A Proposed Monitoring and Adaptive Management Strategy for Mountain Caribou Recovery Implementation

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Executive Summary

The government of BC announced a recovery implementation plan for mountain caribou in October 2007. One of the actions included in the plan was to "support adaptive management and research and implement effective monitoring plans for habitat, recreation and predator-prey management". This report presents a strategy that focuses on identifying the key information requirements and methods that can be used to meet the monitoring and adaptive management requirements of the implementation plan. It is intended to identify knowledge gaps, guide the integration of monitoring and research activities, and optimize learning.

The challenges that face all adaptive management programmes are particularly relevant to mountain caribou recovery because the required management actions are complex, caribou range is large and diverse, and recovery is expected to take a long time. For these reasons, we do not propose a “grand experiment” across the range of mountain caribou. Instead, we suggest a weight-of-evidence approach will be more useful, allowing comparisons to be made among areas that are subject to different management regimes, or through modelling of policy options and predicted outcomes. In other words, the approach to adaptive management will largely be passive, rather than active. Nevertheless, where feasible, active adaptive management should be considered because it offers a powerful and efficient way to test and improve policies.

The monitoring and adaptive management strategy is based on the following components:

- *Effectiveness measures* articulate the objectives of the recovery implementation plan;
- *Management levers* are the classes of actions that are expected to effect changes in the effectiveness measures;
- *Relationships* and *interactions* illustrate the relationships among effectiveness measures and management levers; and,
- *Key adaptive management questions* articulate the uncertainties associated with the relationships and interactions.

Implementing the strategy involves designing and implementing the management actions, monitoring the implementation and effectiveness of various actions, and revising actions, if necessary. The key to adaptive management is ensuring that monitoring outcomes are translated into revised management actions.

We offer the following key recommendations:

1. Projects should align with specific monitoring and adaptive management questions as outlined in this strategy. In particular, projects addressing the effectiveness of recreation closures and SMAs, as well as the effectiveness of reducing prey to influence predator densities, should be priorities.

2. Responsibility for guiding and supporting all caribou monitoring and adaptive management work be assigned to a standing team or committee at the provincial level.

3. Because of the long timeframe needed to assess caribou population responses to policy changes and new management techniques, special attention needs to be directed towards ensuring continuity of monitoring and AM projects.

4. Project teams with clear roles and responsibilities should be assembled that has broad expertise including ecology, resource management, field operations, modelling, sampling and/or experimental design, and data management and analysis.

5. Project teams should jointly plan projects in a workshop setting.

6. A model should be employed during the assessment and design stages of each adaptive management project. Models can be useful for documenting the team's understanding of the system, identifying key uncertainties and sensitivities, forecasting expected outcomes of policy and management interventions.

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Acknowledgments

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Introduction

In 2007, the government of BC announced a recovery implementation plan for the province's mountain caribou population. One of the actions included in the plan was to "support adaptive management and research and implement effective monitoring plans for habitat, recreation and predator-prey management". More specifically, the plan committed that:

- Implementation of the recovery plan would be monitored closely to determine whether the strategy needs to be modified in order to meet the recovery goals;
- Research addressing knowledge gaps would be supported; and,
- The plan would include the development of adaptive management and monitoring plans for habitat, recreation, and predator-prey management; both within core mountain caribou habitat areas as well as other areas that contribute to connectivity and predator reduction.

This strategy lays out a broad framework for monitoring, research, and adaptive management of mountain caribou in BC. Because it is a strategic document, it focuses on identifying the key information needs and methods that can be used to meet those needs, rather than details of recommended studies or monitoring programs. It is intended to identify knowledge gaps, guide the integration of monitoring and research activities, and optimize learning.

Definitions

Clear definitions of some key terms may be helpful to reduce the confusion that sometimes arises over the meaning of the terms "monitoring", "research", and "adaptive management". For the purposes of this strategy:

- **Monitoring** means observing or measuring environmental characteristics or management activities. Monitoring can address issues related to implementation (whether proposed actions are being implemented), compliance (whether limits are being followed), or effectiveness (whether actions are resulting in the desired outcomes). This strategy recommends a suite of indicators covering these different aspects of monitoring;
- **Research** means scientific investigation or experimentation; and,
- **Adaptive management** means a formal, systematic, and rigorous approach to learning from the outcomes of management actions, accommodating change, and improving management. It involves synthesizing existing knowledge, exploring alternative actions, and making explicit forecasts about their outcomes
- **Resource managers** monitor to assess the state or trend of animal populations, vegetation growth, snow depth, and many other variables of interest. Monitoring is

also a key component of adaptive management projects, as described in more detail below. **Researchers** carry out studies where the main goal is to gain new knowledge rather than to achieve a management objective (although the resulting knowledge may be valuable to managers because it subsequently assists them in achieving their goals). Adaptive management combines the goals of learning and achieving management goals, and is usually conducted by teams of managers and scientists.

Monitoring and research as defined above are both well known to BC's resource managers, and need little further explanation. The same cannot be said of adaptive management, which has been defined in many different ways and seldom has been implemented effectively. Because adaptive management is such a key element of this strategy, the next sections provide more details on its objective, principles, and methods.

Overview of Adaptive Management

> "*Adaptive management embodies a simple imperative: policies are experiments; learn from them.*"
>
> *Kai N. Lee, 1993*

The core idea behind adaptive management is simple: human demands for resources drive us to exploit (manage) the natural world, but in many cases we do not understand all implications of our actions for those resources and the environment. We should therefore study the effects of management policies and actions to learn what we are doing well and poorly, and thus be able to improve management in the future.

The originators of the concept of adaptive management viewed it as a structured and analytical process, one that was far more thoughtful and focused than traditional trial-and-error management (Holling 1978). Many managers now use the term adaptive management much more loosely, applying it to any management activity that changes over time; however, this is a simplistic view of a powerful management tool and one that is far less likely to lead to improved management policies than would a well-planned, carefully implemented adaptive management program that is deliberately designed to resolve important uncertainties and, ideally, test alternative policies or practices.

As in everyday resource management, adaptive management is concerned with learning about how human actions affect resources and the environment. What makes adaptive management different from both everyday management and research is that it holds the two goals of learning and "doing" (managing) as more or less equally important.

Approaches to Adaptive Management

Various AM practitioners have proposed similar, but slightly different, stepwise sequences or cycles as the organizing framework for AM projects. For discussion purposes here, we will use the six-step cycle applied by the BC Ministry of Forests and Range in its adaptive management initiative. Those steps are:

1. Assess the problem or opportunity to be investigated and select policies or practices that might achieve the desired results;
2. Design a project that will test one or more of the selected policies or practices;
3. Implement the project in the field;
4. Monitor the response of indicator variables representing the key values or relations of interest;
5. Evaluate the results, comparing them to forecasts made at the problem assessment stage; and
6. Adapt future management policies or practices to incorporate what was learned in the previous steps.

This sequence might then be repeated (forming an AM cycle) if new uncertainties have arisen since the project began.

Two types of AM are recognized widely in the literature: active and passive (Walters 1986). Active AM (also called "parallel" AM by Bormann et al.1999) entails deliberate and concurrent (parallel) testing of two or more alternative policies or practices, usually in a somewhat controlled experimental approach such as a before-after-control-impact (BACI) trial (Schwarz 1998). Active AM trials are usually only somewhat controlled because they take place in real-life management settings, where the operational scale at which policies and practices are applied prevents the careful control of potential confounding factors that would be needed for a scientific experiment. Nevertheless, well-conducted active AM strives to produce data that reliably can distinguish more successful from less successful policies; therefore statistical considerations are often important. Active AM is frequently used in forestry settings, to test alternative stand-level silviculture and harvesting treatments.

Passive AM (called "sequential" AM by Bormann et al. 1999) applies only one policy at a time, and then evaluates the results of that policy before considering other alternatives. Even though it entails a simpler experiment than would be the case in active AM, passive AM still requires careful implementation, monitoring, and evaluation to generate improved understanding of the benefits and costs of the selected policy. Once the results of the initial policy have been evaluated, changes may be made to it based on what was learned during the first AM sequence. At that point a new passive AM sequence might be initiated to test the revised policy (hence Bormann' et al.'s notion of sequential AM). This approach has been applied, for example, to North American waterfowl management, in which the harvest results of one season's hunting regulations are used to guide changes in the regulations for the following year (Johnson et al. 1997).

In cases where the lag time between treatment (new policy) and response by caribou is long, as it often is, active AM has an important theoretical advantage over passive AM because it tests simultaneously different policy alternatives. For example, if it takes five years before caribou show a measurable response to a new policy, under an active AM scenario managers could identify the most effective of three policy alternatives in just five

years. Under a passive AM scenario, on the other hand, it would take 15 years to test the same three policies.

In theory, either active or passive adaptive management could be applied to issues at almost any geographic scale relevant to mountain caribou. For practical reasons, however, active AM methods are usually applied to relatively small areas such as sites, forest stands, or landscape units; rather than to large units such as occupied range or planning units. This mainly is due to the difficulty of finding two or more large treatment units that are similar in all important respects save the different caribou management policies that are applied in them. Without such comparable units, it is difficult to provide appropriate control sites and replication of treatments, thus weakening any conclusions that might be drawn.

Thus, although active AM offers some significant advantages over passive AM in the right circumstances, there probably will be few mountain caribou policies and settings amenable to it. Where such conditions do occur active AM is certainly worth considering, because it can lead to more rapid and reliable learning than the passive AM approach.

Challenges in Applying Adaptive Management

Few concepts in wildlife management and forestry have been so often praised and promoted as adaptive management over the last 40 years, and few have been so seldom applied successfully (Walters 1997, Bormann et al. 2007). Reasons for the shortage of successful AM projects are many (Taylor et al. 1997); here we explore some of the most important for applying AM to recovery of mountain caribou in BC:

- Lack of a common definition and understanding of AM principles and methods: All cooperators in AM projects need to share the same understanding of what AM is and how it will be applied to the problem or opportunity at hand;
- Lack of firm commitments to the project by key agencies: AM projects addressing issues as complex as mountain caribou require the cooperation of multiple agencies and specialists. All need to make a commitment to the goals and methods of the project, and agree to cooperate to implement the design.
- Lack of a plan for all stages of the project, with clear assignment of responsibilities: Without such a plan, it is common for projects to lose focus or gradually become neglected as priorities and interests change;
- Fluctuations in resources over the life of a project: Because many AM projects require 5-10 years or more to reach a conclusion, fluctuations in funding and staffing are bound to occur. Somehow the cooperators need to ensure the project does not run out of money or key people at critical times;
- Changes in managerial or political priorities: These can divert attention from earlier priorities. In the face of such pressure, AM project teams may have to stick doggedly to their original plans in order to get reliable answers to the key questions.

The challenges that face all adaptive management programmes are particularly relevant to mountain caribou recovery because the required management actions are complex, caribou range is large and diverse, and recovery is expected to take a long time. For these reasons, we do not propose a "grand experiment" across the range of mountain caribou as part of the AM strategy. Instead, a weight-of-evidence approach will be more useful, allowing comparisons to be made among areas that are subject to different management regimes, or through modelling of policy options and predicted outcomes. Nevertheless, where it is feasible in smaller areas AM offers a powerful and efficient way to test and improve policies in a timely manner, and it should be implemented as soon as possible to test those key questions that can be answered with policy experiments.

Principles

The following are principles that were followed in the development of this monitoring and adaptive management strategy:

- Because the recovery area is very large and a defensible experimental design is not feasible, the focus of the strategy will be on "passive" rather than "active" adaptive management (Schwarz 1998);
- Monitoring and evaluation effort will be directed towards those activities that pose the greatest risk, or have the potential to provide the greatest benefit, to mountain caribou recovery;
- The adaptive management program will be scalable to available resources; and,
- The success of the recovery implementation plan will be assessed on a planning unit basis, although management action will be targeted at individual herds.

Structure of the Monitoring and Adaptive Management Program

The monitoring and adaptive management strategy is based on the following components (Figure 1):

- *Effectiveness measures* articulate the objectives of the recovery implementation plan and are associated with a monitoring question and effectiveness indicators, which are the specific measurables required to address the monitoring question. The desired result or condition is the state of the indicator required to meet the objective.
- *Management levers* are the classes of actions that have been enabled by the mountain caribou recovery implementation plan and that are expected to effect changes in the effectiveness measures. Each management lever is associated with a monitoring question, one or more implementation or compliance indicators and desired results or conditions.
- *Relationships* and *interactions* illustrate the relationships among effectiveness measures and management levers. Direct relationships imply cause and effect while

interactions indicate a dependency. There are two interactions in the monitoring and adaptive management strategy:

  - Between *Population Size & Trend* and *Population Distribution*, because distribution cannot be interpreted except in the context of population size; and,
  - Between *Population Size & Trend* and *Habitat Management* because interpretation of population parameters require a knowledge of the abundance of suitable habitat (i.e., carrying capacity).

- *Key adaptive management questions* articulate the uncertainties associated with the relationships and interactions. These are largely research questions that are addressed outside the monitoring framework but are supported by the program.

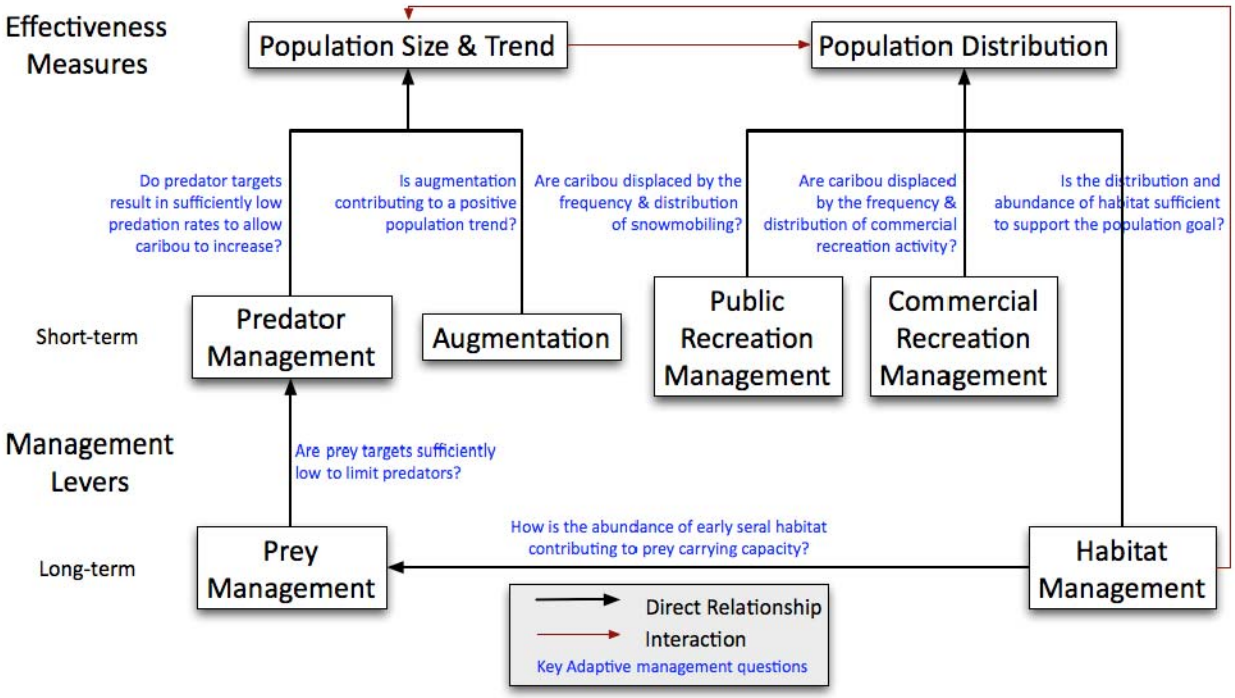

Figure 1. Structure of the proposed monitoring and adaptive management strategy for mountain caribou implementation.

Monitoring

The focus of the strategy is on monitoring the implementation of management actions to determine whether management actions are resulting in the desired conditions associated with each management lever. If they are not meeting the desired conditions then the management actions should be adjusted (see *Implementation of the Strategy* below), or the desired conditions should be revisited to ensure that they are responsive to changes in management. Even where no management actions are being implemented, it is still important to monitor indicators; this information will be important when management actions in other areas are evaluated.

The following sections outline the monitoring components of the strategy.

Population Size and Trend

Objective:

Recover the mountain caribou population to >2500 animals range wide.

Analysis:

A population target of >2500 animals was first articulated by the Mountain Caribou Technical Advisory Committee (2002) and confirmed in government's announcement of the mountain caribou recovery implementation plan. The range-wide population target was derived by summing targets from individual planning units (Table 1). Mountain caribou have declined since the mid-1990's from a population of approximately 2500 (Hatter 2006).

Table 1. Population targets for mountain caribou. These targets were based on the area of high suitability mountain caribou habitat protected in each planning unit.

Planning Unit	Name	Target density (caribou/1000 km^2)	Latest population estimate (2006-8)	Target Population
1-A	Southwest Kootenay	100	46	91
1-B	Southeast Kootenay	100	20	159
2-B	Central Kootenay	200	102	227
3-A	Revelstoke	200	172	363
4-A	Wells-Gray Thompson	200	250	326
5-B	Quesnel Highland	150	286	366
5-A	Upper Fraser	150	315	353
6	Hart Ranges	335	682	712
	Status quo units	NA	10	NA
Total			1883	2597

Management Actions and Programs:

Government is committed to periodic censuses of mountain caribou herds. Surveys provide the percent calves and a population estimate. Adult survival can be inferred from data collected on census flights.

Monitoring Question, Indicators and Desired Conditions:

1. Are the caribou populations within each planning unit growing or have they met their targets?

Indicator	Desired Condition
Population trend/size	lambda >1, averaged over 3 years, or herd at the target
Proportion of calves	>15% calves, averaged over 3 years
Adult survival	>88%, averaged over 3 years

Population Distribution

Objective:

Maintain a distribution of mountain caribou that approximates the distribution of high suitability habitat protected throughout the range.

Analysis:

Paralleling the commitment to recover mountain caribou to a population of >2500 was a commitment to recover to an approximate distribution. This commitment is articulated in planning unit population objectives and in the distribution of high suitability habitat legally protected. Ideally, the distribution of caribou should approximate the distribution of protected high suitability habitat, allowing for the fact that caribou can move extensively throughout large home ranges and shift their habitat use both seasonally and among years.

The purpose of monitoring caribou distribution is to ensure that habitat caribou are using is adequately protected, and conversely, that habitat unlikely to be used is not alienated from other uses. Of course there are many factors that influence the distribution of mountain caribou in space and time and these factors need to be considered in the evaluation of this objective.

Management Actions and Programs:

The distribution of mountain caribou can be informed by collating and analyzing telemetry, GPS and census data, as well as anecdotal reports (e.g., from snowmobile clubs, commercial backcountry operators, public).

Monitoring Question, Indicators and Desired Conditions:

1. Does the distribution of mountain caribou reflect the distribution of protected high suitability habitat?

Indicator	Desired Condition
Spatial distribution of mountain caribou detections	75% of high suitability winter habitat occupied, based on 1-km buffered detections over 3 years

Predator Management

Objective:

Reduce and/or maintain wolves and cougars at densities that allow mountain caribou populations to grow (i.e., positive lambda).

Analysis:

Wilson (2009) recommended targets for wolf and cougar densities, scaled to risk facing mountain caribou herds (Table 2, Table 3). These represent long-term averages that are likely to allow mountain caribou to persist. Note that predators will need to be reduced to much lower targets in the short term if a strong positive response by caribou is expected.

Table 2. Estimated number and density of wolves within caribou and matrix habitat, by planning unit (2008). Targets based on equilibrium predator-prey equations and based on suitable habitat expected under a natural disturbance regime ("NCT-based target") are also presented (see Wilson 2009).

Planning Unit	Planning Unit Name	Target density (/1000 km^2), NDT-based target, where applicable	Estimated resident wolf population	Estimated wolf density (/1000 km^2)
1A	Southwest Kootenay	<1.5	8	2.0
1B	Southeast Kootenay	<1.5	24	7.5
2B	Central Selkirks	<1.5-3.0	33	6.2
3A	Revelstoke-Shuswap	<1.5-3.0, 5.2	18	7.5
4A	Wells Gray- Thompson	<1.5-3.0, 4.4	44	6.0
5B	Quesnel Highland	<1.5-3.0, 2.1	106	14.4
5A	Upper Fraser	3-6.5, 5.7	29	4.6
6	Hart Ranges	<6.5, 7.3	50	5.4

Table 3. Estimated number and density of cougars within caribou and matrix habitat, by planning unit (2008). Targets based on equilibrium predator-prey equations are also presented (see Wilson 2009).

Planning Unit	Planning Unit Name	Target density (/1000 km^2)	Estimated resident cougar population	Estimated cougar density (/1000 km^2)
1A	Southwest Kootenay[1]	<2.5	4	1.0
1B	Southeast Kootenay[1]	<2.5	11	3.4
2B	Central Selkirks[1]	<2.5-5.0	3	0.6
3A	Revelstoke-Shuswap	<2.5-5.0	6	2.5
4A	Wells Gray- Thompson	<2.5-5.0	60	7.4
5B	Quesnel Highland	<2.5-5.0		
5A	Upper Fraser	5.0-10	12	1.9
6	Hart Ranges	<10	10	1.1

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

Management Actions and Programs:

Hunting seasons for wolves and cougars has been liberalized throughout the range of mountain caribou. Targeted trapping/snaring of wolves in key areas was initiated in winter 2007-8 and continued in 2008-9. Results of these initial actions are being evaluated.

Monitoring Question, Indicators and Desired Conditions:

1. Are predator density targets being achieved?

Indicator	Desired Condition
Wolf density in and near caribou habitat	<1.5-6.5 wolves/1000 km^2 depending on planning unit risk

Cougar density in and near caribou habitat	<2.5-10 cougars/1000 km^2 depending on planning unit risk

Key Adaptive Management Questions:

1. Do predator targets result in sufficiently low predation rates to allow caribou to increase?

Augmentation

Objective:

Accelerate the recovery of very small herds by transplanting caribou into their range.

Analysis:

Critically small herds are at a high risk of extirpation from stochastic events. The Mountain Caribou Science Team recommended augmentation as a strategy to reduce short-term risk for several small herds while other management actions are implemented.

Management Actions and Programs:

Planning is underway for transplanting animals from northern caribou herds to very small southern herds. The short-term goal is to transplant 20 caribou into the South Purcells in fiscal 2009-10. Challenges include: identifying a suitable donor herd, gaining First Nations and stakeholder support, and funding.

Monitoring Question, Indicators and Desired Conditions:

1. How many animals are being transplanted into critically small herds?
2. Are transplanted animals contributing to the population growth of the receiving herd?

Indicator	**Desired Condition**
Number of animals transplanted per year	20 animals/year transplanted into herds of <50 animals in each of the 4 years 2010-2013
Contribution of transplanted animals to population trend	Calving and recruitment success of transplants >50% that of residents.

Key Adaptive Management Questions:

1. Is augmentation contributing to a positive population trend (i.e., are transplants remaining with the receiving herd and reproducing)?

Public Recreation Management

Objective:

Prevent public recreation activities from displacing mountain caribou from preferred winter habitats.

Analysis:

The Mountain Caribou Science Team identified snowmobiling as a significant risk to mountain caribou recovery because of the potential of the activity to displace animals from otherwise suitable habitat, thereby reducing the habitat's effectiveness. Evidence of displacement in the scientific literature is relatively sparse but is increasing (e.g., Seip et al. 2007). Some Science Team members and agency biologists have anecdotally observed evidence of displacement in several areas throughout mountain caribou range.

Management Actions and Programs:

Areas to be closed were first identified by the Mountain Caribou Science Team through an expert review process. Government gave local snowmoble clubs the opportunity to propose Stewardship Management Agreements (SMA's) for their local areas. An initial set of SMA's has been proposed and the majority of the remaining areas recommended for closure by the Science Team were legally closed to snowmobiling in February 2009 under the Wildlife Act.

Monitoring Question, Indicators and Desired Conditions:

1. What is the compliance with closures and SMAs?

Indicator	Desired Condition
Index of snowmobile use (observed machines plus estimate of additional tracks per survey day	High compliance with closures (<1 violation/day) and declining rate of non-compliance with SMAs over time (5-year horizon)
Evidence of displacement of mountain caribou from closed and SMA areas	No evidence of displacement based on aerial survey or telemetry information

Key Adaptive Management Questions:

1. Are caribou displaced by the frequency and distribution of snowmobiling activity?

Commercial Recreation Management (Heli- and snow-cat skiing)

Objective:

Prevent commercial recreation activities from displacing mountain caribou from preferred winter habitats.

Analysis:

Commercial recreation activities, in particular heli-skiing and snow-cat skiing, have the potential to displace mountain caribou from preferred habitat, thereby reducing the habitat's effectiveness. Government has committed to monitoring the effectiveness of

operating practices that have been established by Helicat Canada for their members operating in mountain caribou habitat.

Management Actions and Programs:

The Species at Risk Coordination Office sought external advice on the development of an effectiveness monitoring strategy for the commercial recreation sector (AMEC and Jelinski 2008). They provided comprehensive recommendations for monitoring the effectiveness of operating procedures, including, a system of self-reporting and third-party auditing of compliance with, and effectiveness of, industry operating procedures.

Monitoring Question, Indicators and Desired Conditions:

1. What is the compliance with operating practices?

Indicator	Desired Condition
Compliance data from commercial backcountry operators	Increasing rate of compliance over time (5-year horizon)
Evidence of displacement of mountain caribou from commercial recreation tenures	No evidence of displacement based on aerial survey or telemetry information

Note that additional indicators and desired conditions need to be developed in collaboration with the commercial recreation sector, building off of the AMEC and Jelinski (2008) report.

Key Adaptive Management Questions:

1. Are caribou displaced by the frequency and distribution of heli-skiing and snow-cat activity?

Prey Management

Objective:

Reduce and/or maintain moose populations at densities that support wolf densities that allow mountain caribou populations to grow (i.e., positive lambda).

Analysis:

The Mountain Caribou Science Team identified the increasing population and range of moose, deer and elk populations as a likely factor in the decline of mountain caribou because of the of higher-than-historic predators population that are supported by the expanding prey population. Moose populations are the most feasible to manage to support mountain caribou recovery efforts. Deer are likely infeasible to manage where they are most abundant (i.e., in the southernmost sections of mountain caribou range; Wilson 2009).

Initial moose density targets were based primarily on standing biomass equations (Fuller 1989) and informed by a literature review of moose and wolf densities (Bergerud 2007), as well as an analysis of early seral forest conditions in relation to forest conditions expected under a natural disturbance regime (Wilson 2009; Table 4).

Table 4. Estimated density of moose within caribou and adjacent matrix habitat, by planning unit (2008). These densities were based on a static equation (Fuller 1983). Targets based on equilibrium predator-prey equations and based on suitable habitat expected under a natural disturbance regime ("NCT-based target") are also presented (see Wilson 2009).

PU	Herd	Target moose density (/1000 km^2), NDT-based target, where applicable	Estimated moose density (/1000 km^2)
1A	Southwest Kootenay	<50	70
1B	Southeast Kootenay	<50	120
2B	Central Selkirks	<50-150	40
3A	Revelstoke-Shuswap	<50-150, 180	270
4A	Wells Gray- Thompson	<50-150, 150	170
5B	Quesnel Highland	<50-150, 70	120
5A	Upper Fraser	150-300, 200	300
6	Hart Ranges	<300, 250	300

Management actions and programs:

A pilot project is underway in the Parsnip to reduce moose through hunting regulation changes and to monitor mountain caribou for responses (Steenweg et al. 2009). There have been no other changes to hunting regulations to date related to the implementation of the mountain caribou recovery implementation project.

Monitoring Question, Indicators and Desired Condition:

1. Are prey density targets being achieved?

Indicator	Desired Condition or Result
Summer moose density in and near caribou habitat	<50-300/1000 km^2 depending on planning unit risk

In addition, deer abundance will be monitored less formally in some regions to detect increases that might have implications for predator populations.

Key Adaptive Management Questions:

1. Are moose targets sufficiently low to limit wolves?
2. What is the role of changes in deer abundance in influencing mountain caribou predator-prey dynamics?

Habitat Management

Objective:

Protect sufficient winter habitat from forest harvesting and road-building to support a range-wide population of 2500 mountain caribou.

Analysis:

A range-wide habitat suitability model was developed to illustrate the abundance and distribution of mountain caribou habitat throughout the range. Early and winter habitat combined was used to drive protection of incremental habitat because it is considered the limiting season for mountain caribou. High suitability habitat was modelled such that values captured approximately the highest-ranked 50% of telemetry locations. The abundance of high suitability habitat was multiplied by density targets, by planning unit, to generate population objectives. Density targets varied by planning unit and were based primarily on estimates of caribou abundance and habitat availability in the mid-1990's. Based on these targets, the goal of achieving a population of 2500 animals was deemed feasible, if 95% of high suitability habitat was protected within areas zoned, or proposed to be zoned, as mountain caribou habitat in non status-quo units.

Management Actions and Programs:

Local habitat teams were assigned the task of identifying incremental habitat protection, based on impact budgets derived from the range-wide suitability analysis. Revised management zones with objectives that eliminated forest harvesting and road-building were legalized as Ungulate Winter Ranges under the Forest and Range Practices Act.

The legal orders capture not only forest licensees but also other crown-land tenure holders who remove trees, such as commercial recreation operators, independent power producers and mineral tenure holders. There will be exceptions to the no-road-building and no-forest-harvesting provisions of the legal orders for some small-scale activities, and other activities could be exempted on a case-by-case basis, subject to approval by the Regional Manager of the Ministry of Environment.

Monitoring Question, Indicators and Desired Conditions:

1. Are legal measures protecting mountain caribou habitat from forest-harvesting and road-building?

Indicator	**Desired Condition**
Hectares of forest openings created in caribou habitat/year	Net increase in abundance of high suitability habitat over time (20-year horizon)
Kilometres of road-building in caribou habitat/year	Net decrease in total length of roads in caribou habitat over time (deactivation exceeds new construction, 5-year horizon)

Key Adaptive Management Questions:

1. Is the distribution and abundance of habitat sufficient to meet the population goal?
2. Are harvest treatments in caribou habitat retaining caribou attributes and resulting in continued use by caribou?

Implementation of the Strategy

Implementing the strategy involves designing and implementing the management actions, monitoring the implementation and effectiveness, and revising actions, if necessary (Figure 2). The key to adaptive management is ensuring that monitoring outcomes are translated into revised management actions.

Revising Management Actions

Management actions will need to be revised where monitoring indicates that desired conditions are not being met, or where they are being met but the outcomes are not being achieved. In the first instance, the following outlines steps that should be taken before changes to management are implemented.

1. **Sufficient time should elapse under a management regime to determine with certainty that the desired conditions will not be met.** For example, a new hunting opportunity might be undersubscribed or compliance with a new snowmobile closure might initially be low but could improve over time.

2. **Causes of the failure to meet desired conditions should be carefully evaluated.** There are three general reasons that management actions might not be achieving the desired conditions:

    a. Capacity (government, stakeholders): there might be insufficient resources to effectively implement the management action. For example, additional moose surveys might be required to detect a predicted change in abundance, or there might be too few hunters to exert sufficient pressure on a particular ungulate or predator population (e.g., as is likely with wolves).

    b. External factors/stressors: circumstances might arise that were either unanticipated or beyond the control of managers. For example, the spread of a forest health problem might be much more extensive than predicted.

    c. Deliberate non-compliance: disagreement with government direction might lead to actions by some that are intended to undermine recovery efforts.

3. **Potential options and expected benefits should be developed.** Based on monitoring data and outcomes, both within and among mountain caribou planning units, managers should develop a potential list of management options and their expected benefits to mountain caribou.

4. **Decisions regarding new management actions should consider the following factors:**

    a. Risk to mountain caribou: risk to herds varies throughout the range and should be considered when revising management actions. For example, if compliance with a voluntary snowmobile closure is low but there is no

immediate risk to the local caribou herd, then additional measures could be implemented in an attempt to improve compliance in the next season.

b. Feasibility of proposed management action: there are many management actions that could be beneficial to caribou recovery, but for a variety of reasons are infeasible to implement. An honest assessment of capacity and external factors is required.

c. Likelihood of achieving the desired condition: the goal of revising the management action is to achieve the desired condition. Situations where desired conditions are achieved but caribou responses are not meeting expectations are addressed in the next section.

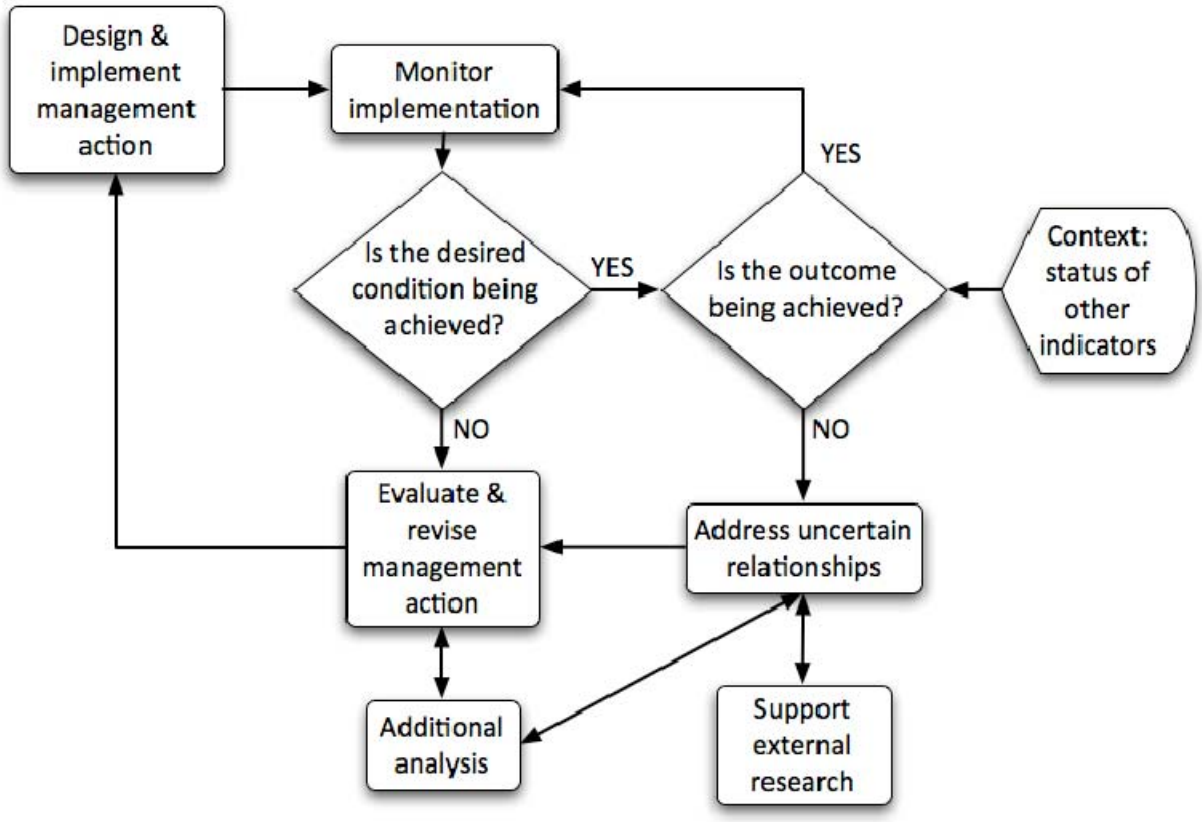

Figure 2. Structure to implement and revise management actions for mountain caribou recovery.

Addressing Uncertain Relationships

To answer the monitoring questions and the key adaptive management questions identified in the "Monitoring" section above, a mix of standard monitoring programs, adaptive management projects and research studies will be required. This report is not intended to provide specific details of such work because, as noted above, the nature of the

adaptive management program will depend in part on available resources. However, the details should be documented in annual workplans, as suggested below.

But given the framework outlined above, where are adaptive management efforts most needed? One way to address this question is to examine which key AM questions are already being investigated through existing research programs. Currently, much of the existing and planned research on caribou in BC addresses questions related to predation and the effects of alternate prey on predator populations (Table 5). Recent research has addressed management levers, such as habitat management (e.g., Apps et al. 2001, Johnson and Seip 2008) and snowmobiling activity (e.g., Seip et al. 2007, Freeman 2008). We are aware of no ongoing or planned research that looks at questions of caribou augmentation, displacement by snowmobiling or heliski/snowcat operations, or adequacy of habitat to support recovery.

Table 5. Current research in relation to key adaptive management questions associated with mountain caribou recovery implementation.

Adaptive management question	Studies underway	Location
Are predator targets sufficiently low to allow caribou to increase?	Habitat use studies of wolves, cougars and grizzly bears to determine the degree of spatial overlap with mountain caribou	Revelstoke
	Testing the effectiveness of sterilization as a technique to limit the growth and maintain the social structure of wolf packs	Quesnel Highlands planning unit
	Isotope analysis to determine the contribution of caribou to the diet of predators	Range-wide
	Predator necropsies to provide information on age, gender, relative body condition, reproductive status and body size	Range-wide
	Mortality rates of caribou vs. densities of wolves and cougars	Revelstoke (proposed research 2008-2012)
	Testing the effectiveness of licensed, regulated trapping of wolves as a technique to reduce predation on caribou	Chase caribou herd, Mackenzie area
Is augmentation contributing to a positive population trend?		
Are caribou displaced by the frequency and distribution of snowmobiling activity (in all areas, including those closed and not closed to snowmobiles)?		

Adaptive management question	Studies underway	Location
Are caribou displaced by the frequency and distribution of heliskiing and snowcat activity?		
Are prey targets sufficiently low to limit predators?	Experimental moose population reduction (through increased hunting allocations) to understand resulting effects on the local wolf population and on caribou survival Estimating wolf and cougar abundance to measure the effect of the recent decline in moose abundance	Parsnip River drainage (Hart Ranges) Revelstoke
What is the role of changes in deer abundance in influencing mountain caribou predator-prey dynamics?	Retrospective and prospective study of deer, caribou, wolves, and cougars before and after the 1997 crash in the Kootenay deer population and the current rapid decline in moose	Revelstoke (proposed external research 2008-2012)
How is the abundance of early seral habitat contributing to prey carrying capacity?		

The lack of current and upcoming studies to address augmentation, public and commercial recreation, and habitat points to topics where AM projects could potentially be helpful. In our view, the implementation of snowmobiling Stewardship Management Agreements (SMAs) is an especially high priority for monitoring and AM.

More work will also be required on questions related to predator-prey relations because these systems are complex and dynamic. Alternative approaches to managing the prey aspects of the predator-prey dynamic appear to be the highest initial priority, because managing prey will likely be a focus in efforts to reduce predators and there are considerable uncertainties.

Recommendations for Developing Monitoring and Adaptive Management Projects

In this section we provide some general recommendations for developing an administrative and project planning approach for monitoring and adaptive management projects. Recommendations 1 and 2 are applicable to all types of projects across the province, while Recommendations 3-5 are directed at cases in which a more formal policy experiment is to be conducted through either passive or active AM.

For more specific advice on the "how-to" issues of conducting effectiveness monitoring for wildlife, see Huggard and Kremsater (2006), Guidance on making AM work in the real world is available from Holling 1978, Margoluis and Salafsky 1998, Stankey et al. 2005,

Nyberg et al. 2006, Bormann et al. 2007, and the BC Ministry of Forests and Range. Also, a unique software package called Miradi™ offers a integrated, interview-based method of guiding project teams on how to practice good adaptive management and may be worth trying in some caribou AM projects.

The following are our recommendations related to developing monitoring and adaptive management projects:

7. Projects should align with specific monitoring and adaptive management questions as outlined in this strategy. In particular, projects addressing the effectiveness of recreation closures and SMAs, as well as the effectiveness of reducing prey to influence predator densities, should be priorities.

8. Responsibility for guiding and supporting all caribou monitoring and AM work be assigned to a standing team or committee at the provincial level. This could either be a re-aligned Directors' Team, or a new group reporting to the Directors' Team. It should include the MOE Ungulate Specialist and others with expertise in monitoring and AM. Its responsibilities could include:

    - review progress toward filling knowledge gaps;
    - assess the need and potential for filling remaining gaps;
    - provide a link between the strategic level of government and those who will implement monitoring and AM projects at the field level;
    - promote a consistent approach, structured along the lines we have outlined here, for designing and conducting monitoring and AM projects;
    - identify monitoring priorities and oversee monitoring and AM projects;
    - develop monitoring and AM workplans;
    - advocate for the resources needed to carry out important AM projects; and,
    - report on results of monitoring and AM projects, and recommend changes to management actions.

9. Because of the long timeframe needed to assess caribou population responses to policy changes and new management techniques, special attention needs to be directed towards ensuring continuity of monitoring and AM projects. This can be encouraged by measures such as:

    - ensuring that monitoring and AM projects align with strategic priorities, that a formal monitoring or AM plan is developed for each project, is shared with all participants, and is archived by the lead agency. This plan should describe the goals, objectives, methods, schedule, responsibilities, budget, and other relevant details of the project. Projects should be tied specifically to indicators or AM questions as outlined in this document. Such a plan will aid communication among the current project team and with other interested parties, and can be invaluable for future newcomers to the team who may assume responsibility for the project as members of the original team leave.

- developing contingency plans for dealing with changes in budgets, staffing, and organizational priorities. Many caribou projects will require 5-10 years to answer key questions. Over that time, fluctuations are bound to occur in available resources, turnover will occur in key positions, and participating organizations may lose interest, be reorganized, or even disappear. Project teams and the provincial committee should anticipate these problems and find ways to sustain ongoing projects. There are no easy solutions, but some project teams in the past have found that they could maintain relatively stable budgets by acquiring contributions from multiple sources both inside and outside government, thus buffering the effects of shortfalls in funding from some of their sources. In cases where budget busts and booms were inevitable, other teams have designed monitoring schedules that allowed some measurements to be postponed during times of lower budgets. Problems that could arise from staff turnover can be mitigated in some cases by ensuring that responsibility for participating in AM projects is clearly assigned as part of the work assignments of the positions filled by team members, and not just as a voluntary activity taken on out of personal interest.

10. For AM projects such as those described in Recommendation 2, a project team with clear roles and responsibilities should be assembled that has broad expertise including ecology, resource management, field operations, modelling, sampling and/or experimental design, and data management and analysis.

    A project leader and champion should be appointed to head this team. Good AM projects require considerable work to initiate and shepherd through to completion, so leadership needs to be assigned to someone with enough energy, time, and vision to succeed. That person should be good at cooperating and communicating, because collaborative teamwork will be critical to many projects.

11. AM projects should be jointly planned by the project team in a workshop setting. Many people experienced in AM have stressed the value of having a team of people with diverse expertise work together to develop the plan for each AM project. Holling (1978) described a methodology for conducting Adaptive Environmental Assessment and Management workshops when designing AM projects, and that approach is still useful today. Alternative methods include the consultative approach described by Margoluis and Salafsky (1998) for conservation projects in the tropics, and the Open Standards for the Practice of Conservation (Conservation Measures Partnership 2007).

    The main benefits of the structured workshop approach are that it ensures that all project participants have the opportunity to contribute their knowledge and insights to the project design, and it produces a shared understanding of why and how the project is to be carried out.

12. A model should be employed during the assessment and design stages of each AM project. Models can be useful for documenting the team's understanding of the ecosystem, identifying key uncertainties and sensitivities, forecasting expected outcomes of policy and management interventions, and other purposes (Nyberg et al. 2006). Because of the effort expended on modelling mountain caribou in BC over the

last ten years, there should seldom if ever be a need to develop a new model for a caribou AM project. Existing models may need to be modified, however, to suit a particular geographic area or to incorporate new data or understanding that has been acquired since the model was built.

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