Recommendations for Predator-Prey Management to Benefit the Recovery of Mountain Caribou in British Columbia

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Executive Summary

On 16 October 2007, the BC government announced its endorsement of an implementation plan for mountain caribou recovery. The plan included several commitments, including managing predator and primary prey populations to reduce predation pressure in areas where predators are preventing caribou recovery. The purpose of this report is to recommend a framework for predator-prey management in support of mountain caribou recovery efforts in British Columbia.

The government-appointed Mountain Caribou Science Team was very clear that without immediate action to reverse population declines by reducing predation losses, some mountain caribou herds could be extirpated before the benefits of other management actions are realized. Therefore, it is imperative that the intensity of predator-prey management actions be scaled to the relative risk facing different mountain caribou herds.

Wolf predation is considered the major factor limiting the growth of caribou populations in North America and there is ample evidence that reductions in wolf populations can result in immediate and dramatic increases in caribou populations. The role of other predators in limiting caribou is less clear; however, high cougar abundance was correlated with a large decline in mountain caribou abundance in the South Purcells in the late 1990's.

The following are recommended principles to guide predator management:

1. wolves and cougars will be the focus of predator management to benefit mountain caribou;
2. actions to benefit mountain caribou will be balanced against conservation objectives related to wolves and cougars; and,
3. wolf and cougar management will vary with the risk to mountain caribou herds.

Grizzly and black bears are also important predators throughout mountain caribou range; however, reducing the risk of predation posed by bears would require either large-scale reductions, or the identification of individual problem bears, both of which are difficult. As a result, bears will continue to pose a mortality risk to mountain caribou, which will reduce the effectiveness of other predator management actions.

Based on available literature and data, predator densities in mountain caribou range and in the surrounding "matrix" habitat should average <6.5 wolves/1000 km^2 and <10 cougar/1000 km^2 and in most areas should be much lower, depending on the size and trend of mountain caribou herds. Other studies have indicated that only very aggressive reductions of 80% or more of the wolf population will result in immediate, positive responses by mountain caribou populations. Even this level of reduction might not result in responses similar to those observed elsewhere because of the role of bear predation. Removal of all resident packs and/or individuals is a legitimate goal where even rare predation events would further jeopardize the viability of a caribou herd. Sterilization of alpha male and female wolves might also be effective in reducing the growth rate of resident packs.

Regulated hunting and trapping will not be sufficient to reduce wolves to target densities. Hired trappers can be more effective but many biologists doubt that recovery objectives can be met without resorting to shooting wolves from helicopters, which they consider to be the most effective and humane approach. In contrast, cougars can be well-regulated by conventional hunting techniques.

In the long term, caribou persistence will likely require reducing prey abundance within and adjacent to mountain caribou range, otherwise, predator reductions will need to be ongoing and intense. Based on the outcomes of a workshop in January 2008 ungulate and caribou biologists deemed it possible to reduce moose to reduce wolf carrying capacity. But biologists concluded that the population of white-tailed deer in southern BC is too large and resilient to be effectively reduced; therefore, high hunting pressure on cougars will need to be maintained indefinitely.

Biologists expressed concern about the northward expansion of deer and cougars and the subsequent effect on mountain caribou. As a result, they recommended that deer should be prevented from increasing where populations are currently low.

The following are recommended principles to guide the implementation of primary prey management:

1. moose will be the focus of prey reductions to benefit mountain caribou;
2. moose reductions to benefit mountain caribou will be balanced against moose conservation and use objectives;
3. moose targets will fall within the bounds generally expected under a natural disturbance regime; and,
4. deer populations should be prevented from increasing, where feasible.

There are several methods that can be used to inform moose density targets: a review of wolf and moose densities observed in other jurisdictions; static biomass-based equations; dynamic modelling; and, habitat analyses based on natural disturbance return intervals. Analyses based on available data suggest that target densities of 50-300 moose/1000 km^2 would benefit mountain caribou recovery, depending on the circumstances of individual caribou herds.

Reducing moose to benefit mountain caribou has a strong theoretical basis, but it has not been tested experimentally. Trials are underway in two mountain caribou planning units and future decisions need to be informed by the outcomes of these trials. It may be necessary to initiate reductions in other areas where mountain caribou are most at risk, before results of the trials are known.

The relationships between management action outcomes and mountain caribou herd sizes and trends will be the basis for assessing the effectiveness of the predator-prey strategy. The Ministry of Environment has established specific population goals for mountain caribou and evaluation of the programme should be based on the soonest-available caribou data following implementation of predator-prey management actions.

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Introduction

On 16 October 2007, the BC government announced its endorsement of an implementation plan for mountain caribou recovery. The plan included several commitments:

1. legal protection of 95% of high suitability mountain caribou habitat in areas where recovery was deemed feasible;
2. managing recreation to reduce human-related disturbance in mountain caribou habitat;
3. managing predator and primary prey populations to reduce predation pressure in areas where predators are believed to be preventing caribou recovery;
4. increasing small mountain caribou populations by transplanting caribou from larger herds; and,
5. a monitoring and adaptive management plan.

The purpose of this report is to recommend a framework for predator-prey management in support of mountain caribou recovery efforts in British Columbia. Specific objectives of the report are to:

1. describe the role of predator-prey management in effecting the recovery of mountain caribou herds;
2. develop initial density targets for wolves and cougars, moose and deer in areas managed for mountain caribou recovery;
3. outline possible techniques to manage wolves and cougars, moose and deer; and,
4. describe requirements for monitoring and adaptive management.

Background

Government's recovery goal for mountain caribou is to:

"Halt the decline of mountain caribou within seven years for each Planning Unit and recover mountain caribou to 1995 population levels (2500 animals) across the mountain caribou range within 20 years in those Planning Units with greater than 10 animals."

To achieve this goal, a mix of actions will be required, including habitat protection, recreation management and the management of predators and other ungulates. The actions required to achieve recovery will be different among herds and there is considerable uncertainty related to the intensity and extent of actions required to achieve the recovery goal (Mountain Caribou Science Team 2006). However, the government-appointed Mountain Caribou Science Team was clear that without immediate actions to reduce predation losses, some mountain caribou herds could be extirpated before the benefits of additional habitat protection, prey management, and recreation management are realized.

Although the Science Team identified habitat change as the most important cause of mountain caribou declines, the most significant consequences of habitat change are thought to be indirect. Forest harvesting has removed forest stands that support arboreal lichens, which caribou depend upon for winter food. The resulting early seral stands favour deer, elk and moose, which all thrive in younger-aged forests. The increase in ungulate populations in turn increases the abundance of predators - particularly wolves and cougars, which is hypothesized to result in an increase in caribou mortality. In addition, for many decades in British Columbia hunting management has favoured deer, elk and moose, and throughout the first half of the 20th century there was extensive predator control. Climate change has the potential to affect all these factors through increased frequency and/or severity of forest fires, changes in snow conditions and altered predator-prey dynamics (Dzus 2001).

These interactions among habitat and predator-prey populations make it difficult to predict the outcomes of future management actions to benefit mountain caribou (Figure 1).

Mountain caribou are part of a complex predator-prey system. Wolves are the principal predator of ungulates in the northern part of the range while cougars are the principal predator in the south. Grizzly and black bears are also important predators throughout the entire mountain caribou range (Wittmer et al. 2005). Moose are generally the dominant ungulate in the north while deer and elk dominate in the south; however, there is considerable overlap.

The dynamics of multi-predator-multi-prey systems are poorly understood. It is difficult to accurately predict changes to the system caused by natural events such as severe winters, or from human-related interventions such as changes in harvest levels or predator reductions, because there are likely significant interactions and lags that are difficult to characterize. Hence, a combination of modelling and adaptive management trials will be required to understand how actions are benefitting mountain caribou recovery.

Relative Risk to Mountain Caribou Herds

The intensity, duration and extent of predator-prey management actions should be scaled to the relative short-term risk facing different herds. Risk should be based on herd size and population trend; over one caribou generation or 7 years, to reflect current ecological circumstances (Figure 2).

Rationale for Predator Reductions to Benefit Mountain Caribou

Wolf predation is considered the major factor limiting the growth of woodland caribou populations in North America (Bergerud and Elliot 1998 and references therein). There is also ample evidence that aggressively reducing wolf populations (i.e., 80%, Boertje et al. 1996, Hayes et al. 2003) can result in immediate and dramatic responses in caribou populations (Gasaway et al. 1983, Boertje et al. 1996, Bergerud and Elliot 1998, Hayes and Harestad 2000, Hayes et al. 2003). This is also supported by theoretical work (Lessard et al. 2005).

In multiple-prey systems, wolf reduction can result in strong increases in moose, elk and caribou (Bergerud and Elliot 1998, Hayes et al. 2003). There is also evidence that differences in wolf densities can initiate “trophic cascades” that can alter the structure of prey populations (e.g., Hebblewhite et al. 2005). Following reductions, wolf populations can rebound quickly as immigrants occupy vacant territories (Bergerud and Elliot 1998, Hayes and Harestad 2000).

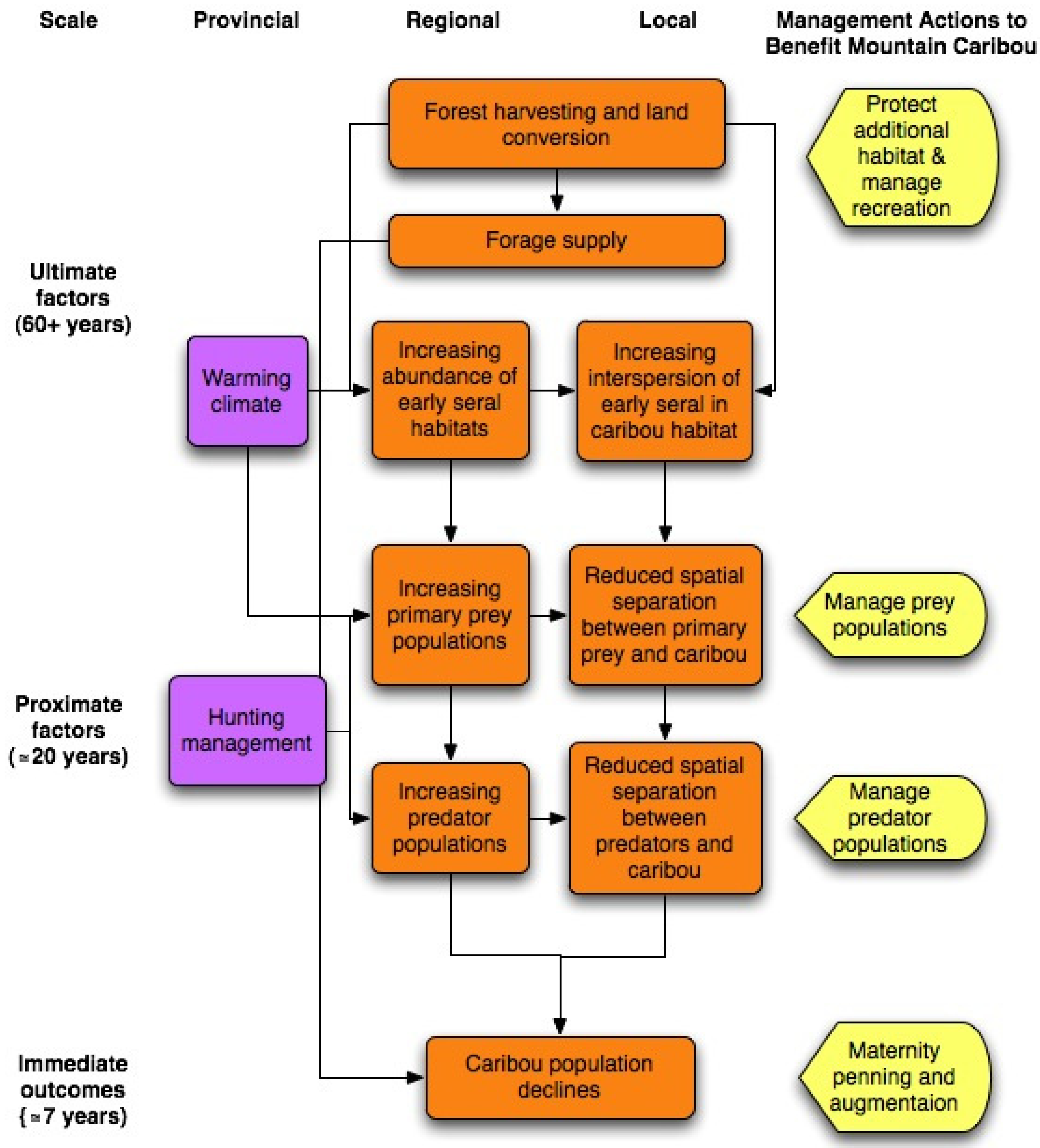

Figure 1. Relationship among variables thought to influence mountain caribou population trends, by spatial and temporal scale, as well as management interventions available to influence the system.

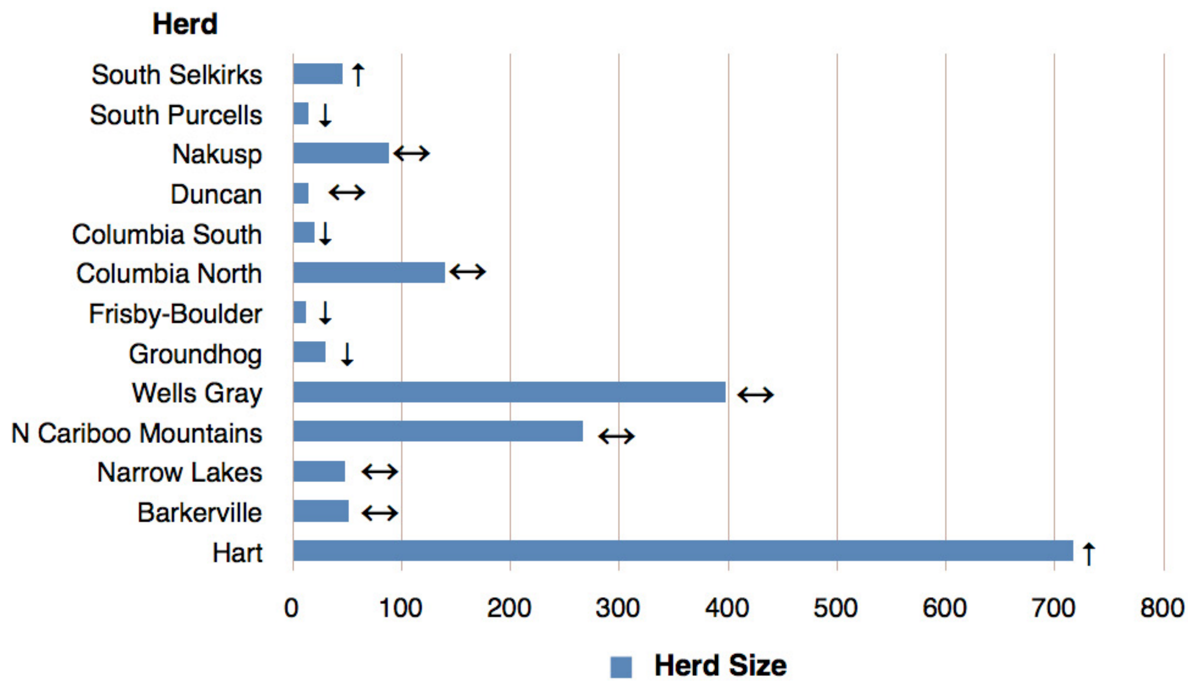

Figure 2. Population size and recent trend (indicated by arrows) of mountain caribou herds in BC.

The role of other predators in limiting mountain caribou populations is less clear. High abundance of cougars in the South Purcells during the late 1990's was correlated with a decline in the local mountain caribou herd from 63 in 1995 to 13 in 2000 (Kinley and Woods 2006). Elk and mule deer also declined during this time. Since 2000, cougar numbers have remained relatively low, caribou have been stable and deer and elk have increased.

Wittmer et al. (2005) identified grizzly and black bears as important predators throughout mountain caribou range. Like deer, elk and moose, bear populations have benefitted from the expansion of early seral habitat because of the forage these areas provide (Brodeur et al. 2008, Hamilton and Austin 2004). Their abundance is likely higher than would be expected under natural disturbance assumptions.

Bear populations can respond numerically to the abundance of ungulate prey (Schwartz and Franzmann 1991). But bears are omnivorous and are not ungulate specialists like wolves and cougars. As a result, reductions of bear populations would need to be very large to be effective, unless individual predatory bears could be identified and removed (Hart and Cariboo Mountains Caribou Recovery Implementation Group 2005). The infeasibility of large-scale reductions, the difficulty of indentifying individual problem bears, and the conservation status of grizzly bears suggests that bears will continue to pose a mortality risk to mountain caribou (particularly calves), and will reduce the positive response of caribou populations to reductions in wolves and cougars.

Predation by wolverines is rare (Wittmer 2004) and therefore no control actions should be considered.

There is some public resistance to reducing wolves and cougars. This resistance arises from three principal concerns:

1. **Direct management disrupts a natural predator-prey balance.** The concept of a natural balance suggests that there is a single optimum that ecological systems tend toward. Predator-prey systems are dynamic and likely to do not have a single optimum, but rather cycle (Peterson et al. 1984, Gasaway et al. 1992) or self-organize into one of many possible states (Scheffer et al. 2001). The predator-prey system in BC has been managed extensively and cannot be considered "natural" in large parts of the Province. Both predator and prey populations have been, and continue to be, influenced by human-caused changes in habitat, hunting policies, and climate trends.
2. **Animal welfare concerns.** Some public are morally opposed to the killing of predators for any reason. Using humane methods to hunt, trap, or otherwise remove predators will not satisfy this moral opposition. However, both wolves and cougars are legal game species in British Columbia.
3. **Hunters are the main beneficiaries of predator management.** There is a history in BC of killing predators to increase game populations. This is unacceptable to some because they consider hunting a recreational activity of a minority of residents and affluent non-residents. However, the focus here is to benefit an endangered species and recovery actions could ultimately reduce some hunter opportunities with respect to moose and deer. Mountain caribou have not been hunted in BC since 1995

Predator Management Principles

The following are recommended principles to guide predator management:

4. wolves and cougars will be the focus of predator management to benefit mountain caribou;
5. actions to benefit mountain caribou will be balanced against conservation objectives related to wolves and cougars; and,
6. wolf and cougar management will vary with the risk to mountain caribou herds.

Rationale for Reducing Ungulates to Benefit Mountain Caribou

In the long term, caribou persistence will require reducing prey abundance within and adjacent to mountain caribou range, otherwise, predator reductions will need to be ongoing and intense. Mountain caribou are sufficiently rare that they cannot serve as primary prey for any predators (Kinley and Woods 2006); instead, wolves rely mostly on more abundant moose, and cougars mostly on deer. Wolf and cougar numbers are largely governed by the abundance of these two prey species. A substantial increase in the abundance of prey will be followed by an increase in wolves or cougars, which then increases the risk to mountain caribou where they co-occur with these predators. Seip (1992) and Wittmer et al. (2005) have suggested that high moose populations sustain high wolf numbers and in turn, increase the predation rate by wolves on sympatric mountain caribou. This phenomenon is referred to as "apparent competition" or "prey subsidy" and has also been hypothesized in white-tailed deer-mule deer-cougar systems (Robinson et al. 2001) and in domestic stock-bighorn sheep-cougar systems (Rominger et al. 2004). This hypothesis has not been tested empirically in mountain caribou but has been explored theoretically by Lessard et al. (2005).

Based on the outcomes of a workshop in January 2008 ungulate and caribou biologists deemed it possible to reduce moose to reduce wolf carrying capacity. But biologists concluded that the population of white-tailed deer in southern BC is too large and resilient to be effectively reduced; therefore, reducing cougar carrying capacity in these areas by reducing deer is infeasible. Biologists expressed concern about the northward expansion of deer and cougars and the subsequent effect on mountain caribou. As a result, they recommended that deer should be prevented from increasing where populations are currently low.

Managing predation on mountain caribou by reducing moose, rather than by reducing predators directly, increases uncertainty because the system is complex. Some simplifying assumptions need to be made in order to develop management targets and the outcomes of actions will need to be monitored closely. In general, the greatest prey reductions will be required where caribou habitat is associated with higher proportions of early seral habitat due to a legacy of forest harvesting or extensive natural disturbances, and where habitat conditions naturally favour a higher abundance of moose and deer (e.g., drier and/or lower elevation portions of caribou range).

Prey Management Principles

The following are recommended principles to guide the implementation of primary prey management:

5. moose will be the focus of prey reductions to benefit mountain caribou;
6. moose reductions to benefit mountain caribou will be balanced against moose conservation and use objectives;
7. moose targets will fall within the bounds generally expected under a natural disturbance regime; and,
8. deer populations should be prevented from increasing, where feasible.

Area-of-Interest for Predator-Prey Actions

Predator-prey management actions designed to benefit mountain caribou should be focussed and limited to defined areas. This area should be used to estimate wolf, cougar and moose densities to compare against targets. The area-of-interest should be defined by the forested portion of no-harvest and modified-harvest zones of mountain caribou habitat (as defined by the respective Government Actions Regulation orders) as well as areas outside of caribou range that provide habitat that influences wolf or cougar density in caribou range. The Hart and Cariboo Mountains Caribou Recovery Implementation Group (2005) referred to the area inhabited by primary prey outside caribou range as “matrix” habitat. The Group mapped this habitat for the northern half of mountain caribou range. Kootenay regional biologists and Science Team members have mapped equivalent habitat in the remainder of the range (Figure 3).

Predator Management Targets

This report proposes targets for wolf and cougar densities in mountain caribou habitat that are scaled to the short-term risk facing mountain caribou herds. There are several caveats that need to be applied to predator targets:

1. the targets reflect long-term averages that should be sufficient to allow mountain caribou to persist, but only aggressive reductions to low densities will likely result in a significant population response by mountain caribou;
2. some targets might not be achievable in some areas due to technical constraints or stakeholder opposition; and,

3. there will be situations where there will be insufficient information to accurately measure predator densities or other responses. In these cases management will have to proceed on the best available information.

Wolf Density Targets

Wolf-caribou systems are relatively well studied. Bergerud (1988) reviewed mortality and recruitment data for both barren ground and woodland caribou populations throughout the world and concluded that mortality equalled recruitment (12%) where wolf density was 6.5 wolves/1000 km^2. At lower wolf densities, recruitment increased rapidly, while at higher densities, mortality rates increased rapidly. Bergerud's (1988) review provides a coarse basis on which to base wolf density targets, although it relied heavily on data collected from barren-ground and boreal systems. I suggest that wolf densities within mountain caribou range and matrix habitat should not average more than 6.5 wolves/1000 km^2 in the long term, and in most cases should be much lower. Where caribou herds are most at high risk, <1.5 wolves/1000 km^2 should be the target and removal of all resident packs within ranges of these herds could be considered. To generate a significant, positive population response by mountain caribou, wolf densities should be managed to the lowest target.

An alternative method can be used to derive wolf density targets based on prey densities and the functional response described by Messier (1995). This is most useful where the predator-prey system is dominated by wolves and moose rather than by deer and cougars. This approach is explored below in relation to the setting of density targets for moose.

Cougar Density Targets

There is no analysis similar to Bergerud's (1988) to inform target densities for cougars. Cougar targets need to be set according to the best ecological criteria and adjusted as more information is gathered.

Individual cougars can become specialist predators (Festa-Bianchet et al. 2006) and can kill a high proportion of a small mountain caribou herd in a short time. In these situations the cougar should be removed as soon as possible. Except in the rare situation where a cougar is radio-collared, there is no way to identify individuals that might be preying on caribou. As a result, density targets are the only feasible method of controlling the risk of predation on mountain caribou.

Wilson (2003) reviewed published cougars densities in western North America. Most estimates were between 10 and 40 cougars/1000 km^2. Cougars are usually studied where they are abundant. In mountain caribou range, cougar densities could be lower than in areas where deer densities are high. I recommend a target of <10 cougars/1000 km^2 as the upper limit on cougar density throughout caribou range plus matrix habitat. Where caribou herds are most at risk, a lower target density of <2.5 cougars/1000 km^2 is appropriate.

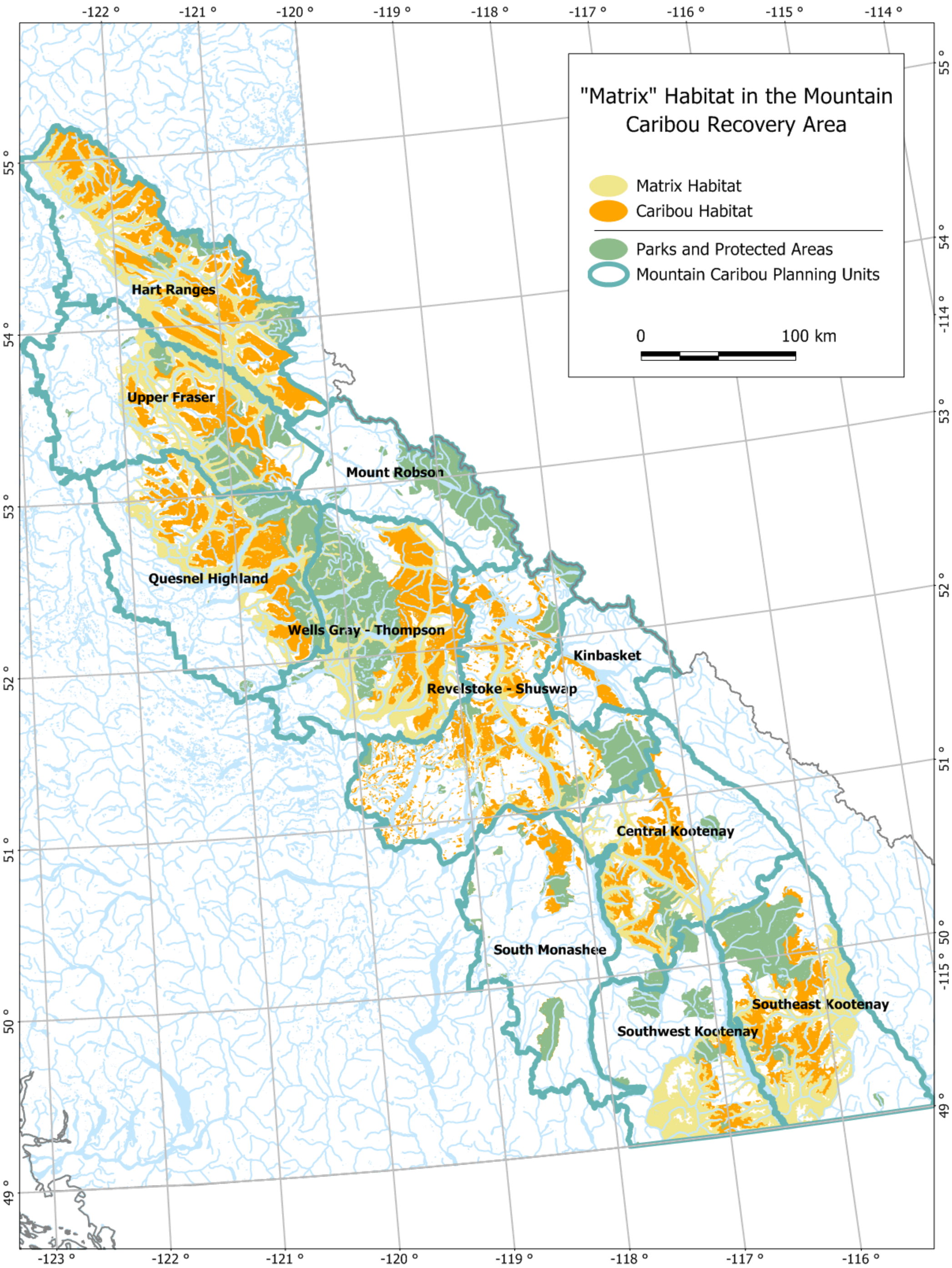

Figure 3. Distribution of "matrix" habitat throughout mountain caribou range, in relation to habitat managed for caribou. Matrix habitat is defined as habitat suitable for the production of non-caribou ungulates in areas where predators dependent on these populations can affect predation rates on mountain caribou. Matrix and caribou habitat together comprise the target area for predator-prey management.

Removing all cougars from areas where mountain caribou herds are very small is a justifiable goal, and any cougar in any herd range that is specializing on mountain caribou should be removed.

The risk of mortality from wolves and cougars is considered additive. Where two predators share caribou range, target densities should be adjusted toward the lower density targets.

Wolf and Cougar Monitoring

Wolf Population Monitoring

Wolf density estimates will be most accurate where all packs within the range of a caribou herd are radio-collared and monitored regularly (Fuller and Snow 1988). Track surveys have identified the general size and location of wolf packs in the Kootenays (Gaynor et al. 2007). When combined with radio-telemetry, track count data can assist in describing territory structure and wolf population size (Hayes and Harestad 2000). The transient population is more difficult to establish, but can inflate estimates based on packs only by up to 20% (Fuller et al. 2003).

Cougar Population Monitoring

Counting cougars is more difficult than counting wolves because cougars are solitary and secretive. Population trends are usually inferred from hunter survey data and animal control mortalities. In some cases, local populations might include some radio-collared individuals. Track surveys can be used to estimate cougar abundance in areas where they are relatively rare (Gaynor et al. 2007). In areas where cougars are more common, other techniques such as snaring hair and analyzing DNA might be practical, as has been done for grizzly bears (Mowat and Strobeck 2000).

Wolf and Cougar Management Actions

Reducing Wolves

Wolves need to be reduced before, or concurrently with, moose. Reducing moose first runs the risk of increasing predation on mountain caribou in the short term because natural declines in a wolf population following a moose reduction will take many years (Mech and Peterson 2003) and in the interim wolves may search more widely for scarce prey.

A review of harvest history and wolf population trends show that reductions of <29% are ineffective in reducing wolf numbers because animals that are removed are quickly replaced, primarily through immigration. Exploitation rates >29% are inversely correlated with population growth rates (Adams et al. 2008). Other studies that have documented strong responses in caribou populations have removed 80% of wolves (Boertje et al. 1996, Hayes et al. 2003). This suggests that management actions aimed at reducing wolf populations need to be intense to be effective. They will need to be more intense than in other studies to achieve the same effect because of the confounding role of bear predation. Removing a few individuals is unlikely to have an effect on wolf density, and would be expected to have no impact on caribou growth rates. Hunting and trapping alone are unlikely to generate sufficient removals to significantly alter caribou population growth rates and, therefore, targeted removal of individual wolves and packs is also required.

The Mountain Caribou Science Team and Ministry of Environment biologists consulted in the drafting of this report strongly recommended that wolves targeted for removal should be shot from helicopters. This is the most humane and cost-effective strategy. The next best method is to hire professional trappers to trap or snare wolves; however, trapping and snaring success has been limited in the past, and without large increases in available resources, reduction targets are unlikely to be met. Even with large increases in trapping efforts, trapping is simply not feasible in some geographic areas due to remoteness or heavy snow loads.

Sterilization of alpha pairs has played an important role in the success of wolf reduction programs elsewhere (e.g., Hayes et al. 2003). The goal of fertility control is to maintain the structure and distribution of wolf packs while reducing the overall density of wolves on the landscape (Hayes et al. 2003, Roorda and Wright 2007). Of course reducing the number of wolves per pack does not eliminate the mortality risk to mountain caribou. In some circumstances, caribou populations are simply too small to tolerate even very low predation rates.

Reducing Cougars

Hunting has been demonstrated to be an effective method to control cougar populations. Regulating harvest using season lengths, bag limits, and quotas, will continue to be the preferred method to meet cougar population targets. Additional permits will be issued to guide-outfitters for specific areas if resident hunting pressure is insufficient to meet cougar reduction targets. Where individual cougars preying on mountain caribou can be identified, they should be targeted for removal.

Moose Targets

There are several methods that can be used to inform moose density targets. The purpose of limiting moose is the limit carrying capacity for wolves and in turn reduce predation pressure on mountain caribou.

Review of Moose and Wolf Densities

Based on a review of wolf, moose and caribou densities, Bergerud (2007) suggested that densities of >100 moose/1000 km^2 are likely to result in densities of >6.5 wolves/1000 km^2, in turn leading to eventual declines in woodland caribou.

Estimation Using Static Biomass-based Equations

Initial targets for moose densities in and near mountain caribou habitat can be investigated using relatively simple, static equations, although equations imply a “closed loop” system where populations are limited only by the factors considered in the equation. For example a moose density that is inferred to limit a wolf population assumes that there is no prey switching to sources not considered in the equation.

Fuller (1989) rearranged Keith’s (1983) equation to yield the moose density required to support a given wolf density and hunting intensity:

$$U = \frac{S}{(\lambda_p - 1)} + \frac{K \cdot W}{1000(\lambda_p - 1)}$$

Based on the following parameters:

- W (wolves/1000 km^2): <6.5, 3 and <1.5
- λ_p (intrinsic rate of increase of moose population): 1.24 (Keith 1983)
- S (hunter kill/km^2): set to 0 because densities are based on winter survey estimates conducted after the hunting season
- K (annual moose kill/wolf): 12, averaging estimates from Keith (1983) and Hayes et al. (2000)

this equation results in target densities for moose of <300 and <50 moose/1000 km^2 for densities of <6.5 and <1.5 wolves/1000 km^2, respectively.

Estimation Using a Natural Disturbance Approach

One of the principles of prey management set forth by this report is that moose density targets will fall generally within ranges expected under a natural disturbance regime applied to their habitat. This principle is to ensure that management to benefit mountain caribou does not push prey, and hence, predator populations lower than would be predicted under "natural" habitat conditions.

To inform the setting of moose density targets, I focussed on the "matrix" habitat, which includes areas that support the moose populations that ultimately influence the number of wolves living in mountain caribou habitat (Figure 3). I examined the distribution of early seral forests located in the lower-elevation portions of the matrix habitat (i.e., below the Engelmann spruce-subalpine fir [ESSF] zone), based on year 2000 forest cover maps. I compared the proportions of early seral forest in each mountain caribou-planning unit against the proportions of early seral forest expected under a natural disturbance regime. These proportions are based on the cumulative forest age distribution described in the Biodiversity Guidebook (BC Ministry of Forests and BC Ministry of Environment 1995).

The analysis estimated the proportion of early seral forest that exceeds that expected in a naturally disturbed forest (Table 1). Assuming that the carrying capacity of a forested landscape for moose is proportional to the abundance of early seral forests, these percentages indicate the contribution of human-related landscape change to the potential abundance of moose.

Table 1. Abundance of early seral forest habitat (<40 years) compared to its expected abundance under a natural disturbance regime.

PU	PU Name	Estimated area of early seral forest (km^2)	Area of early seral expected under a natural disturbance regime (km^2)	Proportion
1A	Southwest Kootenay	922	518	1.78
1B	Southeast Kootenay	957	626	1.53
2B	Central Selkirks	912	437	2.09
3A	Revelstoke-Shuswap	538	211	2.56
4A	Wells Gray- Thompson	937	654	1.43
5B	Quesnel Highland	1348	508	2.65
5A	Upper Fraser	1258	492	2.56
6	Hart Range	1329	779	1.71

This analysis is limited for the following reasons:

- the precision, resolution and year 2000 map of the forest cover used for the analysis (Valdal et al. 2007);
- no attempt was made to distinguish habitat suitability for moose beyond forest age. Riparian stand, "not sufficiently restocked", or other highly suitable habitats not consistently captured by forest age were not considered, and all forested areas <40 years old in non-ESSF and non-alpine habitats were considered equally suitable; and,
- estimates were based entirely on natural disturbance return intervals taken from the Biodiversity Guidebook (BC Ministry of Forests and BC Ministry of Environment 1995).

The analysis shows that suitable moose habitat (assumed here to be forests <40 years old) represents 35% of the caribou matrix habitat compared to 18% for the natural disturbance regime model. Based on current moose densities we can also use this analysis to generate targets for moose and also for wolves. Moose are approximately 1.4 times more abundant in early seral than in old forest conditions (Walker et al. 2006, R. Serrouya, *unpublished*). Therefore, the over-abundance of early seral can indicate the proportional over-abundance of moose. Note that moose densities are influenced by factors other than the abundance of suitable habitat, and that density targets will be low if moose populations are currently depressed in parts of their range for one reason or another.

Target moose densities based on this method for mountain caribou planning units dominated by wolf-moose predator-prey systems (planning units 3A-6) are reasonably consistent with targets derived using static biomass equations (Table 2). The target density in 3A is higher than the previously derived target, which might reflect a high current moose density in Revelstoke, despite recent declines. Similarly, the low target in 5B might reflect a low current moose population in that planning unit. Extending the target moose density to suggest a target wolf density results in a target <6.5/1000 km^2 in all planning units except the Hart Ranges (6). This is based on the functional response described by Messier (1995), assuming that moose equal 7 deer-sized prey items.

Table 2. Moose and wolf density targets based on the area of early seral habitat in matrix habitat that exceeds that expected under a natural disturbance regime.

Planning Unit	Area of excess early seral (km^2)	Current estimated moose density (/1000 km^2)	Estimated current population	Estimated "excess" moose (x1.4)	Population without excess	Moose density target (/1000 km^2)	Wolf density target (/1000 km^2)
3A	327	270	357	124	234	180	5.2
4A	283	170	558	67	491	150	4.4
5B	840	120	359	141	218	70	2.1
5A	766	300	920	322	598	200	5.7
6	550	300	1348	231	1117	250	7.3

An important limitation of this approach is that the resulting moose and wolf density targets represent a theoretical, long-term equilibrium with their habitat under a natural disturbance regime, but they do not reflect the wolf and related moose densities that would be required to elicit a strong positive response in mountain caribou populations.

Dynamic Modelling Approach to Setting Targets

Understanding the implications of moose management policies over time in different landscapes requires more complex modelling (Lessard et al. 2005). In contrast with static models based on biomass calculations of predators and prey, dynamic models can more closely approximate the characteristics of predator-prey systems because such systems are themselves dynamic. The Ministry of Environment contracted B. Lessard in 2007 to adapt his wolf-caribou model (Lessard 2005) to mountain caribou parameters. This model should be used to explore the possible implications of policy changes related to moose harvest on wolf and caribou dynamics

Prey Monitoring

The Ministry of Environment has systems in place to monitor moose and deer abundance throughout mountain caribou range and matrix habitat. Aerial censuses and analyses of hunter survey data will provide most of the information.

Reducing moose to benefit mountain caribou has a strong theoretical basis, but it has not been tested experimentally. Trials are underway in Revelstoke and the Parsnip, where moose populations and mountain caribou responses are being monitored. Future decisions need to be informed by the outcomes of these trials. It may be necessary to initiate reductions in other areas where mountain caribou are most at risk, before results of the trials are known.

Prey Management Actions

Hunting will likely remain the primary tool used to manage prey populations. The ability of hunters to exert sufficient pressure to reduce moose to targets might be a concern in some remote regions of the Province or in parks and protected areas. There have been, and there are expected to be, some changes to habitat management in the matrix habitat aimed at influencing habitat use by moose and associated population densities (e.g., adjustments to ungulate winter range boundaries).

Managing habitat to reduce the proportion of early seral habitat and therefore influence moose carrying capacity is an option; however, managing populations through hunting is faster and more certain because moose populations are influenced by more than just the proportion of early seral habitat.

Current Wolf, Cougar and Moose Densities and Targets

There is current information available on the abundance of wolves (Table 3), cougars (Table 4) and moose (Table 5) within mountain caribou range and matrix habitat. Relating current density estimates to targets derived by this report suggest the intensity of reductions that are required in different parts of mountain caribou range.

Table 3. Estimated number and density of wolves within caribou and matrix habitat, by planning unit.

Planning Unit	Planning Unit Name	Estimated resident wolf population	Estimated wolf density (/1000 km^2)
1A	Southwest Kootenay	8	2.0

Planning Unit	Planning Unit Name	Estimated resident wolf population	Estimated wolf density (/1000 km^2)
1B	Southeast Kootenay	24	7.5
2B	Central Selkirks	33	6.2
3A	Revelstoke-Shuswap	18	7.5
4A	Wells Gray- Thompson	44	6.0
5B	Quesnel Highland	63	7.0
5A	Upper Fraser	29	4.6
6	Hart Ranges	50	5.4

Table 4. Estimated number and density of cougars within caribou and matrix habitat, by planning unit.

Planning Unit	Planning Unit Name	Estimated resident cougar population	Estimated cougar density (/1000 km^2)
1A	Southwest Kootenay[1]	4	1.0
1B	Southeast Kootenay[1]	11	3.4
2B	Central Selkirks[1]	3	0.6
3A	Revelstoke-Shuswap	6	2.5
4A	Wells Gray- Thompson	60	7.4
5B	Quesnel Highland		
5A	Upper Fraser	12	1.9
6	Hart Ranges	10	1.1

[1]Estimates based on track survey data and likely underestimated.

Table 5. Estimated density of moose within caribou and adjacent matrix habitat, by planning unit. These densities were based on a static equation (Fuller 1983).

Planning Unit	Planning Unit Name	Estimated moose population	Estimated moose density (/1000 km^2)
1A	Southwest Kootenay	284	70
1B	Southeast Kootenay	844	120
2B	Central Selkirks	240	40
3A	Revelstoke-Shuswap	640	270
4A	Wells Gray- Thompson	1400	170
5B	Quesnel Highland	510	120

Planning Unit	Planning Unit Name	Estimated moose population	Estimated moose density (/1000 km^2)
5A	Upper Fraser	1895	300
6	Hart Ranges	2755	300

Adaptive Management and Adjusting Targets

The Ministry of Environment has established specific population goals for mountain caribou (averaged over 3 years):

1. caribou calf recruitment >15% in March (as a proportion of the total population);
2. adult survival ≧88% per annum; and,
3. positive population growth.

Evaluation of the programme should be based on the soonest-available caribou data following the implementation of predator-prey management actions. Evaluation needs to consider the implementation and effectiveness of actions related to all the management levers, not just those related to predators and their prey. Targets can be refined as monitoring results become available following the implementation of management actions. The relationships between management action outcomes and mountain caribou herd sizes and trends will be the basis for assessing the effectiveness of the predator-prey strategy.

Research Initiatives

In addition to monitoring predator, prey and mountain caribou populations, and implementing management actions to benefit caribou recovery, research into various aspects of mountain caribou predator-prey systems is underway. The goal of this research is to better characterize relationships and to improve recovery.

Current research initiatives include:

- experimental moose population reduction (through increased hunting allocations) in the Parsnip (Hart Ranges) to understand resulting effects on the local wolf population and on caribou survival;
- habitat use studies of wolves, cougars and grizzly bears in Revelstoke to determine the degree of spatial overlap with mountain caribou;
- estimating wolf and cougar abundance in Revelstoke to measure the effect of the recent decline in moose abundance;
- testing the effectiveness of sterilization as a technique to limit the growth and maintain the social structure of wolf packs (Quesnel Highland planning unit);
- testing the effectiveness of chemical sterilization techniques on wolves which would reduce the health risk and costs associated with physical sterilization techniques; and
- isotope analysis to determine the contribution of caribou to the diet of predators.

In addition predator necropsies are being conducted to provide information on age, gender, relative body condition, reproductive status and body size.

Recommendations

The following summarizes recommendations arising from this report:

- Intensity, duration and extent of predator-prey management actions should be scaled to the relative short-term risk facing different mountain caribou herds.
- Wolves and cougars should be the focus of predator management to benefit mountain caribou.
- Moose should be the focus of prey reductions to benefit mountain caribou.
- Deer populations should be prevented from increasing, where feasible.
- The area-of-interest for predator and prey reductions should be defined by the no- harvest and modified-harvest zones plus adjacent "matrix" habitat.
- Wolf densities within mountain caribou range should not average more than 6.5 wolves/1000 km^2 in the long term and should be scaled to the relative risk facing caribou herds, based on population size and trend.
- Wolf densities in ranges of mountain caribou herds most at risk should average <1.5 wolves/1000 km^2.
- To generate a significant, positive population response by mountain caribou, wolf densities should be managed to <1.5 wolves/1000 km^2.
- Cougar densities within any mountain caribou areas should not average more than 10 cougars/1000 km^2 in the long term.
- Cougar densities in ranges of mountain caribou herds most at risk should average <1.5 wolves/1000 km^2.
- Where caribou herds are most at risk, removal of all wolf packs or cougars is a justifiable short-term goal.
- Any cougar specializing on mountain caribou should be removed immediately.
- Wolves need to be reduced before, or concurrently with, moose.
- Moose densities in mountain caribou zones and matrix habitat should average 50-300 moose/1000 km^2, depending on the risk to mountain caribou herds.
- Future decisions related to moose targets should be based on the outcomes of moose reduction trials underway in Revelstoke and the Parsnip.
- The implications of policy changes related to moose harvest should also be explored further through additional modelling.

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