Boreal Caribou Recovery Implementation Plan

Prepared by B.C. Ministry of Environment and
Ministry of Forests, Lands, and Natural Resource Operations

March 2017

About British Columbia Implementation Plans

The Province prepares implementation plans to meet its commitments to manage and/or recover species at risk under the *Accord for the Protection of Species at Risk in Canada*, and the *Canada-British Columbia Agreement on Species at Risk*. Species at risk management and/or recovery is the process by which the decline of an endangered, threatened, or extirpated species is reduced, arrested, or reversed, and threats are removed or reduced to improve the likelihood of a species' persistence in the wild.

What is an Implementation Plan?

The implementation plans the Province develops for species at risk involve a comprehensive understanding of the technical or scientific aspects of the issues for the species, as well as a thorough consideration of the socio-economic implications of the activities and objectives. Provincial implementation plans provide the necessary technical information to rationalize the government's need for enhanced management of the species, the goals and/or objectives of the enhanced management, and a description of the management actions required to achieve the goals and/or objectives.

What's next?

Recovery of Boreal Caribou is a challenging and uncertain process that will require collaboration with a variety of interested parties, including governments, First Nations, and land users. The Province will lead in the implementation of the management actions, and will involve interested parties whenever possible. At the same time, the Province will continue to monitor the health and population of Boreal Caribou to assess the effectiveness of these actions.

For more information

To learn more about species at risk recovery in British Columbia, please visit the Ministry of Environment Recovery Planning webpage at:

http://www.env.gov.bc.ca/wld/recoveryplans/rcvry1.htm

To learn more about the British Columbia Conservation Framework, please visit the Ministry of Environment Conservation Framework webpage at:

http://www.env.gov.bc.ca/conservationframework/

Boreal Caribou Recovery Implementation Plan

Prepared by B.C. Ministry of Environment

And

Ministry of Forests, Lands, and Natural Resource Operations

March 2017

Recommended citation

Ministry of Environment and Ministry of Forests, Lands, and Natural Resource Operations. 2017. Boreal Caribou Recovery Implementation Plan.

Cover illustration/photograph

Brad and Diane Culling

Additional Copies

Additional copies can be downloaded from the BC Ministry of Environment Recovery Planning webpage at: http://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/species-ecosystems-at-risk/recovery-planning/recovery-planning-documents/recovery-planning-documents

Preface

This implementation plan outlines recovery actions that are deemed necessary to recover Boreal Caribou in British Columbia. These actions have been developed in consideration of potential socio-economic affects associated with recovering this ecotype. This plan has been developed collaboratively and endorsed by all provincial ministries and agencies with mandated responsibilities for wildlife and natural resource management. It replaces the existing "Implementation Plan for the Ongoing Management of Boreal Caribou (*Rangifer tarandus caribou* pop.14" (MOE 2011). A number of the actions identified in MOE (2011a) have been accomplished, such as establishing Ungulate Winter Ranges and Wildlife Habitat Areas, developing population monitoring strategies, and developing performance measures to determine the effectiveness of Resource Review Areas. Some actions are carried over to this revised plan, including developing a wildfire response strategy, developing and implementing a predator management program, and continuing to monitor populations.

This plan identifies the recovery actions that are deemed necessary to stabilize and achieve self-sustaining populations in all Boreal Caribou herds and to maintain a positive habitat trend across the existing Boreal Caribou ranges in BC. It was developed using the best available scientific and technical information and considering socio-economic values. Implementation of recovery actions to achieve the goals and objectives identified in this plan are subject to the priorities and budgetary constraints of participatory agencies and organizations. It may also be necessary to modify these actions, while respecting their intent, to 1) accommodate new science resulting from effectiveness monitoring of recovery actions and continuing research on habitat associations; 2) address socio-economic objectives in Boreal Caribou recovery; and/or, 3) meet further direction provided by the government of British Columbia.

Success in the recovery of this species depends on the commitment and cooperation of many different parties that may be involved in implementing the directions set out in this plan. The Province of British Columbia encourages all Canadians to participate in the conservation of Boreal Caribou.

ACKNOWLEDGEMENTS

This plan was created by the collaboration of staff in British Columbia's natural resource ministries. Staff members of the Ministry of Environment, Ministry of Forests, Lands and Natural Resource Operations and Ministry of Natural Gas Development are acknowledged for their fine and dedicated work in drafting this document.

The development of this document was informed by the work of Boreal Caribou Research and Effectiveness Monitoring Board. Board members are acknowledged for their contributions, hard work and professional ability in addressing research and monitoring needs.

EXECUTIVE SUMMARY

Boreal Caribou (*Rangifer tarandus caribou*) are Red Listed and are ranked S2 (imperiled) by the Conservation Data Centre in British Columbia (BC). The British Columbia Conservation Framework ranks Boreal Caribou as a priority 1 under goal 3 (maintain the diversity of native species and ecosystems). Boreal Caribou were recognized as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in May 2002. As a result, the population was listed as Threatened on Schedule 1 of the *Species at Risk Act* (SARA) in 2003.

Boreal Caribou in BC are believed to be in decline. A minimum of 728 Boreal Caribou currently reside in the northeast of BC within 16 core areas among five ranges: Calendar, Chinchaga, Maxhamish, Snake-Sahtaneh, and Westside Fort Nelson. Previously, Boreal Caribou were considered to occur within six ranges, including Chinchaga, Prophet, Parker, Maxhamish, Snake-Sahtaneh, and Calendar (MOE 2011a). Research and monitoring has resulted in an improved understanding of habitat use by Boreal Caribou, and consequently in 2016, ranges and cores were revised such that five ranges are now identified. Boreal Caribou in BC are contiguous with Boreal Caribou populations in Alberta and the Northwest Territories, as individuals move across these jurisdictional boundaries. Boreal Caribou require large areas of contiguous habitat to avoid predators. Indirect effects from habitat loss, fragmentation, and alteration primarily due to human activities; and, direct effects from predation, have threatened the functionality of Boreal Caribou habitat and the populations within BC.

In 2010, the Province of British Columbia identified management actions to address these threats, including initiating an extensive research and monitoring program. In 2011 the Province approved the "Implementation Plan for the Ongoing Management of Boreal Caribou (*Rangifer tarandus caribou* pop.14) in British Columbia". Since 2011, a number of knowledge gaps have been filled by the Boreal Caribou Research and Effectiveness Monitoring Board and associated researchers. Results have suggested that habitat protection and management established for Boreal Caribou requires a revised approach.

To address the results of recent research and monitoring, and address the uncertainty associated with recovering Boreal Caribou, the Province has developed a revised approach to the management of Boreal Caribou. This plan incorporates the results of species experts' analyses and recommendations as well as the results of engaging First Nations, industry, and stakeholders on the management approach. The Province has identified management actions to recover Boreal Caribou that recognize the potential socioeconomic implications of managing Boreal Caribou and the Treaty 8 First Nations right to hunt caribou.

The following population and habitat goals will guide implementation efforts within the province.

1. *Stabilize and achieve self-sustaining populations across each boreal caribou range, and:*

2. *Stabilize and achieve self-sustaining populations across each boreal caribou range*

The following implementation objectives provide measurable targets for action and evaluation to guide recovery efforts:

Forestry:

1. Establish an early seral habitat objective of initially <6% across each Boreal Caribou range;
2. Prohibit forest harvesting and road building in 15 of the 16 core areas. For the Milligan core, the current management practises regarding forest harvesting and road building will be maintained;
3. (alternate F2) Prohibit the creation of new early seral forest in core ranges unless an exception is granted

Petroleum and Natural Gas (PNG) Development:

1. Require a net decrease in the density of linear features within core areas by applying habitat offsets (initially 4:1) for future development impacts across ranges, leading to a positive habitat trend in each range over time;
2. As a short-term solution, replace existing Resource Review Areas (RRAs) with better aligned RRAs over untenured portions of caribou core areas, until incremental habitat protections and population management actions are finalized;

Species Management and Wildfire:

1. Determine if and where other non-habitat related management actions such as predator management and caribou population management (i.e., predator fencing) are required, feasible and supported by First Nations. Align predator management with the provincial Wolf Management Plan;
2. Manage wildfires in each Boreal Caribou range to minimize the creation of natural early seral habitats.

The goals, objectives and actions of the revised plan are tailored to each Boreal Caribou range, and consider the population and habitat status, as well as socioeconomic priorities of each. An individual plan for each range is provided as Appendices A through E; the range plans also provide information on recommended monitoring and research priorities. An important component of this revised Boreal Caribou Implementation Plan is the use of adaptive management, which enables the Province to amend the actions used to best achieve the goals.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1 SCOPE OF THE IMPLEMENTATION PLAN

This implementation plan is limited to the Boreal Caribou that are found in British Columbia and represents direction provided by the Government of British Columbia to manage the population (See Section 4).

2 ENGAGEMENT

Preliminary engagement on revising the BCIP was initiated in January 2015, with the purpose of identifying appropriate goals and objectives for the management of boreal caribou and their habitat.

In 2016, First Nations, industry, and stakeholders were provided opportunities to comment on proposed goals and objectives that could be used in revising the BCIP. A number of the parties engaged recommended that a draft of the revised BCIP be made available for public review to ensure a broader audience had opportunity to provide feedback.

The province is continuing to engage parties in identifying feasible alternative management options that would facilitate the recovery of boreal caribou while minimizing the potential impact to other resource values, including timber values.

3 SPECIES INFORMATION

Only basic assessment and status information are presented in this section. Please refer to Culling and Cichowski (2017), BC MOE website http://www.env.gov.bc.ca/wld/speciesconservation/bc/index.html, and the BC oil and Gas Research and Innovation Society (OGRIS; website (http://www.bcogris.ca/boreal-caribou-home) for more complete information regarding Boreal Caribou in BC, including: population size, trends and distribution information, habitat and biological needs, threats, existing management actions, and knowledge gaps regarding this ecotype of sub-species *Rangifer tarandus caribou* (woodland caribou).

Note that Boreal Caribou is used as the naming convention throughout this document. This is synonymous with, but differs from the English name, Caribou (boreal population), which is the provincial standard.

3.1 COSEWIC* Species Assessment Information

Assessment Summary: November 2014
Common Name: Boreal Caribou
Scientific Name: *Rangifer tarandus caribou*
Status: Threatened (May 2002)
Reason for Designation: A widespread population ranging across the boreal forests of northern Canada. Populations have decreased throughout most of the range. Threatened from habitat loss and increased predation, the latter possibly facilitated by human activities.
Criteria: [a]
Occurrence: BC, AB, SK, MB, ON, QC, NL, NT
Status History: The Boreal population was designated Threatened in May 2000. This newly-defined population is comprised of a portion of the de-activated "Western population" and all of the de-activated "Labrador-Ungava population." Status re-examined and confirmed in May 2002 and November 2014. The 2002 assessment was based on an updated status report.

* Committee on the Status of Endangered Wildlife in Canada.
[a] See COSEWIC quantitative criteria and guidelines for the status assessment of wildlife species (Table 2 of the COSEWIC assessment process guidelines: http://www.cosewic.gc.ca/eng/sct0/assessment_process_e.cfm)

3.2 Species Status Information

Boreal Caribou		
Legal Designation:		
FRPA:[b] Species at Risk OGAA:[b] Species at Risk	**B.C. *Wildlife Act*:**[c] No	**SARA**:[d] **Schedule 1** – Threatened (2003)
Conservation Status[e]		
B.C. List: Red **B.C. Rank:** S2 (2010) **National Rank:** N4 (2011) **Global Rank:** G5TNR		
Other Subnational Ranks:[f] AB: S2; Labrador: S2S3; MB: SNR; NWT: S3; ON: S4; QU: S2S3; SK: SNR; YK: S1		
B.C. Conservation Framework (CF)[g]		
Goal 1: Contribute to global efforts for species and ecosystem conservation.		Priority:[h] 3 (2010)
Goal 2: Prevent species and ecosystems from becoming at risk.		Priority: 6 (2010)
Goal 3: Maintain the diversity of native species and ecosystems.		Priority: 1 (2010)
CF Action Groups:[g]	Compile Status Report; List under *Wildlife Act*; Send to COSEWIC; Habitat Protection; Habitat Restoration; Private Land Stewardship; Species and Population Management; Review Resource Use	

[a] Data source: B.C. Conservation Data Centre (2016) unless otherwise noted.
[b] Species at Risk = a listed species that requires special management attention to address the impacts of forestry and range activities on Crown land under the *Forest and Range Practices Act* (FRPA; Province of British Columbia 2002) and/or the impacts of oil and gas activities on Crown land under the *Oil and Gas Activities Act* (OGAA; Province of British Columbia 2008) as described in the Identified Wildlife Management Strategy (Province of British Columbia 2004).
[c] No = not designated as wildlife under the British Columbia *Wildlife Act* (Province of British Columbia 1982).
[d] Schedule 1 = found on the List of Wildlife Species at Risk under the *Species at Risk Act* (SARA; Government of Canada 2002).
[e] Red: Includes any indigenous species or subspecies that have, or are candidates for, Extirpated, Endangered, or Threatened status in British Columbia. S = subnational; N = national; G = global; X = presumed extirpated; H = possibly extirpated; 1 = critically imperiled; 2 = imperiled; 3 = special concern, vulnerable to extirpation or extinction; 4 = apparently secure; 5 = demonstrably widespread, abundant, and secure; NA = not applicable; NR = unranked; U = unrankable.
[f] Data source: NatureServe (2016).
[g] Data source: B.C. Ministry of Environment 2009.
[h] Six-level scale: Priority 1 (highest priority) through to Priority 6 (lowest priority).

3.3 Populations and Distribution

Boreal Caribou in Canada occur in all provinces and territories except New Brunswick, Nova Scotia, Prince Edward Island, and Nunavut (COSEWIC 2011; Festa-Bianchet et al. 2011; Environment Canada 2012), and are considered Designatable Unit 6 (DU6; COSEWIC 2011). As such Boreal Caribou are discrete from all other DUs in Canada due to lack of opportunity for genetic exchange. This national population is estimated at approximately 34,000 (Environment Canada 2011), with a declining minimum population of 728 individuals currently occupying ranges in British Columbia (Culling and Culling 2016).

In British Columbia, Boreal Caribou reside in the northeast of the province within the Boreal and Taiga Plains. This area can be characterized as a mosaic of peatlands, mixed-wood forests, wetlands, swamps and riparian areas (Goddard 2009, Culling and Cichowski 2017). Boreal Caribou are generally considered sedentary, in that they do not make long-distance migrations, but use habitat throughout their ranges (COSEWIC 2011). The Federal government has defined critical habitat for Boreal Caribou across Canada as the area within each range that provides an overall ecological condition (e.g., peatlands) allowing for ongoing recruitment and retirement cycle of habitat, maintaining a perpetual state of a minimum of 65% undisturbed habitat (EC 2012).

Between 2010 and 2016, Boreal Caribou were considered to occur within six ranges, including Chinchaga, Prophet, Parker, Maxhamish, Snake-Sahtaneh, and Calendar (Table 1). Fourteen core areas were identified in high quality habitat with treed peatlands, and terrestrial and arboreal lichen forage base, in areas known to be used by Boreal Caribou. Cores are typically smaller than ranges, and reflect areas of concentrated use by Boreal Caribou. Research and monitoring has resulted in an improved understanding of habitat use by Boreal Caribou, and consequently in 2016, ranges and core areas were revised. Five ranges are now identified (Table 1; Figure 1). The ranges include 99% of historic and recent telemetry data, while the cores encompass 95% of the telemetry points. The names for the herds and range areas in this plan are synonymous. The 2016 ranges encompass over 20% more habitat than was identified in 2011, while the 2016 cores capture over 12% more important Boreal Caribou habitat. This plan therefore represents the management of significantly more habitat for Boreal Caribou than ever before in BC.

Table 1. Comparison of Boreal Caribou ranges and cores in 2010 and 2016

2010		**2016**	
Ranges/*cores*	**Area (km^2)**	**Ranges/*cores***	**Area (km^2)**
Calendar	4,973	Calendar	5,411
Calendar	*4,973*	*Calendar*	*4,309*
Chinchaga	13,897	Chinchaga	13,903
Milligan	*5,196*	*Milligan*	*5,197*
Etthithun	*780*	*Etthithun*	*1,195*
		Chinchaga North	*2,198*
Maxhamish	7,095	Maxhamish	7,775
Fortune	*2,662*	*Fortune*	*2,301*
Capot-Blanc	*876*	*Capot-Blanc*	*876*
Kiwigana	*1,301*	*Kiwigana*	*1,301*

Snake-Sahtaneh	12,000	Snake-Sahtaneh	12,301
Tsea	*689*	*Tsea*	*689*
Etsho	*60*	*Etsho*	*60*
East Kotcho	*318*	*Kotcho*	*1,795*
North Kotcho	*748*		
West Kotcho	*362*		
Paradise	*403*	*Paradise*	*403*
Shush Creek	*282*	*Shush Creek*	*282*
Clarke	*2,224*	*Clarke*	*2,340*
		Westside Fort Nelson	8,664
Prophet	1,193	*Prophet*	*1,403*
Parker	752	*Parker*	*752*
		Fort Nelson	*537*
Total Area of Ranges	39,910		*48,054*
Total Area of Cores	22,819		*25,638*

The Boreal Caribou Science Update (Culling and Cichowski 2017), Culling and Culling (2016), and Appendices A-E provide detailed information on Boreal Caribou population metrics and trends. Population metrics suggest that Boreal Caribou populations in BC appeared to be declining slightly in 2016 (Culling and Culling 2016), while experiencing an overall decline over the past decade.

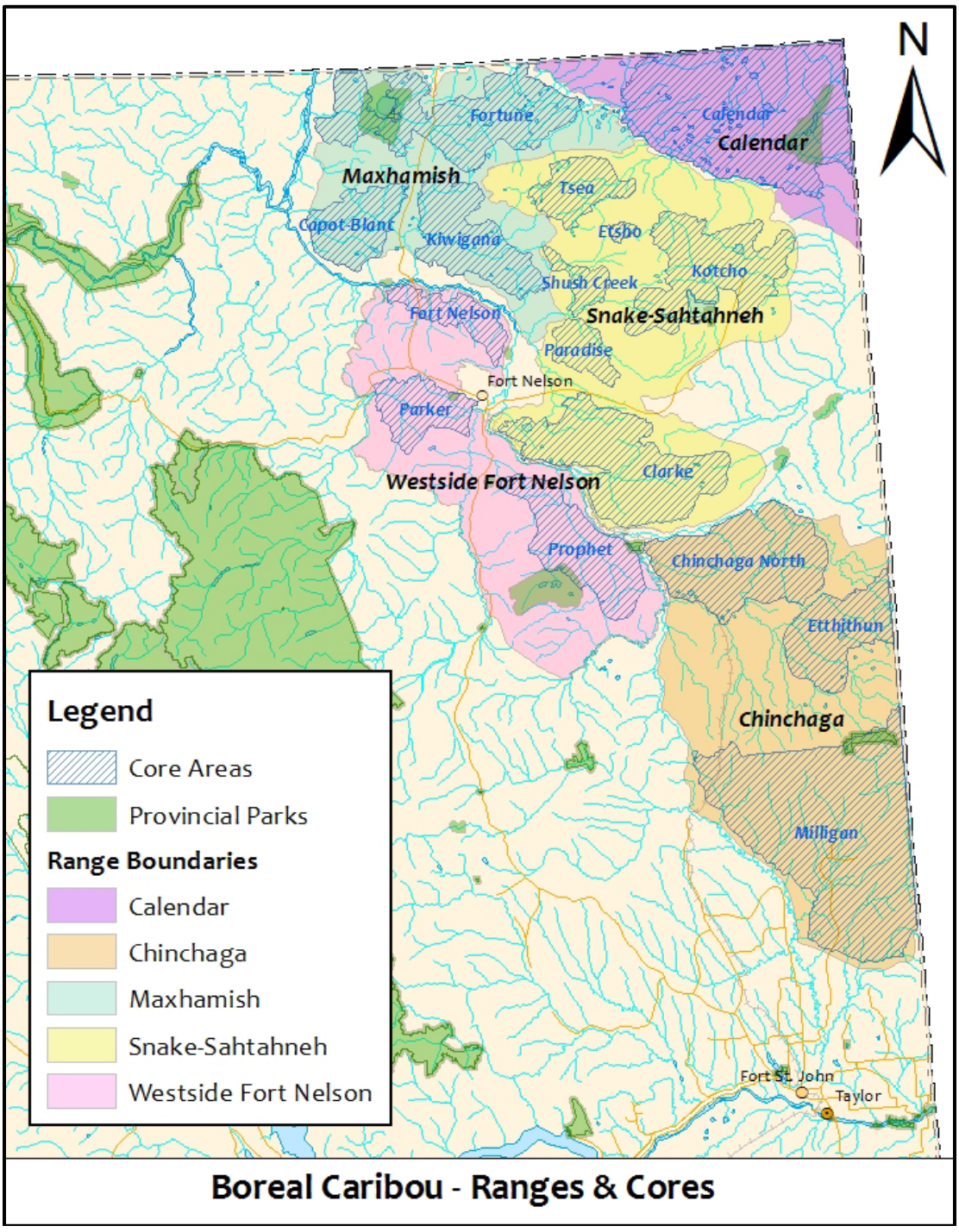

Figure 1. Revised Boreal Caribou Ranges and Cores

4 THREATS

Threats for Boreal Caribou in BC were addressed and are available in the *Boreal Caribou (*Rangifer tarandus) *in British Columbia: 2017 Science Review* (Culling and Cichowski 2017).

5 GOALS, OBJECTIVES, AND ACTIONS

In 2011, the government of British Columbia initiated several management actions, including an extensive research and monitoring program, to support Boreal Caribou management. The primary goal identified in 2011 was to decrease the expected rate of decline in Boreal Caribou populations, while collecting data to effectively inform future management. The results of research and monitoring conducted since 2011 indicate that the habitat protection and management established for Boreal Caribou requires a revised approach. This implementation plan provides a revised and improved approach to the management of Boreal Caribou in BC, and is more consistent with the federal recovery strategy (EC 2012). Implementation actions are tailored to each range in recognition of the distribution of Boreal Caribou in BC. Implementation actions are influenced by past, current and potential future industrial activities, current resource development commitment, future socio-economic considerations (e.g., future revenues from industrial development) and Métis, Aboriginal and Treaty 8 First Nations right to harvest caribou, among other species.

5.1 Population and Habitat Goals

The population and habitat goals for the recovery of Boreal Caribou are variable[1], and are therefore presented by range in Appendices A – E. The goals may be generalized as follows:

1. *Maintain a positive habitat trend across each boreal caribou range, and;*

2. *Stabilize and achieve viable populations across each boreal caribou range*

5.1.1 Rationale for the Population and Habitat Goals

In this plan, population refers to the total Boreal Caribou population size in each range and habitat refers to the area within Boreal Caribou ranges. These goals are consistent with objectives identified by Environment Canada in the 2012 Boreal Caribou recovery strategy (EC 2012), which focusses on stabilizing and achieving self-sustaining populations through habitat management. Self-sustaining populations are defined by Environment Canada (2009) as a local population of Boreal Caribou that on average demonstrates stable or positive population growth (i.e., lambda ≥ 1) over the short term, and is large enough to withstand stochastic events and persist over the long-term, without the need for ongoing intensive management intervention (e.g., predator management or transplants from other population). An important benefit of achieving

[1] The population and habitat goals depend upon which management regimes are ultimately accepted for application, and are therefore subject to change based on feedback obtained during the public review period.

the population goal is the ability for First Nations and Métis to practice their Treaty rights through hunting of caribou.

The performance indicators summarized in Table 2 provide the metrics by which success in meeting the goals, or the need for adaptive management, will be determined. The rate of population growth (Lambda λ) indicates whether a population is stable ($\lambda = 1.0$), increasing ($\lambda > 1.0$) or decreasing ($\lambda < 1.0$), and is typically measured over a five year period (EC 2012). Recruitment rate is an indication of the number of juveniles surviving to the next year, and is measured as the number of calves per 100 cows. Both lambda and recruitment rate are consistent with metrics used by Environment Canada (2012).

This plan focusses on management of the primary factors that affect Boreal Caribou habitat in BC: 1) early seral habitat resulting from forestry activities and wildfire, and 2) linear features associated with oil and gas development. The implications of increased early seral habitat on Boreal Caribou are increased apparent competition (Holt 1977). Ehlers and colleagues (2016) recently reported that wolves did not select for caribou habitat, and suggested that predation risk for caribou was more strongly related to the occurrence of other prey species, such as moose and deer. Creation of early seral habitat can stimulate an increasing moose population that results in higher wolf abundance and changed wolf distribution. This cascade is called apparent competition and has been shown to have adverse impacts on some caribou populations (Wittmer et al. 2007; DeCesare et al. 2010).

The Province is proposing to reduce the amount of early seral habitat to trend habitat condition toward the 65% undisturbed habitat threshold identified by Environment Canada (2012). Environment Canada (2012) defines disturbed habitat as all burned areas ≤ 40 years, and all anthropogenic disturbance visible on Landsat imagery at a scale of 1:50,000 plus a 500 m buffer. The Province is currently defining early seral habitat as young forest ≤ 35 years for burns and ≤ 25 years for cutblocks (Appendix F). The development of potential alternative approaches using forest attributes in assessing habitat condition is underway. In recognition of Environment Canada's (2012) approach to calculating disturbance, the Province will apply a 500 m buffer (representing a zone of disturbance) to cut-blocks and all anthropogenic disturbances. However, the Province suggests that the application of a single buffer size (e.g., 500 m) to all disturbances increases uncertainty in the results, since Caribou respond differently to varying types of disturbances (e.g., Dyer et al. 2001; Johnson et al. 2015). Further, although the movement and distribution of woodland caribou may be altered by timber harvesting (Chubbs et al. 1993), population level responses are not always elicited (Courtois et al. 2008). The Province will therefore determine progress in achieving habitat targets using early seral data without a 500 m buffer. A similar approach will be followed with linear features, where progress relative to targets is measured 1) with a 500 m buffer applied to all linear features except low impact seismic lines, and; 2) without a 500 m buffer (i.e., linear features do not significantly contribute to early seral / disturbed habitat).

The Province proposes to reduce the amount of early seral habitat in two ways: 1) restoration, and; 2) identifying an early seral threshold. Restoration of Boreal Caribou habitat is required to maintain a positive habitat trend and to stabilize/increase populations within ranges, and is a key mechanism for reducing disturbance (Table 2). The other mechanism to reduce disturbance is to

restrict the creation of future disturbance to levels that are compatible with Boreal Caribou recovery. The Province has identified an early seral threshold of 6% of each range, excluding burns (i.e., Less than 6% of each range can be in an early seral condition as a result of timber harvesting). The early seral threshold is based on results of a model (Wilson, *unpublished report*) using predator-prey data and landscape characteristics such as linear feature density and proportion of early seral habitat (Appendix G). The early seral threshold represents an additional 6% over naturally occurring disturbance; in the event of a catastrophic wildfire, the Province will re-evaluate the management levers used in that range.

Linear features are not included in early seral habitat calculations, because their areal contribution is low, but they are an important component of Boreal Caribou management. Linear features, such as roads, pipelines and seismic lines have been found to increase the speed at which wolves travel by two to three times relative to natural forest (Dickie et al. 2016), thereby improving their hunting efficiency. Boutin and Arienti (2008) suggested that a linear feature density of ≤1 km /km^2 is required for stable or increasing Boreal Caribou populations. Similarly, ALT (2009; based on Antoniuk [2006]) indicated that linear feature densities >1.2km/km^2 put Boreal Caribou at high risk of declining, while densities of <0.6 km/km^2 were lower risk for Boreal Caribou. Wilson's unpublished model (Appendix G) indicated that in addition to an early seral threshold of 6%, a linear feature density of 2 km/km^2 was necessary to stabilize local Boreal Caribou populations. The Province will initially use a target linear feature density of 2 km/km^2, adjusting this target as monitoring is conducted. The target will be applied in both the cores and ranges; to ensure that linear features are not concentrated in the core, the linear feature density in neither the cores nor the ranges should exceed 2 km/km^2. The Province has initially excluded low impact seismic lines (i.e., 3D programs) from linear feature density; however, density of low impact seismic lines will be tracked and included should future research demonstrate their value to predators and/or primary prey.

Dickie (2015) reported that vegetation taller than 1 m on linear features reduced wolf movement by 23% in summer, while vegetation needed to be taller than 5 m in winter to decrease wolf travelling speed (Dickie 2015). Similarly, in west-central Alberta, Finnegan et al. (2014) found that movement rates of both wolves and grizzly bears was reduced by 70% at vegetation heights over 1.4 m, while human use decreased significantly at vegetation heights greater than 2 m. The length of time required to achieve these characteristics is highly variable with type of linear feature and site conditions. Conventional seismic lines in northeastern Alberta took at least 35 years to recover woody vegetation; seismic lines in lowland black spruce showed little recovery even after 35 years (Lee and Boutin 2006). The Province considers linear features in upland habitats restored ≥ 35 years from disturbance, while linear features in lowland habitats take at least 100 years to restore naturally (Appendix H).

Table 2. Summary of Implementation Goals, Performance Indicators and Targets.

Goals	Performance Indicators	Description/Rationale	Targets
Population			
Achieve self-sustaining populations in each Boreal Caribou range	Rate of Population Growth (Lambda λ)	Self-sustaining populations are defined by Environment Canada (2009) as a local population of Boreal Caribou that on average demonstrates ***stable or positive population growth***	λ as measured over five year period: Stable: λ = 1.0 Increasing: λ > 1.0

		over the short term, and is large enough to withstand stochastic events and persist over the long-term, without the need for ongoing intensive management intervention (e.g., predator management or transplants from other population).	
	Recruitment Rate (calves/100 cows)	The probability of extinction decreases as ***recruitment rates*** increase (Environment Canada 2008). Bergerud (1992) reported that a recruitment rate of 27.7 calves/100 cows was required to sustain an increasing population. EC (2008) suggested that results of recruitment rates depended upon female survival.	Minimum 28 calves/100 cows[1]
Habitat			
Maintain a positive habitat trend in each Boreal Caribou range	Amount of forestry-related early seral habitat[2]	Early seral habitat is defined as habitat 20 years old or less created by timber harvesting A modified habitat condition balance sheet (Appendix I; ECCC 2016) will be maintained to track the amount of early seral habitat within Boreal Caribou ranges.	Maximum 6% of range to be early seral habitat from timber harvesting. Decreasing amount of forestry-related early seral habitat (measured over a 5 year period)
	Density of linear features	Length of linear features, including roads, trails, pipelines, transmission lines and all seismic lines EXCEPT low impact seismic (i.e., 3D programs), within each Boreal Caribou range and core.	Density of linear features $\leq$ 2 km/km^2 (measured over 5 year periods) in both cores and ranges

[1] 28 calves/100 cows is considered a conservative target, in that lower calf recruitment could yield positive lambda if adult female survival is high. Future amendment of the target will be considered should the data indicate this is necessary.

[2] The amount of burned habitat $\leq$ 40 years old will be tracked by range, but is excluded from the targets because burns are considered to be within the range of natural disturbance.

5.1.2 Timelines to Recovery

Boreal Caribou populations will be considered self-sustaining, and recovered, when the rate of population growth (Lambda) is > 1 when measured over a five year period when no additional population management (e.g., predator control) was conducted. However, because Boreal Caribou reside in a continental environment that has long cold winters and relatively short cool summers (Culling and Cichowski 2017), habitat types in this area generally grow slowly. These conditions will also affect how Boreal Caribou habitat responds to habitat management prescriptions put in place to support Boreal Caribou population recovery. For instance ecological habitat restoration techniques are likely to take many years if not decades (e.g., $\geq$ 40 years) to achieve desired outcomes. Where the objective is to achieve and maintain self-sustaining populations, it is unlikely that some herds will achieve this status for 50 to 100 years.

5.1.3 Disturbance Mapping

The Province has committed to developing a methodology for mapping and classifying disturbances. This methodology will be used not just for Boreal Caribou, but for other ecotypes of caribou and other wildlife species. As of March 2017, the Province is evaluating the suitability of disturbance data collated by the BC Oil and Gas Commission for use in the Area-Based Analysis (BC OGC 2017), as well as the suitability of disturbance data used in the Cumulative Effects assessment. Once the Province has developed a methodology, existing disturbance metrics will be summarized (Appendix F) for each range.

5.2 Implementation Objectives

The implementation objectives for the recovery of Boreal Caribou are as follows:

Forestry:

1. (F1) Establish an early seral habitat objective of initially <6% across each Boreal Caribou range;
2. (F2) Prohibit forest harvesting and road building in 15 of the 16 core habitats. For the Milligan core area, the current management practises regarding forest harvesting and road building will be maintained;
3. (alternate F2) Prohibit the creation of new early seral forest in core ranges unless an exception is granted

Petroleum and Natural Gas (PNG) Development:

1. (P1) Require a net decrease in the density of linear features within core habitats by applying habitat offsets (initially 4:1) for future development impacts across ranges, leading to a positive habitat trend in each range over time;
2. (P2) As a short-term solution, replace existing Resource Review Areas[2] (RRAs) with better aligned RRAs over untenured portions of caribou core habitat, until incremental habitat protections and population management actions are finalized;

Species Management and Wildfire:

1. (SM1) Determine if and where other non-habitat related management actions such as predator management and caribou population management (i.e., predator fencing) are required, feasible and supported by First Nations. Align predator management with the provincial Wolf Management Plan;
2. (SM2) Manage wildfires in each Boreal Caribou range to minimize the creation of natural early seral habitats.

5.2.1 Rationale for the Implementation Objectives

Early seral, disturbed habitat is considered largely unsuitable for Boreal Caribou because of a relatively high risk of predation, and often high levels of human activity. Early seral vegetation

[2] Resource Review Areas (RRA) are established by the Ministry of Natural Gas Development over untenured portions of caribou core habitat, and prohibit issuance of tenures for the duration of the RRA.

results from both natural events, such as wildfire, and anthropogenic tree removal. This Plan considers the impacts of both. Although increased efforts will be made to limit its' negative impacts, the frequency and extent of wildfires is variable, difficult to forecast at this scale, and not always possible to manage. Linear features associated with tree cutting for oil and gas development are addressed as a separate objective with specific management actions. Commercial timber harvesting has been a significant factor in the creation of early seral forest in the past, and could be again in the future.

The science currently available suggests that caribou habitat can be protected by keeping the amount of early seral area created by forestry <6%. Presently, the amount of early seral area varies from a low of 0.2% in the Calendar Range to a high of 4.7% in the Westside Range. Future work may inform different, more specific targets within individual ranges, but in the meantime, a maximum of 6% forestry-created early seral will apply across all. This means that there is room for some timber harvesting in every range, subject to application of the appropriate practices and restrictions.

Further assessment is required to determine the condition, and protection requirements for habitat in core areas within each range, as well as the socio-economic impacts of limited access to that timber supply. Until then, the default objective for core areas is 0% new forestry-created early seral stands. One exception is the Milligan Core area, within the Chinchaga Range, where it has been determined that caribou recovery objectives can be met while accommodating some timber harvesting.

Other exceptions to the default will be considered where there is sufficient new information to suggest a similar or better balance can be achieved by allowing limited timber harvesting. Portions of core areas in the Westside Fort Nelson and Maxhamish Ranges have been identified as potential candidates. Consideration of exceptions may include a requirement for the forest industry to employ special harvesting and mitigation practices to minimize the impacts on caribou and habitat, and for the province to undertake predator management or other suitable population enhancement measures. This will be part of the adaptive management process.

During the life of this plan, the Province will undertake further research required to determine and apply range-specific early seral thresholds. Research will also be done on the effects of wildfire on Boreal Caribou at the range scale, with consideration of how early seral habitat created by wildfire is additive to anthropogenic disturbances (EC 2012). In the meantime, work will be done to identify and implement the options available for fire management to help achieve the habitat goals.

The density of linear features will be decreased by requiring petroleum and natural gas developers to offset the impact of proposed new linear feature development within a range by restoring legacy linear features in the core habitat areas at a ratio of 4:1 (i.e., for every kilometre of linear feature developed, four kilometres of existing linear features must be restored). Restoration plans will be developed for each Boreal Caribou range, providing strategies for prioritizing features for restoration, optimal spatial arrangement of restored features, and determination of when caribou habitat is considered restored. Until these and other strategies are fully developed, the Ministry of Natural Gas Development will establish temporary Resource

Review Areas (RRAs) over untenured portions of Boreal Caribou core areas. Tenure sales are deferred for a specified length of time in Resource Review Areas.

5.3 Actions for Implementation

Table 3. Implementation actions for Boreal Caribou management; these actions replace those identified in MOE (2011). Note: Actions in this table may be modified based on priorities and further research.

Objective	Action	Performance Indicator(s)	Potential Mechanisms
F1 SM2	Develop and implement a strategy to manage the creation of early seral habitat, considering: management of wildfires through collaboration with fire managers to identify options, evaluation of an early seral habitat objective in areas where harvesting is permitted, spatial arrangement of early seral habitats in regards to moose.	• Amount of undisturbed habitat	Wildfire Act, Forest and Range Practices Act, Land Act, Operational Policy
P1	Develop and implement restoration plans for each range, considering, but not limited to, the following: prioritization of disturbance features (e.g., Golder Associates 2016a), restoration of features such that large undisturbed areas are created, focus on core areas, financial considerations, definition of "restored".	• Increasing proportion of habitat on restoration / regeneration trajectory	Forest and Range Practices Act; Oil and Gas Activities Act, Operational Policy
P1	Require the offsetting impacts of oil and gas linear feature development, i.e., requirements for permit holders to offset activities at an initial ratio of 4:1. Implementation of offsetting and associated restoration.	• Net decrease in the density of linear features	Oil and Gas Activities Act, Operational Policy
P1	Establish a fund for broad-scale restoration projects in Boreal Caribou range, targeting core areas, and areas with a higher success and/or faster rate of restoration.	• Availability of funds for restoration projects	To be determined
P1	Update "Interim Operating Practices" (MOE 2011b) to reflect current science, research, and content of revised BCIP	• Develop and implement updated standard operating practices	Oil and Gas Activities Act, Operational Policy
P2	Establish temporary Resource Review Areas (RRAs) over untenured portions of Boreal Caribou core areas, until other actions are finalized. Tenure sales will be deferred in the RRAs.	• Establishment of RRAs over untenured portions of core areas within two years of BCIP approval	Petroleum and Natural Gas Act, Operational Policy
F2	Require no forest harvesting or road construction over specified areas of core habitat. Work with government agencies to determine the optimal mechanism to meet this requirement.	• No net increase in the areas of harvesting or roads.	Forest and Range Practices Act; Oil and Gas Activities Act; Land Act, Operational Policy
SM1	Wolf control to increase adult survival and calf recruitment rates; target <3 wolves/1,000 km^2.	• Reduced wolf density • Increased caribou lambda and recruitment rates	Wildlife Act, Operational Policy
SM1	Management of caribou populations by protecting a portion of herd with a large pen/predator fence (40 – 100 km^2)[1]. Predator fence predicted to significantly increase calf and adult survival. Subject to results of management options assessment.	• Increased caribou lambda and recruitment rates	Wildlife Act, Land Act, Operational Policy
Monitoring	• Caribou: monitoring of effects of revised BCIP on caribou is essential to track status	• Caribou population metrics (minimum population counts,	Various

Objective	Action	Performance Indicator(s)	Potential Mechanisms
	of goals and to identify opportunities for adaptive management • Wolf: monitoring may be required depending on results of caribou monitoring and actions implemented • Restoration: Tracking the amount of restored habitat is important to determine if goals are met.	recruitment and survival) • Wolf density (where necessary) • Success of restoration techniques • Amount of undisturbed habitat	
Research and Outreach for Plan Implementation	• Early seral threshold: research to inform adjusting the early seral stage threshold • Wildfire: improve understanding of how wildfire affects boreal caribou at the range scale. • Offsetting ratio: research to inform the adjustment of offsetting ratios. • Restoration: functional restoration of linear features is currently in pilot phase • Assessment of management options to confirm optimal implementation of actions by range • Role and management of fine scale features, such as mineral licks, lichen patches and calving sites • Development of a research plan to coordinate and prioritize research activities, and maximize efficiencies • Communications, coordination of implementation activities, stakeholder and First Nations engagement	• Development, adaptation, and implementation of management tools • Reports, publications, presentations and meetings	Various

[1] Predator fencing will only be considered for populations where lambda <1, and/or ongoing development reduces the chances of a population becoming self-sustaining.

6 RESEARCH

The Province acknowledges that there is uncertainty in several management actions that have been developed for implementation within this plan; this uncertainty will be addressed through research and adaptive management (see Section 8). Research is required to refine management actions around fine scale features (e.g., mineral licks, calving sites), and early seral habitat created both from human disturbance and from wildfire, and offsetting ratios. Specifically, research is required to support the application of an early seral stage cap and to define conditions achieved by the 40 year early seral threshold, relative to the habitat requirements of Boreal Caribou. The effect of wildfire on Boreal Caribou at the range scale is unclear, as there is evidence that burns provide some degree of habitat for Boreal Caribou. Research is also recommended around restoration and offsetting; the development of policy on application of offset funds to restoration and the effectiveness of restoration techniques. At the broad scale, an assessment should be done to confirm the optimal suite of management actions by range.

7 UNCERTAINTY

As with many aspects of wildlife management, there is a degree of uncertainty associated with not just the response of Boreal Caribou to management actions, but whether the objectives will achieve the ultimate goals. That said, the body of literature on Boreal Caribou management actions, such as restoration, wolf cull, and penning, has increased rapidly over the past few years and is expected to increase substantially over the coming years. The Province will take this research and knowledge from other regions and jurisdictions, and apply to Boreal Caribou management in BC, to reduce the degree of uncertainty with management of this species. Implementation of actions in the revised BCIP will further increase the Province's understanding, allowing for reduction of uncertainty through effective adaptive management.

8 ADAPTIVE MANAGEMENT

Adaptive management acknowledges the uncertainty inherent in the outcomes of implementing strategies. This uncertainty is associated with the amount of information available to develop the strategies and the likelihood of the strategies having the expected outcomes. There is also considerable uncertainty associated with external factors, such as weather, disease, land use management policies, funding availability and others. In the case of Boreal Caribou, there is a good understanding of population dynamics; in contrast, the long-term outcomes of habitat restoration techniques are largely unknown. To accommodate this uncertainty, the Province will adaptively manage Boreal Caribou by monitoring and adjusting implementation actions as necessary to achieve the population and habitat goals. Actions may be added, removed or changed to best achieve the goals; this Plan will not be revised unless there are significant impacts to other strategic goals of the Province (e.g., moose management, cumulative effects management).

9 EFFECTS ON OTHER SPECIES

Actions taken to protect and manage Boreal Caribou and their habitat from identified threats may have positive benefits for the protection of other species and their habitats within Boreal Caribou range. If it is determined that the actions taken to protect and manage Boreal Caribou are having adverse effects on other species and their habitats for which there may be a conservation concern, the actions may be modified to address this concern.

There are a number of regional strategies that may interact with the Boreal Caribou Implementation Plan, such as the Peace-Liard Moose Management Plan led collaboratively by FLNR and First Nations. The management of moose habitat in Boreal Caribou range will need to be carefully coordinated to optimize the trade-off for both moose and caribou.

10 REFERENCES

Antoniuk, T. 2006. Developing and implementing thresholds in the Northwest Territories – A discussion paper. Prepared for Environment Canada, Northern Division by Salmo Consulting Inc.

Athabasca Landscape Team. 2009. Athabasca Caribou Landscape Management Options Report. https://albertawilderness.ca/2009-05-athabasca-caribou-management-options/

BC Oil and Gas Commission (OGC). 2017. Area-Based Analysis (ABA). https://www.bcogc.ca/public-zone/area-based-analysis-aba. Accessed 13 January, 2017.

Bergerud, A.T. 1992. Rareness as an antipredator strategy to reduce predation risk for moose and caribou. In Wildlife 2001: populations. Edited by D.R. McMullough and R.B. Barrett. Elsevier, London. Pp 1008-1021.

Boutin, S. and C. Arienti. 2008. BCC equation reanalysis – final report. *In* Athabasca Landscape Team. 2009. Athabasca Caribou Landscape Management Options Report. https://albertawilderness.ca/2009-05-athabasca-caribou-management-options/

Chubbs, T.E., L.B. Keith, S.P. Mahoney, and M.J. McGrath. 1993. Responses of woodland caribou (*Rangifer tarandus caribou*) to clear-cutting in east-central Newfoundland. Canadian Journal of Zoology 71: 487-493.

COSEWIC. 2011. Designatable Units for Caribou (*Rangifer tarandus*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, ON. 88 pp.

Courtois, R., A. Gingras, D. Fortin, A. Sebbane, B. Rochette, and L. Breton. 2008. Demographic and behavioural response of woodland caribou to forest harvesting. Canadian Journal of Forestry Research38: 2837-2849.

Culling, D. and B. Culling. 2015. BC Boreal Caribou Implementation Plan: Year III (2014-2015) Field Activities Progress Report. Diversified Environmental Services. Fort St. John, BC. http://www.bcogris.ca/boreal-caribou/projects/complete

Culling, D. and D. Cichowski. 2017. Boreal Caribou (*Rangifer tarandus*) in British Columbia: 2017 Science Review. Prepared for the B.C. Oil and Gas Research and Innovation Society, Victoria, BC.

Culling, D. and B. Culling. 2016. BC Boreal Caribou implementation plan: Year IV (2015-2016) field activities progress report. Diversified Environmental Services. Fort St. John, BC.

DeCesare, N.J., M. Hebblewhite, H.S. Robinson, and M. Musiani. 2010. Endangered apparently: the role of apparent competition in endangered species conservation. Animal Conservation 13:353-362.

Dickie, M. 2015. The use of anthropogenic linear features by wolves in northeastern Alberta. M.Sc. thesis. University of Alberta, Edmonton, AB.

Dickie, M., R. Serrouya, R.S. McNay, and S. Boutin. 2016. Faster and farther: wolf movement on linear features and implications for hunting behavior. Journal of Applied Ecology. doi:10.1111/1365-2664.12732

Dyer, S.J., J.P. O'Neill, S.M. Wasel, and S. Boutin. 2001. Avoidance of industrial development by woodland caribou. The Journal of Wildlife Management, 65(3): 531-542.

Ehlers, L.P.W., and C.J. Johnson, and D.R. Seip. 2016. Evaluating the influence of anthropogenic landscape change on wolf distribution: implications for woodland caribou. Ecosphere: 7(12): 1-20.

Environment Canada. 2008. Scientific Review for the Identification of Critical Habitat for Woodland Caribou (*Rangifer tarandus caribou*), Boreal Population, in Canada. August 2008. Ottawa; Environment Canada. 72 pp. plus 180 pp Appendices.

Environment Canada. 2012. Recovery Strategy for the Woodland Caribou (*Rangifer tarandus caribou*), Boreal population, in Canada. *Species at Risk Act* Recovery Strategy Series. Environment Canada, Ottawa. Xi + 138 pp.

Environment and Climate Change Canada. 2016. Range Plan Guidance for Woodland Caribou, Boreal Population (Draft). Ottawa, ON. 22 pp.

Festa-Bianchet, M., J.C. Ray, S. Boutin, S.D. Côté, and A. Gunn. 2011. Conservation of caribou (*Rangifer tarandus*) in Canada: an uncertain future. Canadian Journal of Zoology 89: 419-434.

Golder Associates. 2016. Parker caribou range: boreal caribou restoration pilot program plan. Report 1529978/5000. Submitted to BC Oil and Gas Research and Innovation Society. January 2016. http://www.bcogris.ca/boreal-caribou/projects/complete

Hauer, G., J. Anderson, T. Antoniuk, and V. Adamowicz. 2014. Caribou protection and recovery program (predator exclosure) cost effectiveness analysis. Prepared for Canada's Oil Sands Innovation Alliance.

Holt, R. D. 1977. Predation, apparent competition, and the structure of prey communities. Theoretical Population Biology 12:197-229.

Johnson, C.J., L.P.W. Ehlers, and D.R. Seip. 2015. Witnessing extinction – Cumulative impacts across landscapes and the future loss of an evolutionarily significant unit of woodland caribou in Canada. Biological Conservation 186: 176-186.

Ministry of Environment (MOE). 2011a. Implementation plan for the ongoing management of boreal caribou (Rangifer tarandus caribou pop. 14) in British Columbia. http://www.env.gov.bc.ca/wld/speciesconservation/bc/

Ministry of Environment (MOE). 2011b. Interim operating practices for oil and gas activities in identified boreal caribou habitat in British Columbia. http://www.env.gov.bc.ca/wld/speciesconservation/bc/

Skatter, H. 2016. Woodland caribou use of residual patches for calving in the high fire/low anthropogenic Boreal Shield of Saskatchewan. Presentation at the 16th North American Caribou Workshop, Thunder Bay, ON.

Skatter, H.G., J.L. Kansas, M.L. Charlebois, and B. Balicki. 2014. Recovery of terrestrial lichens following wildfire in the boreal shield of Saskatchewan: early seral forage availability for woodland caribou (*Rangifer tarandus caribou*). Canadian Wildlife Biology and Management 3(1): 1-14.

Van Rensen, C.K., S.E. Nielsen, B. White, T. Vinge, and V.J. Lieffers. 2015. Natural regeneration of forest vegetation on legacy seismic lines in boreal habitats in Alberta's oil sands region. Biological Conservation 184: 127-153.

Wittmer, H.U., B.N. McLellan, R. Serrouya, and C.D. Apps. 2007. Changes in landscape composition influence the decline of a threatened woodland caribou population. Journal of Animal Ecology 76: 568-579.

APPENDIX A

PLAN FOR THE CALENDAR RANGE OF BOREAL CARIBOU IN BC

1 INTRODUCTION

1.1 Populations

The Calendar range is the most northeastern range of Boreal Caribou in BC, and extends north into the Northwest Territories and east into Alberta as the Bischto range. The Calendar range contains a single core area, also named Calendar. The Calendar range is the smallest of the five ranges at 5,411 km^2. The latest population count was 107 animals (Table 4), including 28 who were in the Northwest Territories. The rate of population change (lambda) was close to or at 1.00 in 2015 and 2016, indicating stable population trends. The recruitment rate was also approaching the target of 28 calves per 100 cows that is typically required for stable or increasing populations. Assuming that the low recruitment rate in 2014 was a rare, atypical event, the Calendar herd may be approaching stability.

Table 4. Minimum population counts, rate of population change (lambda) and recruitment rate for the Calendar herd (2013-2016)

Year	Minimum Population Count	Lambda[1]	Recruitment Rate
2013	135	--	35 calves:100 cows
2014	79	0.78	13 calves:100 cows
2015	81	0.97	22 calves:100 cows
2016	107[1]	1.00	26 calves:100 cows
Average	*101*	*0.92*	*24 calves:100 cows*

[1] Lambda was calculated as follows: [(annual adult female survival for all ranges combined) / 1-(Recruitment rate/100)/2]. Adult female survival per range should be used when these data are available.

2 POPULATION AND HABITAT GOALS

2.1 Population Goal

The population goal is to stabilize and achieve a self-sustaining Calendar herd. The herd population will be monitored to determine if the goal is being achieved.

2.2 Habitat Goal

The habitat goal is to maintain a positive habitat trend in the Calendar range. Levels of habitat disturbance and habitat restoration will be monitored to determine if the goal is being achieved. Approximately 0.2% of the Calendar range is in an early seral condition at present.

3 OBJECTIVES

The following objectives are to be applied in the Calendar range and core areas.

Forestry:

1. (F1) Establish an initial early seral habitat objective of <6% across the Calendar range.
2. (F2) Prohibit forest harvesting and road building in the Calendar core area.

Petroleum and Natural Gas (PNG) Development:

1. (P1) Require a net decrease in the density of linear features within the Calendar core by applying habitat offsets (initially 4:1) for future development impacts.
2. (P2) As a short-term solution, replace existing Resource Review Areas (RRAs) with better aligned RRAs over untenured portions of caribou core habitat, until incremental habitat protections are finalized.

Species Management and Wildfire:

1. (SM2) Manage wildfires in the Calendar range to minimize the creation of natural early seral forests

4 ACTIONS

The primary threats to Boreal Caribou in the Calendar range are disturbance from industrial development and predation risk. Recently stabilized population trends and recruitment rates suggests that population and predator management is not required at this time. Table 5 identifies the recommended actions that address the objectives in the Calendar range and/or core. These actions may change if monitoring indicates that adaptive management is required, or if there are changes to other strategic goals in the Province that affect Boreal Caribou.

Table 5. Actions that will address objectives in the Calendar Boreal Caribou range and the recommended application in range or core area.

Action	Objective(s) Addressed	Applicable Areas	
		Range	Core
Management of early seral forest	F1, SM2	✓	
Require no harvesting or road construction	F2		✓
Habitat restoration plan	P1	✓	✓
Restoration fund – broad scale restoration	P1	✓	✓
Habitat offsetting	P1		✓
Updated operating practices	P1		✓
RRA establishment	P2		✓
Predator management	n/a		
Population management	n/a		
Monitoring	n/a	✓	✓
Research	n/a	✓	✓
Adaptive management	n/a	✓	✓
Communications	n/a	✓	✓

4.1 Monitoring

The following monitoring (Table 6) will be conducted in the Calendar range; however, both the monitoring type and frequency may be amended depending on monitoring and research results, as well as other factors such as industrial pressures and funding availability.

Table 6. Initial monitoring and frequency for the Calendar range.

Monitoring	Initial Frequency
Deployment and maintenance of radio-collars on caribou	Maintenance of at least 5% of the estimated caribou population
Caribou Minimum Population Counts and Recruitment Surveys	Annual
Wolf Counts	Every three to five years, or as necessary
Length of linear features functionally and/or ecologically restored	Continuous tracking of restoration activities, but summarize every five years
Linear feature density	Every one to five years
Amount of anthropogenic early seral habitat ≤40 years	Every five years
Habitat condition relative to ECCC criteria	Every five years

Results of monitoring will be made publically available through methods identified in a communication plan. Methods may include posting to a website, electronic and/or hardcopy reports, social media, or presentations.

APPENDIX B

PLAN FOR THE CHINCHAGA RANGE OF BOREAL CARIBOU IN BC

1 INTRODUCTION

The Chinchaga range is the southern-most Boreal Caribou range in BC, and extends east into Alberta. The Chinchaga range is the largest of the five Boreal Caribou ranges at 13,903 km^2. The range contains three cores areas: Milligan to the south, Etthithun in the centre, and Chinchaga North, a new core located in the extreme northwest corner of the range. The latest population count was 194 individuals with a rate of population change (lambda) just below 1.00 in 2016 (Table 7), indicating a slightly decreasing population. Recruitment rates have been consistently low, however, as confirmed through the overall declining population trend for the Chinchaga herd.

Table 7. Minimum population counts, rate of population change (lambda) and recruitment rate for the Calendar herd (2013-2016)

Year	Minimum Population Count	Lambda[1]	Recruitment Rate
2013	256	--	14 calves:100 cows
2014	214	0.77	10 calves:100 cows
2015	189	0.90	9 calves:100 cows
2016	194	0.96	18 calves:100 cows
Average	*213*	*0.88*	*13 calves:100 cows*

[1] Lambda was calculated as follows: [(annual adult female survival for all ranges combined) / 1-(Recruitment rate/100)/2]. Adult female survival per range should be used when these data are available.

2 POPULATION AND HABITAT GOALS

2.1 Population Goal

The population goal is to stabilize and achieve a self-sustaining Chinchaga herd. Because of continuing industrial pressures in this range (see Section 3), it is likely to be decades before the Chinchaga herd is self-sustaining. There is a high degree of uncertainty regarding the likelihood of when and if the Chinchaga herd may become self-sustaining. The herd population will be monitored to determine if the goal is being achieved.

2.2 Habitat Goal

The habitat goal is to maintain a stable habitat trend in the Chinchaga range. Because of socio-economic values, forestry activity could continue in accordance with the current management practices prescribed in existing UWR and WHA orders in the Milligan core area (Chinchaga Range). Although positive habitat trends are the ultimate goal, the likelihood of achieving the goal is somewhat dependent upon the level of forest harvesting that could occur in the Milligan core. Levels of habitat disturbance and habitat restoration will be monitored to determine if the goal is being achieved. The current proportion of the Chinchaga range in early seral condition is 2%.

3 OBJECTIVES

The following objectives are to be applied in the Chinchaga range and core areas.

Forestry:

1. (F1) Establish an early seral forest objective of <6% across the Chinchaga range
2. (F2) Prohibit forest harvesting and road building in the Etthithun and Chinchaga North cores. Maintain current management practices regarding forest harvesting and road building in the Milligan core.

Petroleum and Natural Gas (PNG) Development:

1. (P1) Require a net decrease in the density of linear features within the Etthithun, Chinchaga North, and Milligan core areas by applying habitat offsets (initially 4:1) for future development impacts.
2. (P2) As a short-term solution, replace the existing Resource Review Area (RRA) with better aligned RRAs over untenured portions of caribou core area, until incremental habitat protections are finalized.

Species Management and Wildfire:

1. (SM1) Determine if and where other non-habitat related management actions such as predator management and caribou population management (i.e., predator fencing) are required, feasible and supported by First Nations. Align predator management with the provincial Wolf Management Plan.
2. (SM2) Manage wildfires in the Chinchaga range to minimize the creation of natural early seral forests

4 ACTIONS

The primary threats to Boreal Caribou in the Chinchaga range are disturbance from industrial development and predation risk, with lesser threats from agriculture. The likelihood of forest harvesting, and oil and gas development occurring in the Chinchaga range over the next ten years is relatively high. When considered together with generally declining population trends and recruitment rates, as well as very high wolf densities, this suggests that population and predator management are required to achieve stable or increasing population trends. A large scale pen/predator fence is recommended as the most effective method of increasing survival of both calves and adult Boreal Caribou; wolf control within the range would also be required. Table 5 identifies the recommended actions that address the objectives in the Chinchaga range and cores. These actions may change if monitoring indicates that adaptive management is required, or if there are changes to other strategic goals in the Province that affect Boreal Caribou.

Table 8. Actions that will address objectives in the Chinchaga Boreal Caribou range and the recommended application in range or core area.

Action	Objective(s) Addressed	Applicable Areas	
		Range	Cores
Management of early seral forest	F1, SM2	✓	
Require no harvesting or road construction	F2		✓ Etthithun, Chinchaga North

Action	Objective(s) Addressed	Applicable Areas	
		Range	Cores
Habitat restoration plan	P1	✓	✓
Restoration fund – broad scale restoration	P1	✓	✓
Habitat offsetting	P1		✓
Updated operating practices	P1		✓
RRA establishment	P2		✓ Etthithun, Chinchaga North
Predator management	SM1	✓	✓
Population management	SM1		✓
Monitoring	n/a	✓	✓
Research	n/a	✓	✓
Adaptive management	n/a	✓	✓
Communications	n/a	✓	✓

4.1 Monitoring

The following monitoring (Table 9) will be conducted in the Chinchaga range; however, both the monitoring type and frequency may be amended depending on monitoring and research results, as well as other factors such as industrial pressures and funding availability.

Table 9. Initial monitoring and frequency for the Chinchaga range.

Monitoring	Initial Frequency
Deployment and maintenance of radio-collars on caribou	Maintenance of at least 5% of the estimated caribou population, plus collaring of individuals in predator fence.
Caribou Minimum Population Counts and Recruitment Surveys	Annual
Deployment of radio-collars on wolves	As required for predator management
Wolf Counts	Every three to five years, or as necessary
Length of linear features functionally and/or ecologically restored	Continuous tracking of restoration activities, but summarize every five years
Linear feature density	Every one to five years
Amount of anthropogenic early seral habitat ≤40 years	Every five years
Habitat condition relative to ECCC criteria	Every five years

Results of monitoring will be made publically available through methods identified in a communication plan. Methods may include posting to a website, electronic and/or hardcopy reports, social media, or presentations.

APPENDIX C

PLAN FOR THE MAXHAMISH RANGE OF BOREAL CARIBOU IN BC

1 INTRODUCTION

The Maxhamish range is the most northwesterly Boreal Caribou range in BC, and extends north into the Northwest Territories. The Maxhamish range contains three core areas: Kiwigana, Fortune, and Capot-Blanc. The Maxhamish range is the second smallest of the five ranges at 7,775 km^2. The latest minimum population count was 100 animals (Table 10). The recruitment rate in 2016 exceeded the threshold of 28 calves per 100 cows that is typically required for stable or increasing populations. Similarly, the rate of population change (lambda) was just above 1.00 in 2016, indicating slightly increasing populations. Assuming that the low recruitment rate in 2014 was a rare, atypical event, the Maxhamish herd may be approaching stability.

Table 10. Minimum population counts, rate of population change (lambda) and recruitment rate for the Maxhamish herd (2013-2016)

Year	Minimum Population Count	Lambda[1]	Recruitment Rate
2013	132	--	28 calves:100 cows
2014	102	0.77	10 calves:100 cows
2015	81	0.96	21 calves:100 cows
2016	100	1.02	29 calves:100 cows
Average	*104*	*0.92*	*22 calves:100 cows*

[1] Lambda was calculated as follows: [(annual adult female survival for all ranges combined) / 1-(Recruitment rate/100)/2]. Adult female survival per range should be used when these data are available.

2 POPULATION AND HABITAT GOALS

2.1 Population Goal

The population goal is to stabilize and achieve a self-sustaining Maxhamish herd. The herd population will be monitored to determine if the goal is being achieved.

2.2 Habitat Goal

The habitat goal is to maintain a positive habitat trend in the Maxhamish range. Levels of habitat disturbance and habitat restoration will be monitored to determine if the goal is being achieved. Early seral habitat currently accounts for 0.9% of the Maxhamish Boreal Caribou range.

3 OBJECTIVES

The following objectives are to be applied in the Maxhamish range and core areas.

Forestry:

1. (F1) Establish an initial early seral forest objective of <6% across the Maxhamish range.

2. (F2) Prohibit forest harvesting and road building in the Fortune, Capot-Blanc and Kiwigana core areas.
3. (alternate F2) Prohibit the creation of new early seral forest in core ranges unless an exception is granted.

Petroleum and Natural Gas (PNG) Development:

1. (P1) Require a net decrease in the density of linear features within the Fortune, Capot-Blanc and Kiwigana core areas by applying habitat offsets (initially 4:1) for future development impacts.
2. (P2) As a short-term solution, establish well-aligned RRAs over untenured portions of caribou core are, until incremental habitat protections are finalized.

Species Management and Wildfire:

1. (SM2) Manage wildfires in the Maxhamish range to minimize the creation of natural early seral forests.

4 ACTIONS

The primary threats to Boreal Caribou in the Maxhamish range are disturbance from industrial development and predation risk. Recently increasing population trends and recruitment rates suggests that population and predator management is not required at this time. Table 5 identifies the potential actions that could be applied in the Maxhamish range and/or Kiwigana, Fortune, or Capot-Blanc cores.

Table 11. Potential management actions for the Maxhamish Boreal Caribou range and cores.

Action	Objective(s) Addressed	Applicable Areas	
		Range	Cores
Management of early seral forest	F1, SM2	✓	TBD
Require no harvesting or road construction	F2		TBD
Habitat restoration plan	P1	✓	✓
Restoration fund – broad scale restoration	P1	✓	✓
Habitat offsetting	P1		✓
Updated operating practices	P1		✓
RRA establishment	P2		✓
Predator management	n/a		
Population management	n/a		
Monitoring	n/a	✓	✓
Research	n/a	✓	✓
Adaptive management	n/a	✓	✓
Communications	n/a	✓	✓

4.1 Monitoring

The following monitoring (Table 12) will be conducted in the Maxhamish range; however, both the monitoring type and frequency may be amended depending on monitoring and research results, as well as other factors such as industrial pressures and funding availability.

Table 12. Initial monitoring and frequency for the Maxhamish range.

Monitoring	Initial Frequency
Deployment and maintenance of radio-collars on caribou	Maintenance of at least 5% of the estimated caribou population,
Caribou Minimum Population Counts and Recruitment Surveys	Annual
Wolf Counts	Every three to five years, or as necessary
Length of linear features functionally and/or ecologically restored	Continuous tracking of restoration activities, but summarize every five years
Linear feature density	Every one to five years
Amount of anthropogenic early seral habitat ≤40 years	Every five years
Habitat condition relative to ECCC criteria	Every five years

Results of monitoring will be made publically available through methods identified in a communication plan. Methods may include posting to a website, electronic and/or hardcopy reports, social media, or presentations.

APPENDIX D

PLAN FOR THE SNAKE-SAHTANEH RANGE OF BOREAL CARIBOU IN BC

1 INTRODUCTION

The Snake-Sahtaneh range is centrally located within the extent of Boreal Caribou in BC, and is entirely contained within the province. The Snake-Sahtaneh range is the second largest range at 12,301 km^2, and contains six core areas: Tsea, Etsho, Kotcho, Shush Creek, Paradise, and Clarke. The latest minimum population count was 280 individuals (Table 13), with a recruitment rate of 18 calves per 100 cows, which is considerably below the target of 28 calves per 100 cows that is typically required for stable or increasing populations. However, although the rate of population change is just below 1.00, if adult female survival is relatively high and the low recruitment rate of 2014 is a rare, atypical event, the Snake-Sahtaneh herd may be approaching stability.

Table 13. Minimum population counts, rate of population change (lambda) and recruitment rate for the Snake-Sahtaneh herd (2013-2016)

Year	Minimum Population Count	Lambda[1]	Recruitment Rate
2013	321	--	24 calves:100 cows
2014	241	0.77	11 calves:100 cows
2015	258	0.95	18 calves: 100 cows
2016	280	0.96	18 calves:100 cows
Average	*275*	*0.89*	*18 calves:100 cows*

[1] Lambda was calculated as follows: [(annual adult female survival for all ranges combined) / 1-(Recruitment rate/100)/2]. Adult female survival per range should be used when these data are available.

2 POPULATION AND HABITAT GOALS

2.1 Population Goal

The population goal is to stabilize and achieve a self-sustaining Snake-Sahtaneh herd. The herd population will be monitored to determine if the goal is being achieved.

2.2 Habitat Goal

The habitat goal is to maintain a positive habitat trend in the Snake-Sahtaneh range. Levels of habitat disturbance and habitat restoration will be monitored to determine if the goal is being achieved. Approximately 1.1% of the Snake-Sahtaneh caribou range is in an early seral condition at present.

3 OBJECTIVES

The following objectives are to be applied in the Snake-Sahtaneh range and core areas.

Forestry:

1. (F1) Establish an initial early seral forest objective of <6% across the Snake-Sahtaneh range.
2. (F2) Prohibit forest harvesting and road building in the Tsea, Etsho, Kotcho, Shush Creek, Paradise, and Clarke core areas.

Petroleum and Natural Gas (PNG) Development:

1. (P1) Require a net decrease in the density of linear features within the Tsea, Etsho, Kotcho, Shush Creek, Paradise, and Clarke core areas by applying habitat offsets (initially 4:1) for future development impacts.
2. (P2) As a short-term solution, establish well-aligned RRAs over untenured portions of caribou core areas, until incremental habitat protections are finalized

Species Management and Wildfire:

1. (SM2) Manage wildfires in the Snake-Sahtaneh range to minimize the creation of natural early seral forests.

4 ACTIONS

The primary threats to Boreal Caribou in the Snake-Sahtaneh range are disturbance from industrial development and predation risk. It is recommended that population and predator management is not required at this time. Table 5 identifies the recommended actions that address the objectives in the Snake-Sahtaneh range and/or core areas. These actions may change if monitoring indicates that adaptive management is required, or if there are changes to other strategic goals in the Province that affect Boreal Caribou.

Table 14. Actions that will address objectives in the Snake-Sahtaneh Boreal Caribou range and the recommended application in range or core area.

Action	Objective(s) Addressed	Applicable Areas	
		Range	Cores
Management of early seral forest	F1, SM2	✓	
Require no harvesting or road construction	F2		✓
Habitat restoration plan	P1	✓	✓
Restoration fund – broad scale restoration	P1	✓	✓
Habitat offsetting	P1		✓
Updated operating practices	P1		✓
RRA establishment	P2		✓
Predator management	n/a		
Population management	n/a		
Monitoring	n/a	✓	✓
Research	n/a	✓	✓
Adaptive management	n/a	✓	✓
Communications	n/a	✓	✓

4.1 Monitoring

The following monitoring (Table 15) will be conducted in the Snake-Sahtaneh range; however, both the monitoring type and frequency may be amended depending on monitoring

and research results, as well as other factors such as industrial pressures and funding availability.

Table 15. Initial monitoring and frequency for the Snake-Sahtaneh range.

Monitoring	Initial Frequency
Deployment and maintenance of radio-collars on caribou	Maintenance of at least 5% of the estimated caribou population
Caribou Minimum Population Counts and Recruitment Surveys	Annual
Wolf Counts	Every three to five years, or as necessary
Length of linear features functionally and/or ecologically restored	Continuous tracking of restoration activities, but summarize every five years
Linear feature density	Every one to five years
Amount of anthropogenic early seral habitat ≤40 years	Every five years
Habitat condition relative to ECCC criteria	Every five years

Results of monitoring will be made publically available through methods identified in a communication plan. Methods may include posting to a website, electronic and/or hardcopy reports, social media, or presentations.

APPENDIX E

PLAN FOR THE WESTSIDE FORT NELSON RANGE OF BOREAL CARIBOU IN BC

1 INTRODUCTION

The Westside Fort Nelson range is a newly delineated range composed of former Parker and Prophet Boreal Caribou ranges, and the area between Parker and south of the Fort Nelson River. The Westside Fort Nelson range is adjacent to the Muskwa northern mountain caribou range. The Westside Fort Nelson range is 8,664 km^2 in size, and contains three core areas: Prophet, Parker, and Fort Nelson. Population metrics for this new herd have not been previously calculated, but data from the component core areas were combined and summarized (Table 16). Minimum population counts for the Westside Fort Nelson herd have always been relatively small, but reached an all-time low in 2016 at 47 animals, representing a decline of 56% since 2013. Recruitment rates have similarly been consistently low at an average of 12 calves per 100 cows, far below the target of 28 calves per 100 cows recommended for a stable or increasing caribou population.

Table 16. Minimum population counts, rate of population change (lambda) and recruitment rate for the Westside Fort Nelson herd (2013-2016)

Year	Minimum Population Count	Lambda[1]	Recruitment Rate
2013	108	--	9 calves:100 cows
2014	87	0.80	17 calves:100 cows
2015	69	0.90	8 calves:100 cows
2016	47	0.93	13 calves:100 cows
Average	*78*	*0.88*	*12 calves:100 cows*

[1] Lambda was calculated as follows: [(annual adult female survival for all ranges combined) / 1-(Recruitment rate/100)/2]. Adult female survival per range should be used when these data are available.

2 POPULATION AND HABITAT GOALS

2.1 Population Goal

The population goal is to stabilize and achieve a self-sustaining Westside Fort Nelson herd. The herd population will be monitored to determine if the goal is achieved.

2.2 Habitat Goal

The habitat goal is to maintain a positive habitat trend in the Westside Fort Nelson range. Levels of habitat disturbance and habitat restoration will be monitored to determine if the goal is being achieved. Early seral habitat currently accounts for 4.7% of the Westside Fort Nelson Boreal Caribou range.

3 OBJECTIVES

The following objectives are to be applied in the Westside Fort Nelson range and core areas.

Forestry:

1. (F1) Establish an early seral forest objective of <6% across the Westside Fort Nelson range. This objective is subject to change pending the results of a FLNR analysis of forestry impacts and management options.
2. (F2) Prohibit forest harvesting and road building in the Fort Nelson, Parker and, Prophet core areas, unless interest is shown in significant forest harvesting in the future.
3. (alternate F2) Prohibit the creation of new early seral forest in core ranges unless an exception is granted.

Petroleum and Natural Gas (PNG) Development:

1. (P1) Require a net decrease in the density of linear features within the Fort Nelson, Parker, and Prophet core areas by applying habitat offsets (initially 4:1) for future development impacts.
2. (P2) As a short-term solution, replace the existing Resource Review Area (RRA) in the Prophet core area with better aligned RRAs over untenured portions of caribou core habitat, until incremental habitat protections are finalized.

Species Management and Wildfire:

1. (SM1) Determine if and where other non-habitat related management actions such as predator management and caribou population management (i.e., predator fencing) are required, feasible and supported by First Nations. Align predator management with the provincial Wolf Management Plan.
2. (SM2) Manage wildfires in the Westside Fort Nelson range to minimize the creation of natural early seral habitat.

4 ACTIONS

The primary threats to Boreal Caribou in the Westside Fort Nelson range are disturbance from industrial development and predation risk. Drastic recent declines in population numbers and high wolf densities indicate that population and predator management are required to achieve stable or increasing population trends. A large scale pen/predator fence is recommended as the most effective method of increasing survival of both calves and adult boreal caribou; wolf control within the range would also be required. Table 17 identifies the potential actions that could be applied in the Westside Fort Nelson range and cores.

Table 17. Potential management actions for the Westside Fort Nelson Boreal Caribou range and cores.

Action	Objective(s) Addressed	Applicable Areas	
		Range	Cores
Management of early seral forest	F1, SM2	✓	
Require no harvesting or road construction	F2		✓
Habitat restoration plan	P1	✓	✓
Restoration fund – broad scale restoration	P1	✓	✓
Habitat offsetting	P1		✓
Updated operating practices	P1		✓
RRA establishment	P2		✓

Action	Objective(s) Addressed	Applicable Areas	
		Range	Cores
Predator management	SM1	✓	
Population management	SM1		✓
Monitoring	n/a	✓	✓
Research	n/a	✓	✓
Adaptive management	n/a	✓	✓
Communications	n/a	✓	✓

4.1 Monitoring

The following monitoring (Table 18) will be conducted in the Westside Fort Nelson range; however, both the monitoring type and frequency may be amended depending on monitoring and research results, as well as other factors such as industrial pressures and funding availability.

Table 18. Initial monitoring and frequency for the Westside Fort Nelson range.

Monitoring	Initial Frequency
Deployment and maintenance of radio-collars on caribou	Maintenance of at least 5% of the estimated caribou population, plus collaring of individuals in predator fence.
Caribou Minimum Population Counts and Recruitment Surveys	Annual
Deployment of radio-collars on wolves	As required for predator management
Wolf Counts	Every three to five years, or as necessary
Length of linear features functionally and/or ecologically restored	Continuous tracking of restoration activities, but summarize every five years
Linear feature density	Every one to five years
Amount of anthropogenic early seral habitat ≤40 years	Every five years
Habitat condition relative to ECCC criteria	Every five years

Results of monitoring will be made publically available through methods identified in a communication plan. Methods may include posting to a website, electronic and/or hardcopy reports, social media, or presentations.

APPENDIX F

Limits on early seral habitat for ungulates can constrain timber harvest opportunities

Background:

Predation, primarily by wolves, is considered the proximal constraint on caribou recovery in BC. Anthropogenic changes to landscapes have disturbed the historical balance between caribou, moose and wolves. Land clearing can cause a numerical (i.e. change in numbers) or functional (i.e. change in behaviour or activity) response in moose and wolves. Called "apparent competition", this changed relationship can result in unsustainable predation pressure on caribou.

The numerical response arises from an increase in forage (habitat quality) for moose, and other ungulates like deer and elk, when forest cover is removed. The resultant "early seral forest"has an abundant supply of shrubs and deciduous trees, prime forage for moose. Moose may be attracted to these areas, spend more time using them and have increased productivity. The resultant increased moose biomass is an enhanced food supply for wolves. These areas can see increased wolf density and increased predation pressure on ungulates in the area. When this situation arises in or near caribou habitat, caribou in the area can be faced with un-sustainable wolf predation.

The functional response arises from increased use of caribou habitat: by moose due to improved forage; and by wolves due to improved access. Land clearing, especially linear features like roads, pipelines and seismic lines, can increase the speed and mobility of wolves, improving their hunting efficiency. Where linear features occur in caribou habitat, this enables greater use of that habitat by wolves, more encounters with caribou and increased mortality risk. Linear features may also contribute to the numerical response, but their major affect is to improve wolf hunting efficiency. Where increased early seral forage due land clearing in caribou habitat "attracts and retains" moose, wolves have increased incentive (i.e. positive feedback) to hunt in caribou habitat.

An objective of the revised BCIP is to manage early seral forest in caribou range and core to avoid improving the quality of moose habitat and subsequent increase in local moose numbers/density (numerical response), or attracting moose and wolves into caribou habitat (overlap or functional response).

Discussion:

Early seral habitat is typically defined as forest that is less than 40 years old, resulting either from human disturbance or wildfire (Environment Canada 2012). In northeastern BC, the primary concern is the increase and/or attraction of moose to early seral forest, and subsequently an increase in wolves using caribou range, thereby increasing the risk of

predation on caribou. Therefore, the characteristics of early seral forest relevant to conserving/recovering boreal caribou in BC are those that improve moose habitat quality.

Wilson (in preparation) completed modelling to help determine the amount of early seral forest type in a caribou range that would limit the increase in moose. The model uses literature available on the relationship of wolf density to caribou recruitment, and set a wolf density target to permit caribou recovery. The model incorporated the relationship between ungulate prey abundance and wolf populations and recent work on prey biomass-wolf density equations. A relationship between ungulate biomass and the abundance of early seral habitat was derived from unpublished survey data, estimates of ungulate biomass, and estimates of early seral habitat abundance from regional studies conducted in the boreal forest in western Canada. As such, the model can characterize the main elements of "apparent competition" that is limiting caribou recovery.

The management model predicted that stable woodland caribou populations could be achieved or maintained in all six BC ranges if the proportion of early seral habitat remains approximately 5-6% of the range area. This threshold for early seral is inclusive of all human and natural (i.e. fire) caused land clearing. However, for application in a revised implementation plan for boreal caribou, this threshold would only be applied to commercial forest harvesting. The model also provided metrics that would need to be achieved for direct manipulation of wolf or prey (moose) densities to enable caribou recovery.

Moose show a preference for forage within early seral habitats. Moose forage primarily on a range of deciduous trees and shrubs with a preference for willow species, red-osier dogwood, Saskatoon and aspen. The preferred shrub species tend to be most abundant in seral stage deciduous stands less than 20 years old following tree harvest or fire. Timber harvesting also creates early seral habitats that typically attract moose.

Early seral moose habitat can be defined as having the following characteristics:

1. Typically less than 40 years old, and may be less than 20 years old.
2. Dominated by deciduous trees and shrubs.
3. Dense shrub layer, dominated by species preferred by moose.
4. Open tree canopy (less than 30%).
5. Can be human-made or wildfire.

The models recommended limits on early seral forest (i.e. < 40 years old) may be relaxed somewhat if licensees can meet several key objectives in conifer leading blocks to reduce the quality of moose habitat in boreal caribou range:

1. Prevent growth of shrub species preferred by moose, such as willows, red-osier dogwood, Saskatoon, poplar and aspen through brushing treatments completed before a conifer plantation is 5 years old and closely monitoring the stand for brush development.

2. Minimal growth of all deciduous trees and shrubs within harvested openings that are conifer leading.
3. Rapid regrowth of coniferous trees through re-planting conifer seedlings the summer after harvest to help avoid early brush establishment.
4. Achieve canopy coverage that deters shrub growth as quickly as possible by planting larger stock conifers as well as planting at higher than required densities to help ensure early establishment and earlier crown closure.
5. Achieve stands with heights of at least 3.0 m (moose can reach up to 2.5 m; MELP 2000).
6. Achieve conifer stands with a crown closure of >30%

Operational Guidance

The objectives can largely be met through meeting **green-up requirements**, with slight modifications to reflect the specific wildlife values under consideration.

1. Cutblocks should be adequately stocked with 1,000 commercially valuable trees per hectare of at least 1.3 m in height. To minimize moose browse, only coniferous species should be used.
2. Green-up of height of at least 3 m is required, based on the average height of the tallest trees.
3. Green-up requirements must be met on at least 75% of the net area.
4. S68(7)(a) – exclude deciduous from determination of green-up height.

A harvested opening is no longer considered early seral and has attributes not desirable to moose when:

1. 75% of a harvested opening has conifer trees at least 3.0m tall;
2. The opening has met the free growing standard established in the site plan, and;
3. Crown closure is >30%.

Mitigation measures and best management practices are currently under development to assist licencees in meeting the objectives. In general, cutblocks should mimic openings created by natural disturbance wherever possible, and have some or all of the following characteristics (Province of British Columbia 1999):

1. Wildlife trees individually and/or in patches
2. Coarse woody debris
3. Irregular edges
4. Regeneration by a mixture of tree species (preferably coniferous for caribou management)
5. Naturally occurring understorey species (avoiding preferred moose species)
6. Individual trees or patches of trees.

Wildfire

Early seral forage created from wildfire is another issue that needs to be addressed to achieve caribou recovery. This natural phenomenon remains a challenge to effectively manage. Discussion is needed with wildfire managers to explore means to decrease the amount of early seral forage by wildfire. Similar to management of anthropogenic clearing, aggressive and timely reforestation/restoration of habitat areas affected by wildfire may mitigate some of the impact on forage production

Conclusion:

The apparent competition relationship between caribou, wolves and their primary prey (i.e. moose) can be disrupted by management action to reduce wolves, moose or moose forage. Modelling of this relationship suggests that if early seral forest habitat is limited to 5-6% of the range, caribou recovery may be enabled. If additional silviculture treatments, focussed at reducing or inhibiting moose forage, are deployed, this limit could be higher. Direct removal of wolves or moose will also enable caribou recovery and may be necessary in the short to medium term to support habitat management.

APPENDIX G

A model to inform woodland caribou management and policy in northeast British Columbia, Canada

Steven F. Wilson[1]

[1]Boreal Caribou Research and Effectiveness Monitoring Board, 300-390 Harbour Road, Victoria, BC V9A OB7, Canada (Corresponding author: steven.wilson@ecologicresearch.ca).

Abstract: I developed a management model to identify expected benefits of actions aimed at improving population outcomes for woodland caribou *(Rangifer tarandus caribou)* in northeast British Columbia, Canada. The model was structured as a Bayesian Belief Network (BBN) that graphically presented the landscape and predator-prey system as assumed cause and effect relationships among major variables, with parameters based on published empirical relationships, available inventory data and expert opinion. Model output predicted that a land use policy that restricts the creation of early seral habitat to approximately 5-6% of ranges could stabilize local populations. Model output was less sensitive to linear feature density than to the proportion of early seral habit, although this was dependent on assumptions regarding the relationship between linear feature density and the efficiency of wolves in exploiting caribou prey. Management models based on BBNs can be valuable for evaluating the expected outcomes of actions where systems are complex and relationships uncertain.

Key words: woodland caribou, British Columbia, management, Bayesian BeliefNetworks

Introduction

While biologists continue to research the status and ecology of woodland caribou *(Rangifer tarandus caribou),* linking research results to better conservation outcomes through improved decision-making remains a consistent challenge (McNay *et al.*, 2006; Conroy & Peterson, 2013). I developed a management model to inform investments in actions to benefit local populations of woodland caribou in northeast British Columbia, Canada. The model was designed to improve the effectiveness, efficiency and transparency of decision-making, to improve the allocation of scarce resources, and to maximize the likelihood of positive conservation outcomes.

Materials and methods

Study Area

The focus of this study was on woodland caribou inhabiting the boreal plains of northeast British Columbia (BC; Fig. 1). Six local populations totalling approximately 1200 caribou are recognized in the region (Environment Canada, 2012). Although limited population trend data are available, previous analyses have suggested that none of the local populations is considered self-sustaining, based on a risk analysis of available information (Environment Canada, 2012). Woodland caribou in northeast BC are continuous with the range of caribou in the Northwest Territories and Alberta. Collectively with the broader population inhabiting Canada's boreal forest, woodland caribou are designated as *Threatened* under Canada's *Species at Risk Act* (COSEWIC, 2002).

Management Model

The management model was developed as a Bayesian Belief Network (BBN; Marcot *et al.*, 2001; 2006), which graphically represents systems as a series of variables or "nodes," that can exist in discrete "states," with assumed cause and effect relationships being represented by directional links between nodes and parameterized as conditional probabilities (Marcot 2006).

A management model is designed as a support tool that attempts to capture the major elements of a system and their interactions to inform decision-making. As a result, management models focus on predicting the likely responses of a system to management interventions in relation to explicit objectives and constraints. This is an essential step in structured decision-making (Conroy and Peterson, 2013). Management models are not a substitute for purely ecological models that characterize or simulate the dynamics of systems, but compliment them by focusing on the translation of ecological knowledge into predicted management consequences (Marcot *et al.*, 2001).

I based the management model on the emerging consensus that predation by wolves *(Canis lupus)* is the principal proximate factor driving woodland caribou declines (Bergerud, 1988; Seip, 1992; Wittmer *et al.*, 2005). Specifically I addressed two hypotheses regarding the link between landscape condition and caribou demography:

1. increasing populations of moose *(Alces alces)* and white-tailed deer *(Odocoileus virginianus)* caused by habitat change (primarily forestry, agriculture or wildfire; Latham *et al.*, 201la) result in more abundant wolves, which then results in the decline of woodland caribou through

incidental encounters (Seip, 1992; Lessard 2005; Wittmer *et al.*, 2005; Mccutchen 2007); and,

2. linear features (primarily roads and seismic lines) facilitate travel by wolves into caribou habitat, reducing spatial separation with woodland caribou and increasing predation rates (James and Stuart-Smith, 2000; McCutchen, 2007; Mackenzie *et al.*, 2012).

These hypotheses are not exclusive nor do they capture all of the pathways to decline in woodland caribou populations. For example, wolves are not the only predators of woodland caribou (e.g., Gustine *et al.*, 2009; Latham *et al.*, 2011b) and populations might be affected by disease, nutrition, disturbance or other stressors (e.g. Wasser *et al.*, 2011). Again, the resulting management model is intended to capture the major elements of the system, with emphasis on those factors under meaningful management influence. For woodland caribou, this includes land use policy, hunting and trapping management, as well as more intensive techniques such as caribou population augmentation (e.g., maternity penning; Smith & Pittaway 2008) or predator control (Boertje *et al.*, 1996; Hayes *et al.*, 2003).

Model Parameters

Where available, empirical relationships from meta-analyses of caribou research were used to define the conditional probabilities linking nodes of the management model. I used equations relating wolf density to caribou recruitment and survival derived by Bergerud's (1988) in his review of barren ground and woodland *Rangifer tarandus* populations. To characterize the

relationship between ungulate prey abundance and wolf populations I used the biomass-wolf density equation developed by Kuzyk & Hatter *(in press),* which was based on previous work by Fuller *et al.* (2003) and Keith (1983).

The responses of moose and white-tailed deer to early seral habitat (defined as areas subject to timber harvesting or wildfire occurring during the past 40 years, following Environment Canada, 2012) are well researched (e.g., Rempel *et al.,* 1997; Kie *et al.,* 2003; Cote *et al.,* 2004; Fisher & Wilkinson, 2005; Potvin *et al.,* 2005; Bowman *et al.,* 2010); however, a meta-analysis of the relationship between ungulate biomass and the abundance of early seral habitat was not available. I used unpublished survey data, estimates of ungulate biomass, and estimates of early seral habitat abundance from regional studies conducted in the boreal forest of northeast BC and northern Alberta to characterize the relationship (West Central Alberta Caribou Landscape Planning Team, 2008; Athabasca Landscape Team, 2009; Thiessen, 2010; McNay *et al.,* 2013; BC Ministry of Forests, Lands and Natural Resource Operations, *unpublished data;* Fig. 2). Because only moose survey data were available for northeast BC, I inflated the estimates of ungulate biomass for ranges in the region to reflect the relative abundance of other ungulate species, based on regional estimates of ungulate populations and their biomass values (Kuzyk & Hatter *in press;* BC Ministry of Forests, Lands and Natural Resource Operations, *unpublished data).* This adjustment reduced the slope of the relationship and effectively made the model less sensitive to the relationship.

115 Available vintages of data varied among sources; however, most were collected
116 from 2001-2014. Mean values collected over >5 years were used wherever
117 possible. Although range and population conditions changed over the time data
118 were collected, contrast among ranges was sufficient to reveal broad-scale
119 trends.
120 The component of the management model that could not be parameterized
121 based on a known empirical relationship was that between linear feature density
122 and the efficiency of predation on woodland caribou by wolves. Although
123 caribou may face a higher risk of predation closer to linear features (James &
124 Stuart-Smith 2000), and higher densities of linear features have been correlated
125 with caribou declines (Sorenson *et al.,* 2008; Environment Canada, 2012),
126 research to date has not demonstrated that the presence oflinear features
127 increases the efficiency with which wolves depredate caribou (Latham *et al.,*
128 201lc; DeCesare, 2012). Despite this lack of definitive empirical evidence I
129 included the relationship in the model because of the broader correlative
130 (Sorenson *et al.,* 2008; Environment Canada, 2012) and theoretical evidence
131 that suggests the functional response (e.g., Lessard, 2005; Mccutchen, 2007;
132 McKenzie *et al.,* 2012).
133 Wolf efficiency was modelled as a function oflinear feature density, modified
134 by two additional parameters: linear feature *saturation,* to reflect the hypothesis
135 that, at some point the addition of linear features no longer increases wolf
136 efficiency; and a wolf efficiency *constant,* which indicates the maximum
137 proportional increase in predation on caribou adults and calves that could result
138 with the addition of linear features to the landscape. Wolf efficiency was

assumed to increase linearly with linear feature density to a maximum equal to the wolf efficiency *constant* at the linear feature *saturation* density (Fig. 3). Because limited information was available to inform these parameters, different states were assigned different probabilities in model runs *(constant:* 25% 0, 50% 0.25, 25% 0.5; *saturation:* 25% 1, 50% 2, 25% 4 km/km^2; Fig. 4). The resulting BBN model (Fig. 4) was run for each of the six woodland caribou ranges in northeast BC to predict current and future trends in populations under current and potential future landscape and predator-prey conditions. The sensitivity of predictions was measured by the expected reduction in variation in the output node (lambda) due to the conditional probability structure of the BBN among all possible values of parent nodes (Marcot *et al.*, 2006).

Results

Model output (lambda) was most sensitive to early seral, wolf density and prey density inputs, and sensitivities were similar among these variables because of the deterministic relationships among them (Fig. 5). Model output was relatively insensitive to linear feature density and the assumed density at which wolf efficiency reached its maximum (i.e., *saturation),* but was more sensitive to the maximum proportional increase in predation on caribou expected with the addition of linear features to the landscape (i.e., *constant).*

The management model predicted that, under current conditions in northeast BC, the population growth rate in the Calendar local population should be> 1, while rates in the Maxhamish, Prophet and Snake-Sahtaneh local populations

are predicted to not differ significantly from 1. Conditions in the Chinchaga and Parker ranges are consistent with population growth rates of <1 (Fig. 6). Modelled population growth rates did not differ significant from observed rates for local populations where data were sufficient to calculate an average lambda for at least 5 years, including Alberta ranges (2001-2008; http://www.albertacaribouccommittee.ca) and the Maxhamish range in BC (2010-2014; BC Ministry of Forests, Lands and Natural Resource Operations, *unpublished data)*.

The management model predicted that stable woodland caribou populations could be achieved or maintained in all six BC ranges if the proportion of early seral habitat remains approximately 5-6% of the landscape (Fig. 7). Reducing the density of linear features alone is predicted to be insufficient to significantly alter population trajectories. Increasing the hypothesized value of *constant* increases the modelled impact of linear feature density but also generates lambdas that significantly underestimate observed population growth rates for AB and BC local populations.

Rather than, or in additional to managing habitat, the management model predicts that population growth rates could be improved through direct manipulation of wolf or prey densities. Reducing the density of ungulate prey to 0.10-0.15 moose equivalents/km^2 from current densities of>0.20 is predicted to stabilize growth rates in both Chinchaga and Parker ranges. Reducing wolves to <5/1000 km^2 is predicted to have a similar impact.

Discussion

Effective decision-making in resource management requires explicit predictions regarding the outcomes of proposed actions. Rarely do the results of statistical tests from research studies provide these predictions, particularly in complex systems. The benefit of the management model is that it captures what is assumed to be the most critical elements of the system driving woodland caribou population dynamics in a way that can be understood by stakeholders and decision-makers, while generating testable predictions.

BBNs have desirable characteristics that make them particularly well suited for this type of modelling (Marcot *et al.,* 2001). They present a system as both a causal graph and quantitatively as probabilistic relationships among variables. This allows intuitive interpretation of both the hypothesized structure of a system, its consequent predictions, as well as the uncertainty associated with predicted outcomes. BBNs are also very flexible and can use parameters derived from empirical data, expert opinion, or both (e.g., Borsuk *et al.,* 2004; Kuhnert *et al.,* 2010).

Although the management model was based primarily on empirically derived relationships and inventory data, expert opinion was used to design the network topology, the assumed cause and effect relationships among variables, as well as the poorly understood relationship (Latham *et al.,* 201lc; DeCesare, 2012) between linear feature density and the efficiency of wolf predation on caribou.

The use of expert opinion specifically, and Bayesian approaches more generally, are controversial for a variety of epistemological reasons (e.g., Dennis, 1996; Lele and Allen, 2006). While the approach may or may not

generate more reliable predictions than strictly empirical analyses based on frequentist statistical methods, it does have the advantage of providing an explicit and transparent framework for decision-making based on existing information. The alternative is to delay decisions until sufficient data become available, which could carry higher costs than taking decisive action under conditions of uncertainty (Kuhnert *et al.,* 2010).

Parsimony is important when developing management models because ecological systems are complex, and attempting to capture all variables and interactions can generate opaque or intractable models that are difficult to interpret. Complex models also ignore the fact that most management levers aimed at altering ecological systems (e.g., land use policies, hunting regulations) are relatively blunt and are intended to generate coarse-scale results. Still, woodland caribou are part of a complex ecological system and there are factors that the management model ignores, based on the assumption that they are relatively minor drivers in the system. These include the roles of other prey (e.g., beaver; Latham *et al.,* 2013), predators (e.g., wolverines; Gustine *et al.,* 2009), disturbance (e.g., Dyer *et al.,* 2001), stress and nutrition (Wasser *et al.,* 2011). Hence, it is important to test alternative hypotheses and to estimate their relative importance to minimize the risk of unintended consequences when implementing management actions.

As currently structured the management model suggests that the abundance of early seral habitat is a more important driver than linear feature density; however, the relationship between linear features and wolf efficiency was

largely hypothesized. Increasing the sensitivity of the model to this factor significantly reduced the fit of the model to observed population growth rates, but this nevertheless remains one of the key uncertainties that required further investigation.

The management model generated testable predictions regarding current population trends and expected future trends under different landscape conditions and predator-prey circumstances. Forecasts generated targets for early seral habitat (5-6% of ranges) that could form the basis of a revised land use policy in northeast BC. Managing the habitat of moose and deer to benefit woodland caribou has been recommended in other portions of their range in BC (e.g., Seip & Ritchie, 2010; Serrouya *et al.*, 2011, Apps *et al.*, 2013) but this study presents the first proposed targets for habitat management aimed at boreal ranges. These targets would need to be applied to areas larger than just core portions of woodland caribou habitat because the risk of predation could be affected by "spill-over" effects from surrounding areas (Holt 1984).

The model also proposes targets for ungulate prey density, if managers prefer direct population management to indirect management through land use policy, a strategy also employed elsewhere in BC (Serrouya, 2013). Wolf removal or caribou population augmentation can also be accommodated in model predictions. Local circumstances will dictate the mix of management actions that are most likely to meet conservation objectives and the management model will be used to predict the expected benefits of alternative management regimes and policies. An ongoing commitment to inventory and research will be

253 required to measure outcomes and to refine the model to ensure that
254 investments in management actions are optimized.
255 The current and forecasted growth rates predicted by the management model
256 were more optimistic than those previously derived from correlations between
257 landscape conditions and indices of woodland caribou demography
258 (Environment Canada, 2012). Additional inventory is required to determine
259 which approach provides predictions that most accurately reflect current
260 population trends in BC local populations; however, the management model
261 provides the opportunity to explore different function pathways and the
262 potential benefits of different management interventions, which is something
263 not possible with a simple correlative model.

264 Acknowledgments

265 I thank Tyler Colberg and Chris Niziolomski for assistance with data
266 compilation. Brad Culling, Diane Culling, Craig DeMars, Scott Grindal,
267 Conrad Thiessen and Scott Wagner provided comments on earlier versions of
268 the model and manuscript. Funding was provided by the Science and
269 Community Environmental Knowledge (SCEK) Fund.

270 References

271 **Apps, C.D., McLeHan, B.N., Kinley,** T.A., **Serrouya, R., Seip, D.R.** &
272 **Wittmer, H.U. 2013.** Spatial factors related to mortality and population
273 decline of endangered mountain caribou. - *Journal of Wildlife Management*
274 77: 1409-1419.

Athabasca Landscape Team. 2009. *Athabasca caribou landscape management options report.* www.albertacariboucommittee.ca/PDF/Athabasca-Caribou.pdf. 99pp.

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

Boertje, R.D. Valkenburg, P. & **Mcnay, M.E. 1996.** Increases in moose, caribou, and wolves following wolf control in Alaska. - *Journal of Wildlife Management* 60: 474-489.

Borsuk, M.E., Stow, C.A. & **Reckhow, K.H. 2004.** A Bayesian network of eutrophication models for synthesis, prediction, and uncertainty analysis. - *Ecological Modelling* 173: 219-329.

Bowman, J., Ray, J.C., Magoun, A.J., Johnson, D.S. & **Dawson, F.N. 2010.** Roads, logging, and the large-mammal community of an eastern Canadian boreal forest. - *Canadian Journal of Zoology* 88: 454-467.

Conroy, M.J. & **Peterson, J.T. 2013.** Decision making in natural resource management: a structured, adaptive approach. Wiley-Blackwell, Oxford. 456pp.

COSEWIC. 2002. *COSEWJC assessment and update status report on the woodland caribou* Rangifer tarandus caribou *in Canada.* Committee on the Status of Endangered Wildlife in Canada. Ottawa. 98pp.

Cote, S.D., Rooney, T.P., Tremblay, J.-P., Dussault, C. & **Waller, D.M. 2004.** Ecological impacts of deer overabundance. - *Annual Review of Ecology, Evolution and Systematics* 35: 113-147.

DeCesare, N.J. 2013. Separating spatial search and efficiency rates as components of predation risk. - *Proceedings of the Royal Society of London Series B* 279: 4626-4633.

Dennis, B. 1996. Discussion: should ecologists become Bayesians? - *Ecological Applications* 6: 1095-1103.

Dyer, S.J., O'Neill, J.P., Wasel, S.M. & **Boutin, S.2001.** Avoidance of industrial development by woodland caribou. -*Journal of Wildlife Management* 65: 531-542.

Environment Canada. 2012. *Recovery strategy for the woodland caribou* (Rangifer tarandus caribou), *boreal population, in Canada*. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa. 138pp.

Fisher, J.T. & **Wilkinson, L. 2005.** The response of mammals to forest fire and timber harvest in the North American boreal forest. - *Mammal Review* 35: 51-81.

Fuller, T.K., Mech, L.D. & **Cochrane, J.F. 2003.** Wolf population dynamics. -*In:* L.D. Mech & L. Boitani (Eds.). *Wolves: behavior, ecology, and conservation.* University of Chicago Press, Chicago. pp. 161-191.

Gustine, D.D., Parker, K.L., Lay, R.J., Gillingham, M.P. & **Heard, D.C. 2009.** Calf survival of woodland caribou in a multi-predator ecosystem. - *Wildlife Monographs* 165: 1-165.

Hayes, R.D., Farnell, R. Ward, R.M.P., Carey, J. Dehn, M., Kuzyk, G.W., Baer, A.M., Gardner, C.L. & **O'Donoghue, M. 2003.** Experimental

reduction of wolves in the Yukon: ungulate responses and management implications. - *Wildlife Monographs* 152: 1-35.

Holt, R.D. 1977. Predation, apparent competition, and the structure of prey communities. -*Theoretical Population Biology* 12: 197-229.

Holt, R.D. 1984. Spatial heterogeneity, indirect interactions, and the coexistence of prey species. -*American Naturalist* 124: 377-406.

James, A.R.C. & **Stuart-Smith, A.K. 2000.** Distribution of caribou and wolves in relation to linear corridors. -*Journal of Wildlife Management* 64: 154-159.

Keith, L.B. 1983. Population dynamics of wolves. -*In:* L.N. Carbyn (Ed.). *Wolves of Canada and Alaska: their status, biology and management.* Canadian Wildlife Service Report Series 45, Edmonton. pp. 66-77.

Kie, J.G., Bowyer, T. & **Stewart, K.M. 2003.** Ungulates in western coniferous forests: habitat relationships, population dynamics, and ecosystem processes. -*In:* C.J. Zabel & R.G. Anthony (Eds.). *Mammal community dynamics: management and conservation in the coniferous forests of western North America.* Cambridge University Press, Cambridge. pp. 296-340.

Kuhnert, P.M., Martin, T.G. & **Griffiths, S.P. 2010.** A guide to eliciting and using expert knowledge in Bayesian ecological models. -*Ecology Letters* 13: 900-914.

Kuzyk, G. & **Hatter,** I. Using ungulate biomass to estimate abundance of wolves in British Columbia. - *Wildlife Society Bulletin*, in press.

Latham, A.D.M., Latham, M.C., Boyce, M.S. & **Boutin, S. 2011c.** Movement responses by wolves to industrial linear features and their effect on woodland caribou in northeastern Alberta. -*Ecological Applications* 21: 2854-2865.

Latham, A.D.M., Latham, M.C. & **Boyce, M.S. 2011b.** Habitat selection and spatial relationships of black bears *(Ursus americanus)* with woodland caribou *(Rangifer tarandus caribou)* in northeastern Alberta. - *Canadian Journal of Zoology* 89: 267-277.

Latham, A.D.M., Latham, M.C., Mccutchen, N.A. & **Boutin,** S. **2011a.** Invading white-tailed deer change wolf-caribou dynamics in northeastern Alberta. -*Journal of Wildlife Management* 75: 204-212.

Latham, A.D.M., Latham, M.C., Knopff, K.H., Hebblewhite, M. & **Boutin, S. 2013.** Wolves, white-tailed deer, and beaver: implications of seasonal prey switching for woodland caribou declines. -*Ecography* 36: 1276-1290.

Lele, S.R. & **Allen, K.L. 2006.** On using expert opinion in ecological analyses: a frequentist approach. - *Environmetrics* 17: 683-704.

Lessard, R.B. 2005. *Conservation of woodland caribou* (Rangifer tarandus caribou) *in west-central Alberta: a simulation analysis of multi-species predator-prey systems.* Ph.D. thesis, University of Alberta, Edmonton. 202pp.

Marcot, B.G. 2006. Characterizing species at risk I: modeling rare species under the Northwest Forest Plan. - *Ecology and Society* 11: 10. http://www.ecologyandsociety.org/vol11/iss2/art10/.

Marcot, B.G., Holthausen, R.S., Raphael, M.G., Rowland, M.M. & **Wisdom, M.J. 2001.** Using Bayesian belief networks to evaluate fish and wildlife population viability under land management alternatives from an environmental impact statement. - *Forest Ecology and Management* 153: 29-42.

Marcot, B.G., Steventon, J.D., Sutherland, G.D. & **McCann, R.K. 2006.** Guidelines for developing and updating Bayesian belief networks applied to ecological modeling and conservation. - *Canadian Journal of Forest Research* 36: 3063-3074.

Mccutchen, N.A. 2007. *Factors affecting caribou survival in northern Alberta: the role of wolves, moose, and linear features.* Ph.D. thesis, University of Alberta, Edmonton. 187pp.

McKenzie, H.W., Merrill, E.H., Spiteri, R.J. & **Lewis, M.A. 2012.** How linear features alter predator movement and the functional response. - *Interface Focus* 2: 205-216.

McNay, R.S., Marcot, B.G., Brumovsky, V. & **Ellis, R. 2006.** A Bayesian approach to evaluating habitat for woodland caribou in north-central British Columbia. - *Canadian Journal of Forest Research* 36: 3117-3133.

McNay, R.S., Webster, D. & **Sutherland, G. 2013.** *Aerial moose survey in north east BC 2013.* Science and Community Environmental Knowledge Fund, Victoria, Canada 46pp.

Potvin, F., Breton, L. & **Courtois, R. 2005.** Response of beaver, moose, and snowshoe hare to clear-cutting in a Quebec boreal forest: a reassessment 10 years after cut. - *Canadian Journal of Forest Research* 35: 151-160.

Rempel, R.S., Elkie, P.C., Rodgers, A.R. & **Gluck, M. J. 1997.** Timber-management and natural- disturbance effects on moose habitat: Landscape evaluation. -*Journal of Wildlife Management* 61: 517-524.

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

Seip, D.R. 2010. Mountain caribou recovery plan for British Columbia. - *Rangifer,* Special Issue 12: 125.

Serrouya, R.D. 2013. *An adaptive approach to endangered species recovery based on a management experiment: reducing moose to reduce apparent competition with woodland caribou.* Ph.D. thesis, University of Alberta, Edmonton. 237 pp.

Serrouya, R., McLellan, B.N., Boutin, S. **Seip, D.R.** & **Nielsen, S.E. 2011.** Developing a population target for an overabundant ungulate for ecosystem restoration. -*Journal of Applied Ecology* 48: 935-942.

Smith, K.G. & **Pittaway, L. 2008.** Little Smoky woodland caribou calf survival *enhancementproject.-Rangifer,* Special Issue 19: 97-102.

Sorensen, T., **McLoughlin, P.D., Hervieux, D., Dzus, E., Nolan, J., Wynes, B.** & **Boutin,** S. **2008.** Determining sustainable levels of cumulative effects on boreal caribou. -*Journal of Wildlife Management* 72:900-905.

Thiessen, C. 2010. *Horn River Basin moose inventory January/February 2010.* BC Ministry of Environment, Fort St. John. 44pp.

Wasser, S.K., Keim, J.L., Taper, M.L. & **Lele, S.R. 2011.** The influences of wolf predation, habitat loss, and human activity on caribou and moose in the Alberta oil sands. - *Frontiers in Ecology and the Environment* 9: 546-551.

West Central Alberta Caribou Landscape Planning Team. 2008. *West central Alberta caribou landscape plan.* www.albertacaribouсommittee.ca/PDF/WCCLPT-Plan-05_06_08.pdf. 148pp.

Wittmer, H.U., Sinclair, A.RE. & **McLellan, B.N. 2005.** The role of predation in the decline and extirpation of woodland caribou. - *Oecologia* 144: 257-267.

APPENDIX H

Restoration Definition for Boreal Caribou

Restoration can be defined in many ways, and is frequently referenced as re-vegetation, reclamation or rehabilitation (Ray 2014). Restoration can also be ecological, where the primary objective is to return a disturbance to a similar state of ecological function as before the disturbance; or functional, where the main objective is to "deter the interaction between caribou and their predators in the near term, and support habitat recovery in the long-term" (Wilson 2015). As referenced in Section 4.1, the Province's revised management objectives for boreal caribou are to maintain a positive habitat trend and to stabilize and achieve viable populations across all ranges. Key to achieving these objectives is management of disturbance that contributes early seral habitat, either as lineal or polygonal features.

Early seral habitat is typically defined as forest that is less than 40 years old, resulting either from human disturbance or wildfire (Environment Canada 2012). Historically, the amount and distribution of early seral habitat was a function of natural disturbance agents (e.g., wildfire, insect infestations, wind events) that influence the boreal forest. In landscapes with significant anthropogenic impacts, the characteristics of early seral habitat (e.g. amount, patch size, distribution, vegetation composition) may vary from that expected within the natural range of variability. Boreal caribou have evolved with natural disturbance, but have only been exposed to anthropogenic disturbances relatively recently.

In northeastern BC, the primary concern is the increase and/or attraction of moose to early seral habitat, and subsequently an increase in wolves accessing caribou range, thereby increasing the risk of predation on caribou. Therefore, the characteristics of early seral habitat relevant to recovering boreal caribou in BC are those that improve moose habitat quality in caribou range, resulting in a numerical response (i.e., increased moose density) and/or functional response (i.e., drawing moose into caribou range) in moose. The response in moose is believed to lead to a subsequent, and similar, response in wolves. A disturbance can therefore be considered restored when it ceases to function as an attractant to moose, other primary prey species and wolves, or a means by which wolves and their primary prey may travel more easily into boreal caribou range.

Different disturbance features are expected to have different rates of recovery, depending on a large suite of factors, such as forest type, size, site preparation, origin (i.e., natural or man-made), moisture regime, application of treatments, etc. It is necessary, however, to identify thresholds of when these disturbance features are considered restored in terms of boreal caribou recovery in BC. As monitoring and further research is conducted, our understanding of disturbance responses over time will improve, as will the disturbance mapping available for tracking restoration efforts. The Province is currently evaluating disturbance mapping developed by the BC Oil and Gas

Commission for use in the Area-based Analysis (BC OGC 2014). The mapping includes some information on the year of origin for disturbances, but vegetative characteristics associated with regenerating features are not currently available. The Province evaluated following the approach of Environment and Climate Change Canada (EC 2012), in which disturbance was characterized from satellite images, but it was deemed to be too labour-intensive and costly to be feasible.

Natural Disturbances and Timber Harvesting

In northeastern BC, wildfire is the most common natural disturbance, and leads to the creation of potentially extensive tracts of early seral habitat. Moose may be attracted to these areas, spend more time using them and have increased productivity. The resultant increased moose biomass is an enhanced food supply for wolves. These areas can see increased wolf density and increased predation pressure on boreal caribou. Natural recovery of burned forest to a stage at which there is no preferential use by moose (i.e., restored) depends on the severity of the fire, climate and local site conditions and forest type (Bartels et al. 2016). Similarly, recovery of harvested stands depends on site conditions and forest type and silviculture treatment, but tends to be more rapid, particularly in the initiation stage (0 – 10 years). In general, characteristics of habitat selected by moose for foraging include dense cover of preferred shrubs, dominance by deciduous species, open canopy (< 30%), and less than 3 m in height (MELP 2000).

A literature review reported by Ray (2014) characterizes forests of all ages in terms of lichen, vascular plants, trees, boreal caribou, and predators and alternate prey. Ray (2014) considered forest disturbances of both natural and anthropogenic sources. According to this review, the initiation (0 – 10 years) and establishment stages (11 – 25 years) are generally characterized by an increasing abundance of woody shrubs, rapid regeneration of aspen, little to no lichen, and relatively high moose densities (Ray 2014). By the early aggradation stage (26 – 40 years), shrub density starts to decline, coniferous species start to dominate, and use by moose generally declines.

Therefore, for the purposes of boreal caribou recovery in BC, cutblocks will be considered restored when greater than 25 years of age (Table 19). A precautionary approach will be followed in regards to timber harvesting. It is unclear what, if any, treatments may have been applied to past cutblocks and how this may affect restoration. Future timber management regimes will be monitored and the restoration threshold adjusted accordingly. There is more uncertainty around restoration of burned habitat, given that severe wildfires can burn down to the mineral soil and have far greater effects than timber harvesting. To reflect this, burned areas in boreal caribou range will be considered restored when greater than 35 years of age (Table 19)

Linear Features

Linear features like roads, pipelines and seismic lines can increase the speed and mobility of wolves (Dickie et al. 2016), improving their hunting efficiency. Where linear features occur in caribou habitat, this enables greater use of that habitat by wolves, more encounters with caribou

and increased mortality risk. Functional restoration of linear features will limit the benefits to wolves and predators. Functional restoration can occur naturally through re-vegetation, or through the use of techniques such as placement of coarse woody debris, tree felling and bending (Golder 2015).

Dickie (2015) reported that vegetation taller than 1 m on linear features reduced wolf movement by 23% in summer, while vegetation needed to be taller than 5 m in winter to decrease wolf travelling speed (Dickie 2015). Similarly, in west-central Alberta, Finnegan et al. (2014) found that movement rates of both wolves and grizzly bears was reduced by 70% at vegetation heights over 1.4 m, while human use decreased significantly at vegetation heights greater than 2 m. The length of time required to achieve these characteristics is highly variable with type of linear feature and site conditions. Conventional seismic lines in northeastern Alberta took at least 35 years to recover woody vegetation; seismic lines in lowland black spruce showed little recovery even after 35 years (Lee and Boutin 2006). Orientation of linear features may also affect rates of recovery (e.g., east-west vs north-south). The Province assumes that inactive and unmaintained lease sites would follow a similar trajectory to conventional seismic lines (Table 19).

Although low impact seismic (i.e., 3D programs) are excluded from linear feature analyses, the Province will track the length and density of low impact seismic in the event that future research demonstrates value to predators and/or primary prey. It is assumed that low impact seismic lines would respond in a similar manner to harvested stands, and would support vegetation over 2 m in height within ten years of disturbance. Dickie (2015) found that wolf selection of seismic lines was seasonal, and that lines were not always preferred; therefore the assumption of a ten year threshold overestimates the amount of unrestored disturbance. The Province assumed that pipelines, transmission lines and active roads cannot be restored unless they are deactivated. This is likely to overestimate the amount of disturbed habitat because a portion of rights-of-way can be restored (Table 19).

Table 19. Summary of Restoration Thresholds for Disturbances in Caribou Range

Disturbance	Restoration Threshold
Wildfire	➢ 35 years
Timber harvesting	➢ 25 years
Conventional seismic, lease sites, roads and railways, pipelines, and transmission lines	
- In upland stands	35 years
- In lowland stands	➢ 100 years
Low Impact Seismic	10 years

References Cited

Bartels, S.F., Chen, H.Y.H., M.A. Wulder, and J.C. White. 2016. Trends in post-disturbance recovery rates of Canada's forests following wildfire and harvest. Forest Ecology and Management 361: 194-207.

BC Oil and Gas Commission (BC OGC). 2014. Area-based Analysis Data and Process Documentation. https://www.bcogc.ca/node/12267/download. Accessed 6-January-2017.

Dickie, M., R. Serrouya, R.S. McNay, and S. Boutin. 2016. Faster and farther: wolf movement on linear features and implications for hunting behaviour. Journal of Applied Ecology: doi: 10.1111/1365-2664.12732.

Lee, P., and S. Boutin. 2006. Persistence and developmental transition of wide seismic lines in the western Boreal Plains of Canada. Journal of Environmental Management 78: 240-250.

Ministry of Forests. 1995. Biodiversity Guidebook. https://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/biodiv/biotoc.htm. Accessed 6-January-2017.

Ray, J.C. 2014. Defining habitat restoration for boreal caribou in the context of natural recovery: a discussion paper. Prepared for Environment and Climate Change Canada. http://registrelep-sararegistry.gc.ca/document/default_e.cfm?documentID=2854.

Wilson, S.F. 2015. Role of Functional Restoration in Woodland Caribou Recovery. Report prepared for Canadian Association of Petroleum Producers. Report #266452.

APPENDIX I

MODIFIED HABITAT CONDITION BALANCE SHEET TEMPLATE

A modified habitat condition balance sheet will be used for each Boreal Caribou range.

	Total Early Seral (Forestry and Fire)				Forestry Early Seral (≤ 20 years)				Fire (≤ 40 years)		Linear Features[1]			
	No Buffer		500 m Buffer		No Buffer		500 m Buffer		No Buffer		Range		Core	
Time/Year	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Km	Km/Km^2	Km	Km/Km^2
Present														
5 years														
10 years														
15 years														
20 years														
30 years														
40 years														

[1] Linear features include roads, trails, transmission lines, pipelines, and conventional seismic lines. Low impact seismic line (i.e., 3D programs) density will be separately tracked by the Province.