may increase with climate change (Rempel 2012); this could also be a consideration for British Columbia, where increased moose harvest has been proposed as a method to decrease caribou mortality (Serrouya *et al.* 2015).

1.6.2 Escalator/De-escalator: Maintaining alternate prey populations for food

Lack of social acceptance for hunting prey such as moose may also potentially escalate risks for this barrier, with perceptions of successful caribou conservation potentially countering that. Maintaining alternate prey as a food source could also escalate risks for this barrier; this factor might also act in the opposite fashion to de-escalate risks if there is social pressure for conservation to maintain caribou.

1.7 Barrier: Density-dependent limits to predation

Density-dependent limits to predation can counter population decline, because an equilibrium between wolf and caribou populations can emerge at lower population densities (Seip 1991, Seip and Chicowski 1996). A LOPA factor of 1.0 is indicated for this natural barrier to numeric predator increases, in lieu of data needed to quantify this risk (main text Figure 6; main text Table 3).

1.7.1 Escalator: Linear features

Because caribou avoid linear features on the landscape (Dyer *et al.* 2001, Johnson *et al*. 2015), fragmented forests could potentially lead to higher densities of caribou in more limited areas; caribou space-use and home range size has been limited by land use change, such as forestry (Schaefer 2003) and other human-caused disturbances (Wilson et al. 2019). However, it is worth noting that restoration activities could alter the spatial overlap of caribou and predator species (Keim *et al*. 2019; Serrouya et al. 2019b; see Section 1.2).

2.0 Threat 2: Predation specific to female juvenile caribou

Predation may occur in different forms on adult versus juvenile caribou (Festa-Bianchet *et al.* 2011), and may be either additive or compensatory. Environment Canada (2008) lists Chinchaga juvenile recruitment value as 13%; in other words, juveniles experience 87% mortality. This value results from the product of five values: the adult female caribou pregnancy rate, a 50:50 sex ratio, calf survival to 1 day, calf survival to 30 days, and calf survival enumerated at an annual survey. We utilized results summarized in personal communications regarding a maternal penning experiment (Scot McNay pers com., Klinse-Za maternal penning report 2019) to quantify pregnancy rates (0.9), sex ratios (0.5 female), and juvenile survival to day 1 (0.8) without the effects of predation. The initial magnitude of risk for this threat is therefore 1 – (adult female survival rate (0.87) * pregnancy rate (0.9) * sex ratio (0.5) * survival to day 1 (0.8)), which equals 0.687. As above, we assumed that 90% of the "wolf cull effect" (i.e. the additive predation (0.186 λ)) occurred on juveniles (0.167 λ) as compared to adults. We assume that the remaining recruitment of female calves between day 30 (0.687 λ) and a population survey (which is the inverse of female calf recruitment (1-0.13/2 = 0.435 λ) is 90% due to predation (0.223 λ), and allocated the remaining 10% to Threats 3 and 4 equally (see 2.5.3 and 2.5.4 as these threats also include a portion of adult female mortality). These calculations resulted in a barrier LOPA factor of 1.32, which equated to the 0.223 units of λ, partitioned into 0.167 λ (efforts to avoid the additive predation due to wolves) and 0.056 λ (efforts to avoid other/compensatory predation; main text Figure 6, main text Table 3 for complete picture).

2.1 Barrier: Predator avoidance efforts

Seasonal movement of caribou to calving areas can functionally reduce predation levels (Rettie and Messier 2000, Chow-Fraser 2019). The recovery strategy priorities mentioned for general predator avoidance efforts (Section 1.1) also apply here.

3.0 Threat 3: Permanent habitat appropriation

Large-scale human appropriation of habitat has had a significant effect on mammal, and specifically ungulate, distributions across North America (Laliberte and Ripple 2004). This is especially true of caribou in British Columbia and Alberta (Shackelford *et al.* 2018); caribou normally avoid developed areas such as well pads, roads, seismic traces and pipelines, forestry cut-blocks, non-linear oil and gas, and mines (Dyer *et al.*, 2001, Johnson *et al*. 2015).

The above assumptions partitioned reported survival and recruitment values across four threats (see Sections 1.0 and 2.0). There were also high levels of uncertainty associated with threat 3 and 4. We therefore partitioned all 'non-predation' effects on λ equally between Threat 3 (here) and Threat 4. For adult females, this was half (50%) of the 'non-predation' adult female effect on λ (10% of 0.87; 0.006 λ), and for juvenile females, this is half (50%) of the proportion of reduction in λ for female juveniles not due to predation (0.025; 0.012 λ). We summed these values to estimate a current top event magnitude of risk of 0.019 λ for the Chinchaga herd. The initial magnitude of risk was calculated as the product of the current top-event magnitude of risk and the barrier LOPA factors: 0.019 λ (main text Figure 7, main text Table 3).

3.1 Barrier: Designation of habitat set-asides

Our study areas include several parks and part of one Resource Review Area where oil and gas tenure requests are not accepted (Government of British Columbia 2018). GIS data (Section 6.0) show that at least 4% of habitat in our study areas fall within protected areas (parks and Resource Review Areas); given our available remote-sensing data, we were not able to detect any current deforestation events in these areas. We have estimated this barrier to have a LOPA factor of 1.000 (main text Figure 7, main text Table 3) as the protection of land areas from human disturbance and human interventions (e.g., no fire suppression) does not equate to effective species-specific conservation in many situations (Watson *et al*. 2014, Di Minin and Toivoonen 2015, Stewart *et al.* 2019). There might be scenarios where this barrier could be viable (e.g. reduced degradation of the overall landscape), therefore we maintain it within the framework.

3.2 Barrier: Habitat recovery and restoration

Canada's Woodland Caribou (boreal population) recovery plan highlights an urgent need to undertake coordinated actions to reclaim caribou habitat, through restoration of the range of human landscape alterations (Environment Canada 2012); this could therefore be another functional barrier to occurrence of the top event. Although restoration activities can be undertaken after the occurrence of the top event, the benefits of restoration only manifest gradually and the impacts are potentially very long-term (Serrouya *et al.* 2019a; Serrouya et al. 2019b). We therefore view restoration as a measure taken to prevent future risks, i.e. a threat barrier. We are not aware of any current restoration efforts occurring in our study areas, therefore the current LOPA factor for this barrier is assigned as 1.0 (100% failure).

3.2.1 Escalator: Climate change

We indicated climate change as a potential risk escalator for this barrier, because zonal shifts in habitat location could act counter to restoration efforts. Climate envelopes for forests are expected to shift by ca. 10 km/year in northern latitudes, resulting in limited growth and maladaptation of local tree genotypes (Winder *et al.* 2011). More specifically, recent modeling efforts have shown that Northeastern British Columbia may experience significant changes in forest habitat during this century (Mahony *et al*. 2018, Rooney *et al.* 2015).

In the event that climate change makes habitat restoration imperative, assisted migration of appropriate tree provenances (Pedlar *et al*. 2012) could ensure recruitment of climate-adapted tree seedlings and ecological succession in reclamation projects. Without estimating its specific contribution to LOPA factors, we nevertheless include it as a barrier that could potentially be employed in restoration efforts to forestall the escalation of risk due to climate change.

3.3 Barrier: Afforestation via forestry practices

Our study areas include approximately 30% area corresponding to trace caribou occurrence. We have therefore included afforestation in zones of trace occurrence as a potential barrier to habitat appropriation, as it could potentially create more optimal habitat to offset appropriations in other areas. The current LOPA factor for this barrier is assigned as 1.0 as risks are uncertain for this barrier.

4.0 Threat 4: Stresses reducing caribou fitness and health

Although Canada's recovery strategy for Woodland Caribou (Environment Canada 2012) assigns low to moderate concern to a variety of stressors, we considered the cumulative effects of some stressors (parasites and disease, severe weather, noise and light disturbance, vehicle collisions) to be a main threat potentially leading to the top event. While individual stressors may currently have a relatively low impact on herd λ values, they may nevertheless have a high potential severity and impact when viewed as a combined or potentially increasing threat. For example, Schwantje *et al*. (2016) report health concerns for caribou; with the cumulative effects of disease, stress, and pathogens (Wittrock *et al.* 2018) creating potentially serious risks for caribou. Among various ungulate diseases, Chronic Wasting Disease (CWD) is a lethal epizootic currently spreading in Montana towards British Columbia (Wright, 2019). There are knowledge gaps concerning the extent to which many stressors actually affect λ; we therefore consider them to have an 'unknown' annual severity.

We summed the remaining proportions of adult female survival and juvenile female recruitment of the Chinchaga reported values (Environment Canada 2008). For adult females, this was half (50%) of the 'non-predation' reduction in λ for adult females (10% of 0.87; 0.006 λ), and for juvenile females, this is 50% of the proportion of reduction in λ for juvenile females that are not due to predation (0.025; 0.012 λ). As in Threat 3, we summed these numbers to provide the current top-event frequency: 0.019 λ. As always, the initial threat magnitude of risk was calculated as the product of the current top-event magnitude of risk and the barrier LOPA factors; in this case 0.016 λ (main text Figure 7; main text Table 3).

4.1 Barrier: Management of forests for habitat providing food

Concomitant with the management of habitat to provide forest cover (q.v. Section 1.4), caribou also require forest habitat providing food. Again, habitat management is an urgent activity recommended by Canada's Woodland caribou (boreal population) recovery strategy (Environment Canada 2012). We anticipated this LOPA factor should be above 1.0, but precise data for compliance with this objective are not available; the LOPA factor for this barrier was therefore set conservatively to 1.05 (i.e. with a slight reinforcement of risk; main text Figure 7; main text Table 3).

4.1.1 Escalator: Climate change

Climate change could escalate future risks for this barrier in several ways. As climate change proceeds, we expect increased fire frequency to reduce the proportion of old growth forest (Price *et al.* 2013), and therefore availability of normal food sources. The potential concomitant increase in burned areas (Section 1.4) would exacerbate the situation by further limiting available browse. Impacts from extreme events (extreme minimum temperatures, drought, heat waves, spring freeze phenomena, etc.) add additional dimensions of risk this escalator. Using global circulation models to predict extreme events at landscape scales remains challenging, and is an important knowledge gap in researching forest adaptation to climate change (Pedlar *et al.*, 2012). A further complication is that extreme weather primarily causes food deficits rather than direct mortality; this can nevertheless reduce fitness at critical points such as calving (Bergerud 1996).

4.1.2 Escalator/De-escalator: Ongoing disturbance

Ongoing disturbance could potentially outstrip current rates of natural recovery. Because this could be a factor to consider in modeling various future scenarios, it is included as a second potential risk escalator for this barrier. However, limiting the formation of early seral stages is a priority listed in the B.C. Boreal Caribou Recovery Implementation Plan (BCME/BCMFLNRO 2017); de-escalation of risk for this barrier would occur through such a strategy.

4.2 Barrier: Daily selection of high-quality habitat limiting stresses

Habitat selection represents a tradeoff between predator avoidance (Appendix 1, Section 1.1) and forage availability. Landscape disturbance limits the availability of caribou to avoid predators (Wilson et al. 2019; Serrouya et al. 2019b), but on a daily temporal time scale caribou may still select for areas of high quality forage. Figures 3-5 (main text) indicate the presence of disturbed areas that would potentially be avoided by caribou; we therefore set the LOPA factor for this barrier to 1.05 (with a slight reinforcement to risk; main text Figure 7; main text Table 3).

4.2.1 Escalator: Climate change

As with the preceding barrier (Section 4.1), climate change could escalate risks for this natural barrier, by limiting the amount of available high-quality habitat and browse that would counter nutritional and physical stressors.

4.3 Barrier: Stable epidemiology of diseases and parasites

Disease and parasites are widespread in caribou populations, and may cause direct mortality or indirectly increase predation levels by reducing fitness (Schwantje *et al.* 2016). While Canada's Woodland Caribou (boreal population) recovery strategy currently regards diseases and parasites to be a low-level threat (Environment Canada 2012), the severity of their impact is listed as a significant knowledge gap that requires further study. We therefore include stable epidemiology of these pests as a barrier to caribou stressors, but assign the LOPA factor as 1.05 (its impact is unknown, but in the instance of outbreaks with a slight reinforcement of risks to λ).

4.3.1 Escalator: Climate change

Because climate change is generally predicted to change disease incidence, vector relationships, etc. in mammals (Hoberg *et al*. 2008), we have included it as a potential risk escalator for this barrier.

4.4 Barrier: Resistance to endemic diseases, parasites, and epizootics

In parallel with stable epidemiology, caribou resistance to endemic levels of disease and parasites, as well as disease outbreaks, constitutes a second natural barrier to pathogenic stressors. As before, this remains a significant knowledge gap, and we assigned a LOPA factor of 1.0 to the barrier.

4.4.1 Escalator: Nutritional stress

Nutritional stress (starvation) is thought to exacerbate mortality caused by diseases (Schwantje *et al.* 2016); while the full extent of this effect is yet to be quantified, it is included as a potential risk escalator for this barrier.

4.5 Barrier: Measures preventing human harassment of caribou

The portion of Canada's Woodland Caribou (boreal population) recovery strategy dealing with population monitoring contemplates a moderate need to minimize human harassment of caribou (Environment Canada 2012). Beyond producing avoidance effects (via vehicular traffic on linear features, etc.), harassment throughout caribou habitat can come in a variety of modes, e.g. aircraft, all-terrain vehicles, snowmobiles, tourism, research, and equipment activity associated with commercial activity (Webster 1997, Reimers and Colman 2009, Environment Canada 2012). Because there are some positive effects of reduced predation with human 'harassment' (Lesmerises *et al.* 2017), we felt that there were insufficient data to support a clear net effect of this factor, so we set the LOPA factor to 1.0 (indicating uncertain risk).

5.0 Post top event Recovery Barriers (Mitigation Factors)

5.1 Post top event mitigation factor: Wolf culls

Wolf populations have been recently controlled via culling with mixed effects on caribou λ (Hervieux *et al*. 2014, Marris 2015) and has been met with public opposition (Hebblewhite 2017). Culls constitute a direct form of intervention for predator management that may be able to maintain λ values over the short term. We quantified the wolf cull mitigation based on the results of Hervieux *et al.* (2014), and the information outlined in Section 1.0 (0.814; Figure 8).

5.1.1 Escalator: Lack of social acceptance

As with wolf trapping and hunting (Section 1.3), lack of social acceptance for this intervention may also potentially escalate risks for the barrier, with perceptions of successful caribou conservation potentially countering that escalation.

5.2 Post top event mitigation factor: Intensive *in situ* conservation (enclosures, exclosures)

Intensive *in situ* conservation or penning is another form of functional predator management that could prevent extirpation of caribou herds by excluding predators (Environment Canada 2012). Maternal penning entails capturing pregnant female caribou in the wild and moving them to small enclosures. Newborn calves are raised through the neonatal stage, when they are most vulnerable to predators, and subsequently released into the wild (Hebblewhite 2017). Although usually confounded with wolf culls, maternal penning has produced mixed-success in Alberta (Smith and Pittaway 2011), and has been more successful in British Columbia (Hebblewhite 2017) and Yukon Territory (Adams *et al.* 2019). These maternal penning experiments can provide insight into adult female reproductive success and the effect of predation on juvenile survival. Although maternal penning does not currently occur in our study areas, an adjacent area serves as a good reference for an effect of maternal penning on λ. Based on the success of the Klinse-Za caribou maternal penning experiment (Scott McNay pers. com; Serrouya *et al.* 2019a), we quantified the *current* LOPA factor of this barrier as 0.95 (less than a 100% chance of failure; Figures 6-8). Note that future efforts to increase maternal penning in our study areas may or may not further decrease this probability.

An even more dramatic approach is the proposed creation of a caribou 'Ark' (Antoniuk *et al*. 2012, Hayek *et al.* 2016). The proposed ark, or exclosure, would entail fencing hundreds of square kilometers in a predator-free area for caribou in the Oil Sands and the Little Smoky range. Short of establishing a captive breeding program, a caribou 'Ark' would constitute a last-resort method for conserving valuable genetic variation in critically threatened populations in a quasi-natural setting (Weckworth *et al*. 2012, Hebblewhite 2017).

5.2.1 Escalator: Lack of public acceptance

Confinement of caribou may nevertheless encounter a lack of public acceptance; we therefore include that as a potential escalator of risk for this barrier, with impacts requiring further study.

5.3 Post top event Mitigation factor: Responsive restoration of linear features to reduce access

Per Section 1.2, restoration of linear features can also be undertaken as a more immediate response to the occurrence of the top event. In addition, restoration of linear features will affect the success of predator avoidance efforts for caribou females post calving (Appendix 1, Section 1.1). For this mitigation factor, we attribute 100% of the partial λ effect from Section 1.2 in this Appendix (0.022 λ), i.e., the direct effects of linear features, plus 50% of the partial λ effect reported in Section 1.1 of this Appendix ($0.039\ \lambda * 0.5 = 0.019\ \lambda$; the indirect effects of restoring linear features on predation-caused mortality) to estimate an upper limit of the partial λ effect of this mitigation strategy (0.042 λ). We therefore estimate the LOPA factor for this barrier to be 0.957 (1 - 0.042)

6.0 Geospatial data

Table A-1. A summary of geospatial data derived from various sources, pertaining to risk analysis of three study areas in Northeastern British Columbia where habitat of Boreal Woodland Caribou occurs.

	Study Area 1		**Study Area 2**		**Study Area 3**		**Total**	
	km^2	**% Study**	**km^2**	**% Study**	**km^2**	**% Study**	**km^2**	**% Studies**
Study Area	8,000	100.00%	8,000	100.00%	8,000	100.00%	24,000	100.00%
Herd Range	5,615	70.18%	5,553	69.42%	5,712	71.40%	16,880	70.33%
	km^2	**% Range**	**km^2**	**% Range**	**km^2**	**% Range**	**km^2**	**% Ranges**
Protected	17	0.31%	275	4.96%	458	8.02%	751	4.45%
Disturbance	5,380	95.82%	3,745	67.43%	4,366	76.42%	13,490	79.92%
	km	**km/km^2**	**km**	**km/km^2**	**km**	**km/km^2**	**km**	**km/km^2**
Linear Disturbance	12,881	2.29	4,219	0.76	11,793	2.06	28,893	1.71
	km^2/yr	**% Range**	**km^2/yr**	**% Range**	**km^2/yr**	**% Range**	**km^2/yr**	**% Ranges**
Deforested	0.35	0.01%	0.53	0.01%	1.01	0.02%	1.89	0.01%
Fire	0.70	0.01%	7.02	0.13%	1.19	0.02%	8.91	0.05%
Harvested	0.12	0.01%	0.05	0.01%	0.00	0.01%	0.17	0.01%

7.0 Literature cited

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