Environment Canada Environnement Canada

SCIENTIFIC ASSESSMENT TO INFORM THE IDENTIFICATION OF CRITICAL HABITAT FOR WOODLAND CARIBOU (*Rangifer tarandus caribou*), BOREAL POPULATION, IN CANADA

2011 UPDATE

Canada

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Citation:

This report should be quoted as follows:

Environment Canada, 2011. Scientific Assessment to Inform the Identification of Critical Habitat for Woodland Caribou (Rangifer tarandus caribou), Boreal Population, in Canada: 2011 update. Ottawa, Ontario, Canada. 102 pp. plus appendices.

Cat. No.: CW66-296/2011E-PDF
ISBN: 978-1-100-19223-9

Aussi disponible en français

PREFACE

This report describes work undertaken to inform the identification of critical habitat for the Boreal Population of Woodland Caribou (*Rangifer tarandus caribou*) in Canada, as part of the requirement for preparation of a National Recovery Strategy for this species under the federal *Species at Risk Act*. It extends earlier analyses also conducted for this purpose (Environment Canada 2008), and addresses identified limitations associated with implementation of that work. It does not address the need to consider Aboriginal Traditional Knowledge in the development of the National Recovery Strategy, which is being completed through an independent process.

The report presents a conceptual framework for a scientific description of critical habitat for boreal caribou, describes data necessary and available to support implementation of the framework, and applies a variety of analytical procedures and assessment criteria to evaluate and describe critical habitat for 57 boreal caribou ranges and associated populations, which in total, comprise the full extent of occurrence of the species in Canada.

While improved data would enhance our understanding and address outstanding uncertainties, the report concludes that sufficient information exists to support a scientific basis to inform the identification of critcal habitat for boreal populations across Canada. Methodologies to update this assessment with new information are presented, as part of a continual learning and improvement cycle to support the recovery of this species.

EXECUTIVE SUMMARY

Boreal Caribou and the *Species at Risk Act*

The Woodland Caribou (*Rangifer tarandus caribou*), Boreal Population (hereinafter referred to as boreal caribou), was last assessed by the Committee on the Status of Endangered Wildlife in Canada as Threatened (COSEWIC 2002), and listed under the *Species at Risk Act* (SARA) in 2003. Under the Act, the Minister of the Environment is responsible for the development of a National Recovery Strategy, including the identification of critical habitat.

2008 Scientific Review

In 2007, Environment Canada (EC) launched a science-based review with the mandate to identify boreal caribou critical habitat to the extent possible, using the best available information, and/or prepare a Schedule of Studies to complete this task. The results were summarized in a report entitled *Scientific Review for the Identification of Critical Habitat for Woodland Caribou* (*Rangifer tarandus caribou), Boreal Population, in Canada* (hereinafter referred to as the 2008 Scientific Review).

Identifying critical habitat for boreal caribou was framed as an exercise in decision analysis and adaptive management. Establishment of a systematic, transparent and repeatable process was central to the approach. The resultant Critical Habitat Framework was anchored by synthesis and analysis of available quantitative data and published scientific information on boreal caribou population and habitat ecology.

The 2008 Scientific Review established caribou ranges as the appropriate scale at which to identify critical habitat, and applied a probabilistic approach to assessing the adequacy of the current range conditions to support a self-sustaining population based on three lines of evidence: percent total disturbance, population growth and population size. The results were used to classify critical habitat for each local population into one of three states: maintain current conditions, improve current conditions, or assess resilience to further disturbance.

The 2008 Scientific Review recognized that current knowledge and the dynamic nature of landscapes impart uncertainty and that critical habitat identification should be monitored and assessed for the purposes of refinement and adjustment over time, as new knowledge becomes available (i.e., as part of adaptive management).

Additional Scientific Activities

The 2008 Scientific Review established a foundation for the assessment of critical habitat (i.e., habitat conditions required for recovery of boreal caribou under SARA). To support refinement of the resultant description of critical habitat, EC identified key areas for further exploration:

1) implications to critical habitat identification of variation in approaches applied by jurisdictions to delineate ranges;
2) relative impacts of different disturbances and habitat types, and their configurations, on the ability of ranges to support self-sustaining populations, and resultant critical habitat identification;
3) identification of disturbance-based management thresholds (hereinafter referred to disturbance thresholds) for self-sustaining local populations;
4) influence of future range conditions on disturbance thresholds given the dynamic nature of disturbance within a given range.

The purpose of addressing these knowledge gaps was to further inform the identification of critical habitat for boreal caribou, using the best available information. To this end, EC undertook the work presented in this report, and once again engaged experts to provide scientific advice and reviews during the development of this work and completion of this report. An independent process was undertaken to consider Aboriginal Traditional Knowledge (ATK) in the development of the National Recovery Strategy. Information flowing from the two bodies of knowledge will inform strategies to support the survival and recovery of boreal caribou in Canada.

2011 Scientific Assessment: Concepts and Methodology

Similar to the 2008 Scientific Review, the present assessment was designed to provide a probabilistic evaluation of critical habitat relative to the set of conditions (demographic and environmental) within each range. The framework and components developed in the 2008 Scientific Review were expanded and enhanced through the following scientific activities.

- Enhanced Disturbance Mapping: new anthropogenic disturbance maps using an enhanced methodology were created to provide a better temporal match with available caribou data and investigate the relative impact of different disturbance types and their configuration on the assessment of boreal caribou ranges. The maps were supplemented with updated fire data available from jurisdictions.
- Habitat Selection Analysis: evaluation of habitat selection at different spatial scales (national and regional) was conducted using available caribou location data to identify additional bio-physical attributes influencing habitat condition for caribou, beyond the percentage of total disturbance.
- Buffer Analysis: the effects of buffering on 1) the configuration of disturbance and 2) effects of landscape configuration and connectivity on caribou demography were examined.
- Meta-Analysis of Boreal Caribou Population and Habitat Condition: the 2008 meta-analysis of caribou demography in relation to range-level disturbances (i.e., anthropogenic and fire) was extended to incorporate the enhanced disturbance mapping, and results from the habitat selection and buffer analyses.
- Assessment of Current Conditions: the probability that current conditions could support self-sustaining caribou populations was assessed using indicators of two ecological components of sustainability – stable or positive population growth and long term persistence. The indicators were quantified using a non-spatial

population model and probabilistic decision-analysis tool, and integrated through a set of decision rules. Certainty in the result for each range was evaluated based on the quality and consistency of information available.
- Representation of Future Conditions: a simple habitat dynamics model was developed to better understand how future changes in habitat conditions within a range could affect the sustainability of boreal caribou populations. The model included natural disturbance and natural recovery but did not attempt to model future anthropogenic disturbance.
- Determination of Range-Specific Disturbance Thresholds: a methodology for establishing risk-based, range-specific disturbance thresholds based on best available information was developed.

Description of Critical Habitat

The description of boreal caribou critical habitat provided in this report for each range consists of the following four components:

i. The delineation and location of the range, and certainty in range delineation.
ii. An integrated risk assessment based on multiple lines of evidence from three indicators, and application of hierarchical decision rules to evaluate the probability that current conditions on a range will support a self-sustaining population. The result is expressed as a likelihood statement relative to achieving the recovery objective.
iii. Information to support the identification of disturbance-based management thresholds. Specifically, a consistent methodology for deriving such thresholds is provided, along with examples of their potential application, and discussion of their interpretation relative to the criteria and indicators evaluated.
iv. A description of the bio-physical attributes, defined as the habitat characteristics required by caribou to carry out life processes necessary for survival and reproduction. The results from the habitat selection analyses (this report) and published reports were used to summarize key bio-physical attributes by ecozone.

The related goals of assessing the ability of ranges to support self-sustaining populations, and establishment of management thresholds for disturbance, must acknowledge uncertainties arising from the availability and reliability of information about current population condition, as well as how populations might respond to additional and often interacting stressors. The probabilistic approach applied in this assessment explicitly incorporated the effects of uncertainties and data quality in the assessment process. This approach is consistent with the concept of adaptive management, which expresses probable outcomes as hypotheses. Monitoring and evaluation of realized outcomes informs adaptations of management strategies over time.

Key Findings

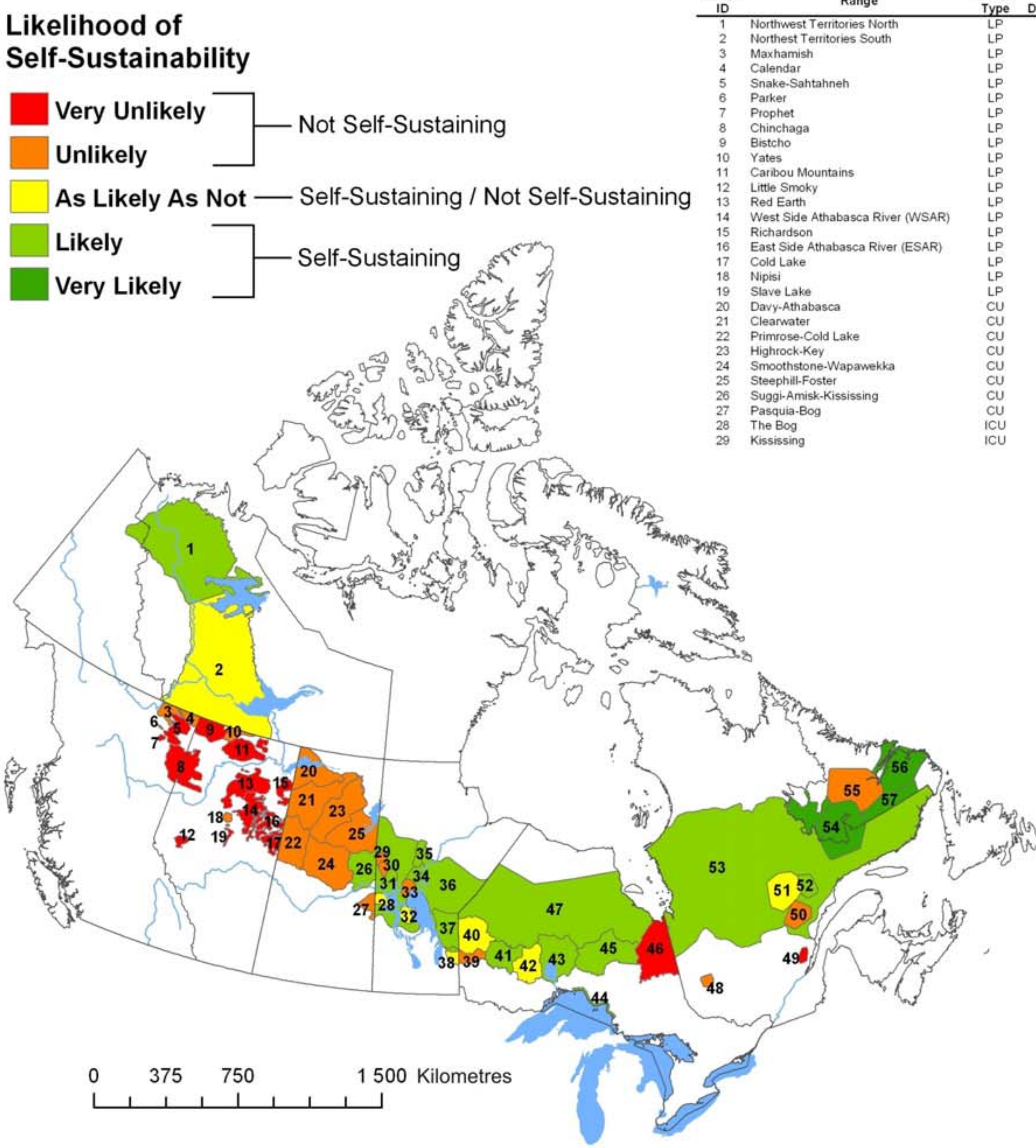
The information and analyses presented in this report address limitations identified with implementation of the work presented in the 2008 Scientific Review. However, neither the approach nor the results of this assessment represent a fundamental shift from the 2008 Science Review conclusion that range is the appropriate geographic delineation for critical habitat description. Further, the amount of total disturbance within a range remains the primary criteria for identifying critical habitat to meet a goal of self-sustaining local populations of caribou.

While improved data would enhance our understanding and address outstanding uncertainties, this report concludes that sufficient information exists to support a scientifically-grounded assessment of critical habitat for populations of boreal caribou across Canada, and provides a scientific basis to inform critical habitat identifcation for each of the 57 identified ranges that comprise the full extent of occurrence of boreal caribou in Canada.

Highlights of the application of the conceptual framework and associated analyses supporting this 2011 assessment include:

- **Nearly 70% of the variation in caribou recruitment across twenty-four study areas spanning the full range of boreal caribou distribution and range condition in Canada was explained by a single composite measure of total disturbance (fire + buffered anthropogenic), most of which could be attributed to the negative effects of anthropogenic disturbance.** Little statistical support was found for distinguishing different types of anthropogenic disturbances (e.g., linear and polygonal types). However, supporting analyses of a range of buffer widths demonstrated that a 500 m buffer on anthropogenic disturbance provided an appropriate, minimum approximation of the zone of influence of these features on caribou demography.

- **Of the 57 identified boreal caribou ranges in Canada, 17 (30%) were assessed in the "self-sustaining" (SS) category, 7 (12%) in the "not self-sustaining/self-sustaining" (NSS/SS) category, and 33 (58%) in the "not self-sustaining" (NSS) category (Executive Summary Figure 1).** Through the integrated risk assessment, these designations were refined to five likelihood categories ranging from very likely (SS) to very unlikely (NSS) with respect to the probability that current conditions would support a self-sustaining boreal caribou population.

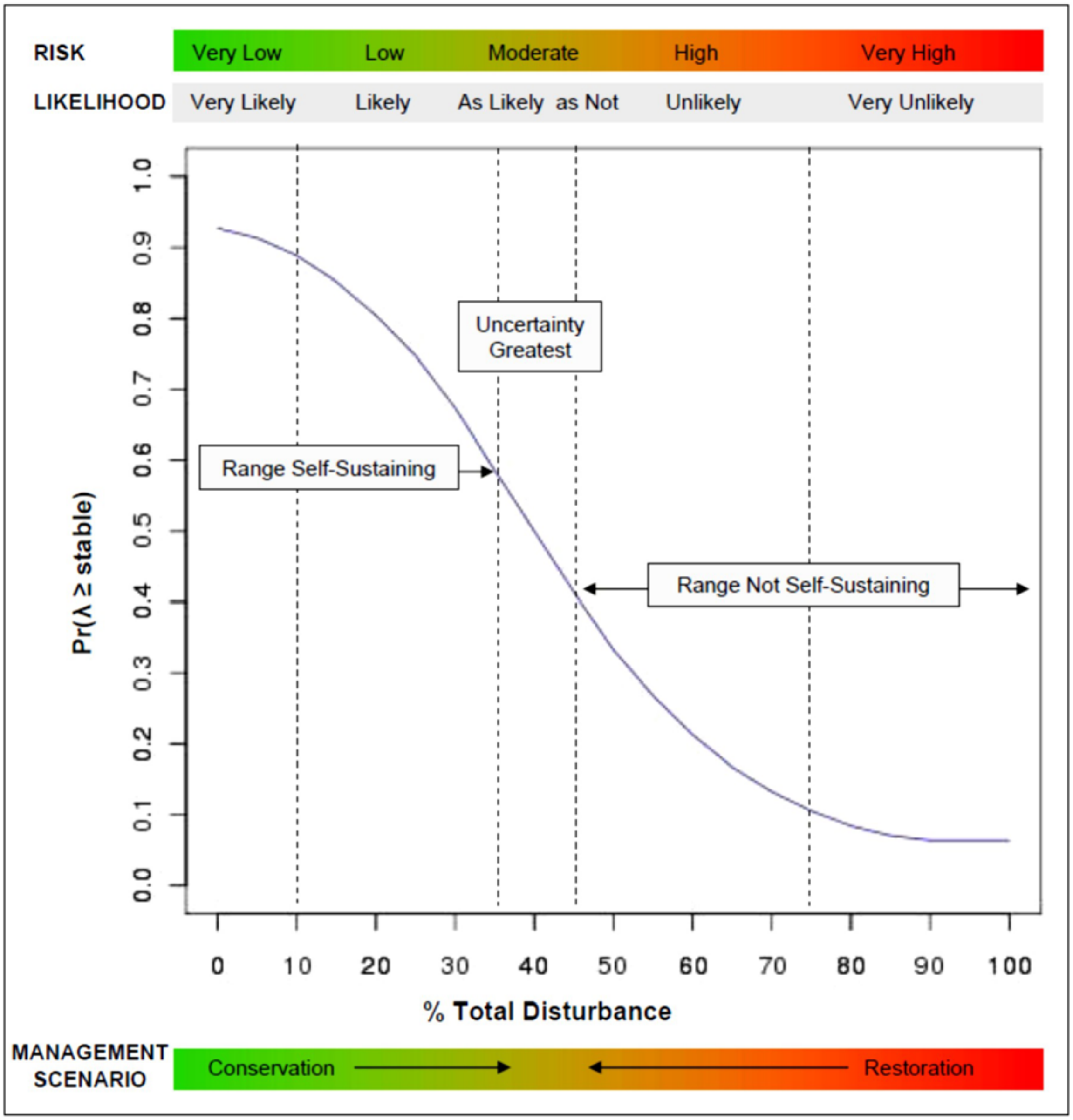


Range ID	Range	Range Type	Total % Disturbance	Range ID	Range	Range Type	Total % Disturbance
1	Northwest Territories North	LP	22	30	Naosap	ICU	50
2	Northest Territories South	LP	38	31	Reed	ICU	26
3	Maxhamish	LP	58	32	North Interlake	ICU	17
4	Calendar	LP	61	33	William Lake	ICU	31
5	Snake-Sahtahneh	LP	87	34	Wabowden	ICU	28
6	Parker	LP	34	35	Wapisu	ICU	24
7	Prophet	LP	79	36	Manitoba	CU	28
8	Chinchaga	LP	76	37	Atikaki-Berens	ICU	35
9	Bistcho	LP	71	38	Owl-Flinstone	LP	39
10	Yates	LP	61	39	Sydney	ICU	58
11	Caribou Mountains	LP	57	40	Berens	ICU	39
12	Little Smoky	LP	95	41	Churchill	ICU	31
13	Red Earth	LP	62	42	Brightsand	ICU	42
14	West Side Athabasca River (WSAR)	LP	69	43	Nipigon	LP	31
15	Richardson	LP	82	44	Coastal	CU	16
16	East Side Athabasca River (ESAR)	LP	81	45	Pagwachuan	ICU	27
17	Cold Lake	LP	85	46	Kesagami	ICU	38
18	Nipisi	LP	68	47	Far North	CU	15
19	Slave Lake	LP	80	48	Val d'Or	LP	60
20	Davy-Athabasca	CU	61	49	Charlevoix	LP	80
21	Clearwater	CU	70	50	Pipmuacan	ICU	59
22	Primrose-Cold Lake	CU	54	51	Manouane	ICU	39
23	Highrock-Key	CU	63	52	Manicouagan	ICU	33
24	Smoothstone-Wapawekka	CU	33	53	Quebec	CU	30
25	Steephill-Foster	CU	50	54	Lac Joseph	LP	8
26	Suggi-Amisk-Kississing	CU	25	55	Red Wine Mountain	LP	8
27	Pasquia-Bog	CU	44	56	Mealy Mountain	LP	2
28	The Bog	ICU	16	57	Labrador	CU	8
29	Kississing	ICU	51				

LP = Local Population
CU = Conservation Unit
ICU = Improved Conservation Unit

Executive Summary Figure 1. Integrated risk assessment for boreal caribou ranges in Canada.

- **Range-specific disturbance-based management thresholds can be derived from a generalized disturbance-population growth function in conjunction with range-specific information (Executive Summary Figure 2).** A methodology was developed to extend the critical habitat description for consideration of disturbance-based management thresholds when acceptable risks are defined by managers. A core component of the methodology is a disturbance-based population growth function that can be used in conjunction with range specific information to derive range specific disturbance thresholds. Examples of the application of the methodology to derive range-specific disturbance thresholds are presented.



Executive Summary Figure 2. The disturbance-based population growth function used in conjunction with range-specific information to derive range-specific management thresholds once an acceptable level of risk by managers has been specified.

In addition to these highlights, several important observations related to the availability of information emerged, and recommendations related to these are advanced.

- **Most boreal caribou ranges in Canada have not been fully described owing to a lack of standardized animal location data and poor understanding of movement within and between ranges.** While a total of 57 ranges are still currently recognized by jurisdictions in Canada, changes to the delineation of boreal caribou ranges have been made since the 2008 Scientific Review, by various jurisdictions, based on different criteria. The issue of appropriate delineation of trans-boundary ranges remains unresolved. Addressing the need for more animal location and movement information, greater inter-jurisdictional collaboration, and a standardized approach to range delineation are important requirements to adequately and consistently describe ranges for local populations of boreal caribou throughout their current distribution, and support continuous improvement of critical habitat description over time.

- **Demographic data are lacking for many boreal caribou ranges in Canada.** Monitoring and assessment programs to provide data on population size, population trend, recruitment and adult mortality are required to improve understanding of factors affecting boreal caribou survival and recovery, increase certainty in assessment results, and to monitor response of populations to recovery actions and assess progress towards meeting the population and distribution objectives for boreal caribou across Canada. The need to acquire demographic data for many boreal caribou ranges should not be equated with a statement that insufficient knowledge exists for the identification of critical habitat for boreal caribou in Canada, but rather embraced as part of an adaptive management cycle designed to improve certainty in management strategies necessary to achieve the desired outcome of self-sustaining boreal caribou populations over time.

In conclusion, the breadth of information and knowledge compiled for this assessment exemplifies the comprehensive nature of, and interrelationships between, types of evidence available to provide a scientifically-based description of critical habitat for informing recovery planning for boreal caribou. Significant advances were made to the conceptual and methodological design during this assessment to address some key uncertainties or limitations identified in the 2008 Scientific Review. These advances improved the robustness of the results with respect to providing a scientific description of critical habitat for boreal caribou across Canada.

DEFINITIONS

Bio-Physical Attributes	Any and all geological, vegetative, topographical, climatological, physical, chemical, or biological attributes, or suite of attributes, that constitute habitat for the species at risk.
Critical Habitat	The habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species (*Species at Risk Act*, S.2).
Current Distribution (Extent of Occurrence)	The area that encompasses the geographic distribution of all known boreal caribou ranges (COSEWIC 2010 – Adapted from IUCN 2010), based on provincial and territorial distribution maps developed from observation and telemetry data, local knowledge (including in some cases Aboriginal Traditional Knowledge), and biophysical analyses.
Demographic Parameters	Refers to the characteristics of a group of animals within a defined area. They include population trend, size, adult female survival and calf recruitment.
Habitat	The suite of resources (food, shelter), and environmental conditions (abiotic variables such as temperature, and biotic variables such as competitors and predators), that determine the presence, survival, and reproduction of a population (Caughley and Gunn 1996).
Local Population	A group of caribou occupying a defined area distinguished spatially from areas occupied by other groups of caribou. Local population dynamics are driven primarily by local factors affecting birth and death rates, rather than immigration or emigration among groups.
Persistence	The survival of a population, expressed as a given probability or likelihood over a specified time frame. The likelihood of not achieving specified persistence levels is a measure of risk of extirpation (i.e., local extinction).
Range	A geographic area occupied by a group of individuals that are subjected to the same influences affecting vital rates over a defined time frame.
Self-Sustaining Population	A local population of boreal caribou that on average demonstrates stable or positive population growth over the short term (≤20 years), and is large enough to withstand stochastic events and persist over the long-term (≥50 years), without the need for ongoing active management intervention (e.g., predator management or transplants from other populations).

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1 INTRODUCTION

The Woodland Caribou (*Rangifer tarandus caribou*), Boreal Population (hereinafter referred to as boreal caribou), was last assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as Threatened (COSEWIC 2002), and added to Schedule 1 of the *Species at Risk Act* (SARA) in 2003. The listing decision was made on the basis of an "observed, estimated, inferred or suspected population size reduction of ≥ 30% over three generations". Evidence of continued declines exists for many regions of Canada (EC 2008) and has been well-documented in a number of closely-monitored populations since the 2002 COSEWIC assessment (e.g., ASRD & ACA 2010; BC MOE 2010).

Boreal caribou have evolved with and adapted to the natural disturbance regimes of boreal forest ecosystems that govern the spatio-temporal distribution and availability of habitat. However, habitat loss, reduction in habitat patch size and fragmentation due to land conversion and resource development, and increased predation associated with these changes, have been identified as the main cause of the decline of boreal caribou in Canada (COSEWIC 2002).

Critical habitat is defined as "the habitat that is necessary for the survival or recovery of a listed wildlife species" (SARA S.2). In 2007, Environment Canada (EC) launched a scientific initiative that culminated in a report entitled *Scientific Review for the Identification of Critical Habitat for Woodland Caribou (Rangifer tarandus caribou), Boreal Population, in Canada* (EC 2008; hereinafter referred to as 2008 Scientific Review), which was intended to identify boreal caribou critical habitat in the species' recovery strategy. In that exercise, "survival and recovery" of boreal caribou was taken to mean the conservation of self-sustaining boreal caribou local populations (i.e., a stable or increasing population that was large enough to persist without human intervention) throughout their current distribution in Canada. Local population ranges were identified by EC as the relevant scale for the identification of conditions that could support self-sustaining populations, and thus for the identification of critical habitat.

A component of the 2008 Scientific Review was the development of a framework, or logic model, for the identification of boreal caribou critical habitat. It was anchored by analysis and synthesis of available data and published scientific information on population and habitat ecology, including boreal caribou population distribution, trends, habitat use, and conditions for self-sustainability. The approach was further grounded in an adaptive management framework, where uncertainties and knowledge gaps could be systematically reported and addressed, and new information considered at each iteration of the planning cycle. The implementation of the framework was bound by a set of guiding principles reflecting the ecological, legal, and scientific underpinnings of the exercise.

The distribution of boreal caribou in Canada (extent of occurrence and the spatial extent of the analysis) was comprised of 57 identified boreal caribou local population ranges or units of analysis. Each range was assessed to determine if the current conditions were sufficient to support a self-sustaining population based on information about current population (size and trend) and habitat (level of anthropogenic and natural disturbance) conditions. The outcome of the assessment was the classification of ranges according to their capacity to maintain self-sustaining populations and consideration of the influence of range-specific conditions relative to critical habitat identification.

The 2008 Scientific Review established a scientific basis for the assessment of critical habitat (i.e., habitat conditions required for recovery of boreal caribou under SARA). To support refinement of these analyses and resultant identification of critical habitat, EC identified key areas that required further exploration:

1. implications to critical habitat identification of variation in range delineation approaches across jurisdictions;
2. relative impact of different disturbance and habitat types and their configuration on range assessment and critical habitat description;
3. identification of disturbance-based management thresholds (hereinafter referred to disturbance thresholds) for self-sustaining local populations; and
4. influence of future range conditions on disturbance thresholds given the dynamic nature of disturbance within a given range.

The purpose of this report is to address these information needs using the best available scientific information to inform the identification of critical habitat for boreal caribou. EC has also completed an independent process to consider Aboriginal Traditional Knowledge (ATK) in the development of the National Recovery Strategy. Information flowing from the two bodies of knowledge will inform strategies to support the survival and recovery of boreal caribou in Canada.

1.1 Background

In August 2007, EC launched an expert, science-based review of the state of knowledge of boreal caribou critical habitat, with the mandate to develop a consolidated, scientifically defensible identification of critical habitat, and/or a valid Schedule of Studies. The results of these activities led to the publication of the 2008 Scientific Review.

The report was instrumental in establishing a transparent and repeatable science-based process to inform the identification of critical habitat for boreal caribou. In that report, an analytical approach was developed and applied to assessing the probability that current population (size and trend) and habitat conditions (levels of habitat undisturbed by anthropogenic activities and forest fire) within each boreal caribou range in Canada were sufficient to support self-sustaining populations of boreal caribou. The general conclusions included:

1. Critical habitat for boreal caribou is most appropriately identified at the scale of boreal caribou ranges, and expressed relative to the probability that the range conditions are sufficient to support a self-sustaining local population.

2. Range is a function of the extent and condition of habitat, where habitat includes the suite of resources and environmental conditions that determine the presence, survival and reproduction of a population.
3. The assessment assigned one of three outcomes for self-sustaining local populations for each of the 57 recognized local populations or units of analysis[1] for Boreal caribou in Canada: Current Range adequate, Current Range and Improved Conditions necessary, or Current Range and Consider Resilience.
4. Critical habitat identification for boreal caribou is a hierarchical process with considerations across multiple spatial and temporal scales. Further elaboration of critical habitat outcomes at spatial scales finer than the range, over specified time frames, may be achieved through spatial population viability analysis linked with dynamic landscape modelling.
5. Acknowledging that current knowledge and the dynamic nature of landscapes impart uncertainty, the 2008 Scientific Review findings should be monitored and assessed for the purposes of refinement and adjustment over time, as new knowledge becomes available (i.e., as part of adaptive management).

Of the 57 local population ranges or unit of analysis, 30 were assessed as "Not Self-Sustaining" (integrated probability of less than 0.5), 17 as "Self-Sustaining" (integrated probability of greater than 0.5), and 10 as either "Self-Sustaining" or "Non-Self-Sustaining" (integrated probability equal to 0.5).

In 2009, EC launched a second science assessment to augment the 2008 Scientific Review, with new information and analyses to inform the identification of critical habitat. EC again engaged experts on caribou ecology and/or related scientific areas who provided advice, guidance, and reviews at key stages during the development of this report.

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[1] It should be noted that the terminology used to describe the different types of geographical units used in the assessment was modified from the 2008 Scientific Review, as described in Section 2.4.2.

2 METHODOLOGY

2.1 Defining Critical Habitat for Boreal Caribou

SARA S.2 defines critical habitat as "[…] the habitat that is necessary for the survival or recovery of a listed wildlife species […]". Consideration of scale is fundamental to identifying the bio-physical attributes (i.e., habitat) required for the survival or recovery of boreal caribou (EC 2008). Caribou select habitat at multiple spatial scales to meet their life history requirements. At fine spatial scales, microclimate and food availability are important factors influencing caribou habitat selection. However, the primary limiting factor on boreal caribou populations is predation (Rettie and Messier 1998; Wittmer et al. 2005), associated with natural or human-induced landscape conditions that favour early seral stages and higher densities of alternative prey, resulting in increased risk of predation to caribou. Habitat conditions at the scale of boreal caribou ranges affect the demography of boreal caribou (e.g., survival and reproduction), which ultimately determines whether or not a population will survive. Therefore, **a local population range was identified as the relevant spatial scale for the identification of critical habitat that provides the conditions required by boreal caribou.**

The survival of boreal caribou local populations requires that both habitat and population conditions are conducive to overall stable or positive population growth and longer-term persistence. This state is referred to here as self-sustaining (see Definitions). If either habitat or population conditions are not favourable, the population will decline and eventually disappear in the absence of intervention. For example, a large population could disappear due to a recurring declining trend, whereas a small population could disappear due to stochastic events (e.g., severe winter). **Self-sustaining local populations are required to improve the likelihood of maintaining boreal caribou in the wild**.

Boreal caribou distribution in Canada spans seven ecozones and many more ecoregions (EC 2008). There is tremendous variation in ecological conditions across this distribution, to which boreal caribou populations exhibit variable local adaptations. Representing this variability with appropriate levels of redundancy is an essential consideration when identifying a distribution objective. Creating a patchy distribution is likely to elevate risk and promote continuation of overall range recession (up to 50% of the potential historical range is already no longer occupied). In addition, all local population or conservation units have been deemed biologically or technically feasible to recover. Therefore, **the scope of the current science assessment is the current distribution of boreal caribou in Canada**.

For the purpose of conducting the current assessment, critical habitat for boreal caribou was therefore defined as the resources and environmental conditions required for self-sustaining local populations, or groups of animals under similar local conditions, throughout their current distribution in Canada.

2.2 Guiding Principles

The present assessment was guided by similar principles that were established for the 2008 Scientific Review:

1. Consider available published scientific information and seek multiple lines of evidence to support conclusions.
2. Recognize the dynamic nature of boreal systems, and the resultant effects on boreal caribou habitat.
3. Acknowledge and consider that both the physical and functional characteristics of habitat for this species operate at multiple spatial and temporal scales, including physical and functional properties.
4. Recognize that variation in population structure, population and landscape condition, and state of knowledge may warrant finer scale approaches to refine the identification of critical habitat across the national distribution of this species.
5. Apply precaution when evidence is insufficient to judge harm (precautionary principle).
6. Recognize that ongoing research and monitoring, as part of an adaptive management approach, are key to reducing uncertainties over time, improving decision-making, and achieving management objectives.
7. Recognize that critical habitat identification is a scientific process, with socio-economic considerations addressed in other phases of the overall SARA recovery planning process.

2.3 Critical Habitat Framework

Similar to the 2008 Scientific Review, this assessment was designed to provide a scientific description and quantitative evaluation of critical habitat relative to the set of conditions (demographic and environmental) within each range. The framework and components developed in the 2008 Scientific Review were expanded to include additional scientific activities (described in Section 2.4), in order to augment the earlier assessment.

Figure 1 illustrates the overarching *Critical Habitat Framework* and its relationship to other stages of the recovery process. A general description of each step in the assessment process is provided below.

Step 1: Identification of the Current Distribution of Boreal Caribou in Canada

The current distribution of boreal caribou was used to define the geographic scope for the identification of critical habitat. The first step in the framework was to update the distribution based on the most recent and best available information.

The designation of the Canadian range for a species-at-risk ordinarily relies on the COSEWIC assessment process (COSEWIC 2010). Since there has been significant new information since the last COSEWIC assessment (COSEWIC 2002), an up-to-date distribution map (see section 2.4.1) was created as an interim product to conduct this critical habitat assessment.

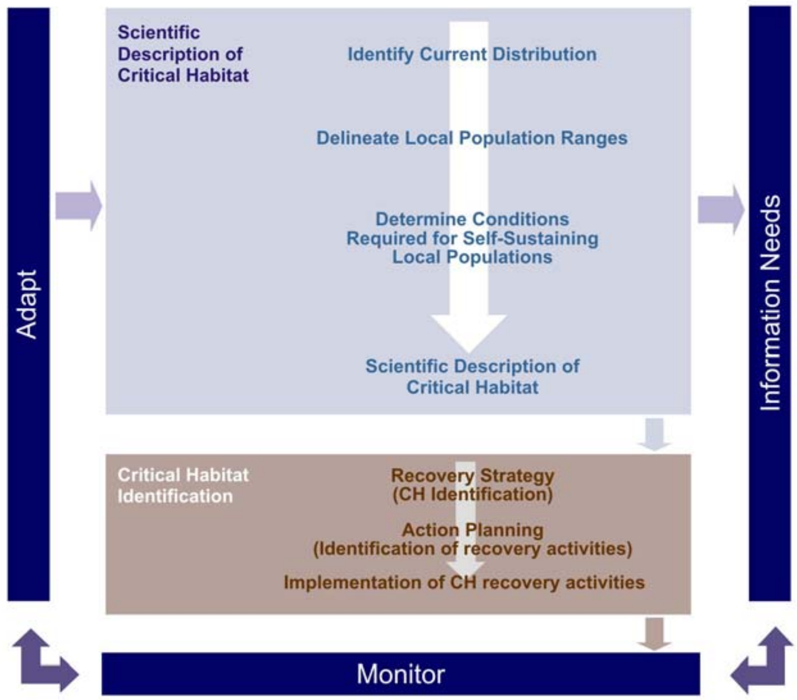


Figure 1. Critical Habitat Framework for boreal caribou. Although other sources of information are considered to identify critical habitat (e.g., ATK), the top panel of this figure is focussed on the scientific activities to inform critical habitat identification.

Step 2: Delineation of Boreal Caribou Ranges

A range is defined as the geographic area within which there is a high probability of occupancy by individuals of a local population, all of which are subjected to the same influences affecting vital rates over a defined time frame. Local populations may experience a limited exchange of individuals with other populations, such that the demography is affected mainly by local factors and not by immigration or emigration among groups. Boreal caribou ranges were identified as the appropriate units of analysis for ensuring the recovery and/or survival of boreal caribou (see section 2.1).

The 2008 Scientific Review noted that ranges were delineated inconsistently across jurisdictions. When sufficient information was available, the range assessment was conducted on recognized local populations. In other cases, management units delineated either mainly or partly by non-ecological considerations (e.g., administrative boundary, land management unit) were assessed. The report recognized the variation in the data and methods for range delineation as a potential source of uncertainty with respect to the assessment of the ability of boreal caribou ranges to maintain self-sustaining caribou populations (EC 2008).

The present report investigated the impact of using different delineation methods on range size, and a standardized delineation method was suggested. In addition, information on the type and quantity of data used to delineate ranges as provided by each jurisdiction was compiled, and a terminology was proposed to reflect the level of certainty with respect to range delineation (see section 2.4.2). However, the current assessment did not provide alternative range delineations using the reported methodology due to time constraints and awareness that parallel processes were being implemented by some jurisdictions to refine their range delineation. As such, the updated range delineation information provided by most jurisdictions at the time of implementing the Critical Habitat Framework was accepted as the best available knowledge.

Step 3: Identification of the Conditions Required for Self-Sustaining Local Populations

Animals use or extract resources (e.g., for food and shelter) from their environment for survival and reproduction. Population growth rate and persistence are related to population condition (trend and size), and are expected to deteriorate with the loss or changes in habitat that influence survival and reproduction. The 2008 Scientific Review acknowledged this link by using habitat condition (percent total disturbance) and population condition as a starting point for assessing the capacity for each range to support a self-sustaining caribou population.

In this update, an enhanced but analogous procedure was developed to increase the certainty in conclusions regarding the state of critical habitat in boreal caribou ranges in Canada. Some jurisdictions provided updated demographic data (trend, size, adult female survival, calf recruitment). These data were used to quantify the likelihood that boreal caribou populations were self-sustaining based on current population condition. However, data availability varied considerably among ranges, and population data were lacking entirely for some ranges.

The suite of analyses characterizing habitat condition was expanded to: 1) include additional bio-physical attributes influencing caribou survival and recruitment, such as the configuration of different habitat types; and 2) quantify the scale-dependent nature of caribou habitat by examining patterns of habitat selection at national versus regional scales.

Disturbance Mapping (section 2.4.3.1)

The 2008 Scientific Review identified anthropogenic and natural disturbances as significant predictors of habitat condition. The analysis of anthropogenic disturbance used the “national anthropogenic disturbance” database developed by Global Forest Watch Canada (Lee at al. 2006). Although the Global Forest Watch Canada data was a valuable contribution to the 2008 Scientific Review, it did not provide discrimination among different disturbance types and buffered all digitized human developments by 500 m.

In this update, new anthropogenic disturbance maps were created to investigate the relative impact of different disturbance types and their configuration on the assessment of boreal caribou ranges.

Habitat Selection (section 2.4.3.2)

A habitat selection analysis was conducted to identify additional bio-physical attributes influencing habitat condition, beyond the percentage of total disturbance. The analysis was conducted at both a national and ecological units (ecozone) scales to understand how variation in the availability of habitats across the boreal forest in Canada might influence patterns of habitat preference and avoidance.

Buffer Analysis (section 2.4.3.3)

In the current context, a "buffer" is referred to as an area assumed to be functionally unavailable to caribou due to its proximity to anthropogenic development. In the 2008 Scientific Review, the national anthropogenic disturbance dataset was developed with a 500 m buffer to each anthropogenic disturbance, but the nature of the data prevented any manipulation of the buffer. While recognizing this limitation, the 500 m buffer was considered a reasonable minimum at the time.

In the present update, the effects of 1) different buffer widths on the configuration of disturbance and 2) effects of landscape configuration and connectivity on caribou demography were examined.

Meta-Analysis of Boreal Caribou Population and Habitat Condition (section 2.4.3.4)

Understanding the relationship(s) between caribou population condition and the condition of the range is central to determining the amount of habitat required to support a self-sustaining population. In the 2008 Scientific Review, a meta-analysis was used to quantify the variation in calf recruitment across twenty-four (24) ranges in Canada as a function of total disturbance (fire and 500 m-buffered anthropogenic disturbance). This recruitment-disturbance relationship was the main tool for quantifying the capacity of a range to maintain a self-sustaining caribou population based on habitat condition.

In this update, the scope of that meta-analysis was broadened to incorporate updated disturbance mapping and results from a more precise habitat selection and buffer analysis to refine the characterization of habitat conditions within boreal caribou ranges, and to better explain the variability among local populations associated with the recruitment-disturbance relationship.

Current and Future Conditions (section 2.4.5)

In the 2008 Scientific Review, current range conditions were assessed using three lines of evidence (or indicators): population size, population trend, and total disturbance (%). Probabilities of persistence (then used to assess the state of "self-sustaining") were assigned to categorical states defined for each indicator informed by either expert opinion (trend), a population model (non-spatial PVA, population size), or the recruitment-disturbance relationship (total disturbance). The range-specific integrated probability of self-sustainability was derived from averaging the sum of indicator values for a range. In other words, it provided a static assessment of the capacity of a range to maintain a self-sustaining caribou population based on its current state.

The present update also evaluated the probability that the current conditions were sufficient to support self-sustaining caribou populations using a set of indicators: two of population growth, and one of persistence. However, the indicators were quantified using a generic population model and a probabilistic decision-analysis tool. The population modelling extended the results from the 2008 non-spatial PVA model (EC 2008).

Also, a habitat-dynamics model was developed to better understand how future changes in habitat conditions within a range might affect the sustainability of boreal caribou local populations. Habitat conditions were modeled based on, and limited to, the likelihood of future fires and natural forest recovery (i.e., regeneration) of disturbed habitats. The model was not designed to provide a full assessment of future conditions (i.e., it does not include future anthropogenic disturbance). Rather, this information can be used in combination with the persistence indicator to provide an indication of the level of active recovery likely to be required (in addition to passive recovery) for self-sustaining local populations, and in the interpretation of disturbance thresholds.

Step 4: Description of Critical Habitat

In the context of the present assessment, the scientific description of boreal caribou critical habitat for each range consists of the following four components: the delineation of the range; an integrated risk assessment of current capacity to maintain self-sustaining populations; information to support the identification of range-specific disturbance thresholds; and a description of the key bio-physical attributes within a range required by boreal caribou.

Integrated Risk Assessment (section 2.4.6.1)

A probabilistic decision-analysis tool (i.e., *Bayesian Decision Network*) was developed to combine each available data input (population trend, population size, percentage total disturbance) for a given range to assess the probabilities that current conditions within boreal caribou ranges would support self-sustaining populations. An indicator-based "lines of evidence" approach was used to evaluate two of the criteria related to self-sustaining populations (stable/positive population growth and persistence). This approach was favored over the averaging of individual probabilities of population growth and persistence (as per EC 2008) because: (i) the demographic and environmental factors that determine population growth rate and population persistence are related, although time lags may create a temporal mismatch between the respective factors, and; (ii) the quantity and type of information available for each range varies widely, and so considering each type of data as a line of evidence enabled the application of a consistent set of decision rules for assessing the evidence. The results were used to identify the risk that the current habitat conditions of boreal caribou ranges would fail to maintain self-sustaining local populations.

The third criterion for self-sustaining populations, i.e., no active management, was assessed based on information available for each range. If a range was assessed as able to support a "self-sustaining" caribou population, based on population information criteria, but was known to be subject to management interventions, it was not considered to be "self-sustaining".

Range-specific Management Thresholds (section 2.4.6.2)

The probabilistic approach to the integrated risk assessment of critical habitat for recovery planning is complemented by the identification of similarly-derived probabilistic intervals of disturbance relative to current and projected caribou population state. This information can be used to support the establishment of risk-based management thresholds. While it falls beyond the scope of the present scientific assessment to recommend specific management thresholds, given the need to explicitly identity acceptable management risk, description of a methodology for deriving these is provided, along with examples of their potential application, and discussion of their interpretation relative to the criteria and indicators evaluated here.

Bio-Physical Attributes (section 2.4.6.3)

Bio-physical attributes are the habitat characteristics required by caribou to carry out the life processes necessary for survival and reproduction. The results from the habitat selection analyses (this report) and published reports were used to summarize key bio-physical attributes by ecozone.

Step 5: Identify Information Needs, Monitor and Adapt

Critical habitat for boreal caribou is an emergent property of dynamic boreal landscapes represented by a suite of conditions that are not fixed in either space or time. A robust research and monitoring program is essential to continually assess the identification and management of critical habitat for each local population or conservation unit, and adjust when needed. At a minimum, monitoring is required to ensure that the protection of critical habitat is effectively meeting specified recovery objectives for populations and distribution in the long term.

The process of adaptive management acknowledges and supports the adjustment of management actions in light of new knowledge. The adaptive management cycle is an essential component of the Critical Habitat Framework. Knowledge gaps and uncertainties are identified, evaluated, and reported as information needs, and addressed through management planning and implementation (see Section 4.0).

2.4 Implementation of the Framework

The implementation of the Scientific Description of Critical Habitat component of the Critical Habitat Framework (see Figure 1) is focussed on three main outcomes: 1) an integrated risk assessment of whether or not the current set of habitat and population conditions within a range are sufficient to support a self-sustaining caribou population; 2) a methodology to identify range-specific disturbance thresholds; 3) and a description of the bio-physical attributes of boreal caribou habitat. Figure 2 illustrates how the framework was expanded to achieve these outcomes and provide a description of critical habitat. The sections below provide a stepwise summary of the decision tools and analyses that were conducted to implement the framework.

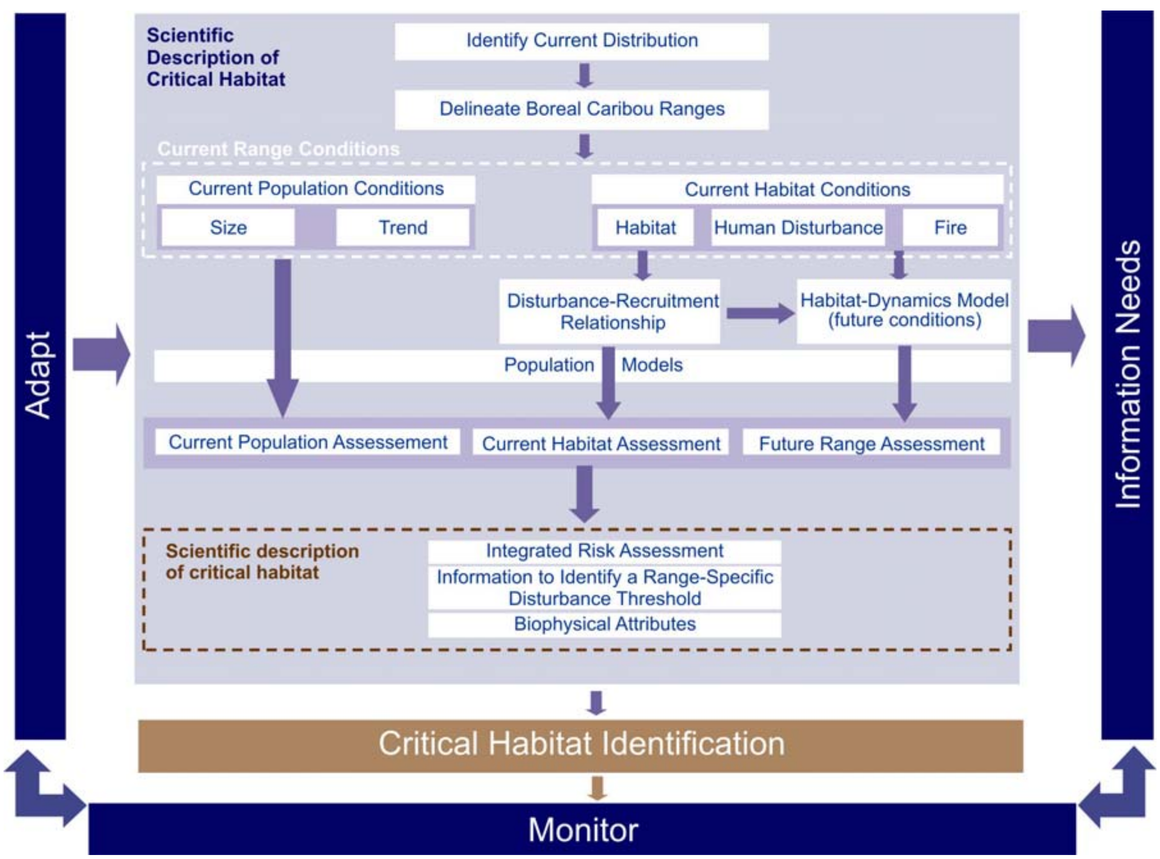


Figure 2. Scientific description of boreal caribou Critical Habitat Framework.

2.4.1 Identification of current distribution

The geographic scope of the assessment was defined by the current distribution, or extent of occurrence, of boreal caribou in Canada. Updated information from most of the jurisdictions on boreal caribou ranges (see Section 2.4.2) revealed some discrepancies with respect to the distribution information used in the context of the 2008 Scientific Review. The species distribution map was updated by increasing the distribution of boreal caribou to include all areas currently identified by the jurisdictions as boreal caribou ranges (Figure 3).

The two main areas where changes relative to the 2008 Scientific Review occurred were:

1. Northwest Territories: a) western boundary moved eastward; and b) changes around Great Bear Lake; and
2. Alberta: numerous changes to the distribution boundary in the province.

The updated distribution map confirms that boreal caribou are found in nine jurisdictions, extending from the Yukon Territory in the west, to Labrador in the east, and as far south as some islands in Lake Superior.

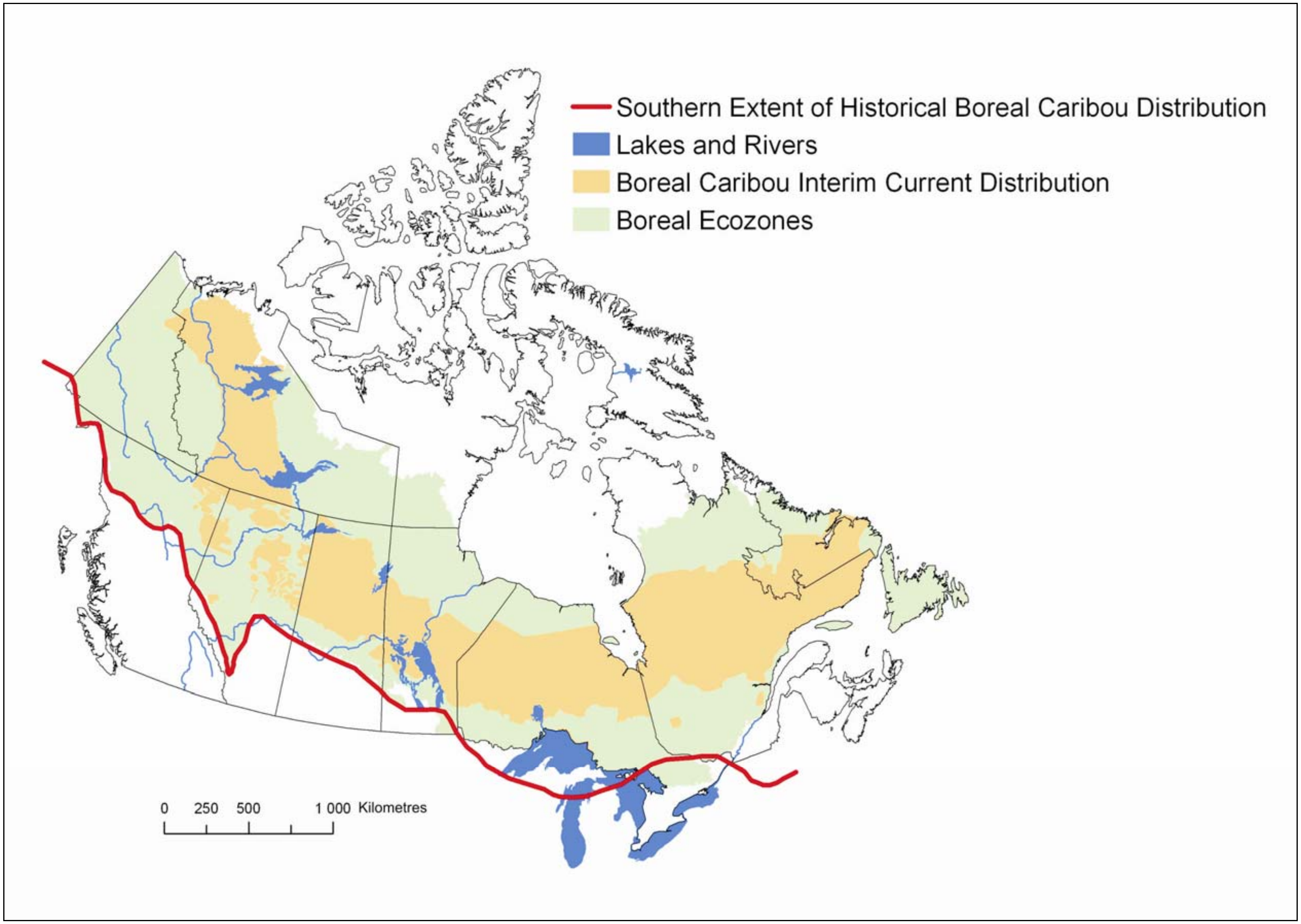


Figure 3. Distribution map of boreal caribou in Canada showing the current distribution of boreal caribou using updated information provided by jurisdictions. Note: Because of the lack of information on the historical distribution of boreal caribou in B.C. relative to the mountain ecotype of woodland caribou, the historical southern extent in that province is based on the boreal ecozones boundary.

2.4.2 Delineating boreal caribou ranges

National variation in range delineation

A survey of how ranges were being delineated across the boreal caribou distribution was conducted to assess the variation in the data and methods used across jurisdictions. An analysis was also developed to better understand the variation in type and quantity of data used to delineate ranges and the implications to the current assessment. Finally, a consistent approach to delineating ranges for this species was suggested to reduce the national variation in the future. This was accomplished by:

a. requesting that jurisdictions provide detailed information on how caribou ranges were delineated to document data and methods currently applied;
b. examining the impact of data availability on range size while controlling for other factors related to habitat condition (using data from the 2008 Scientific Review);
c. developing a categorization of ranges along a continuum that reflects the level of certainty in range boundaries and highlights important biological considerations for each category; and
d. classifying the updated delineation of boreal caribou ranges in Canada according to the categorization based on the type of information available and associated certainty in delineation.

The information provided by the jurisdictions indicated that data availability influenced the methods used for delineating boreal caribou ranges across Canada (Appendix 7.1). The analysis using data from the 2008 Scientific Review suggested that 65% of the variation in size of boreal caribou ranges was explained by data and methods used to delineate the ranges, and three surrogate measures of habitat quality including: the percentage of human disturbance on a range, the size of forest patches, and an inferred measure of forage availability, estimated from the cumulative fraction of photosynthetically active radiation (FPAR) (Table 1 in Appendix 7.1). The analysis revealed that high levels of human activity were associated with more discrete and isolated boreal caribou ranges and that data type had a significant impact on range size, after controlling for the effects of habitat quality.

The updated range boundaries for boreal caribou that were provided by jurisdictions were classified into three types reflecting the level of certainty in range boundaries: Conservation Units (low certainty), Improved Conservation Units (medium certainty), and Local Population (high certainty) (Figure 4). Suggested methods and considerations for developing a standardized approach to delineating each of the three types of ranges are discussed in Appendix 7.1.

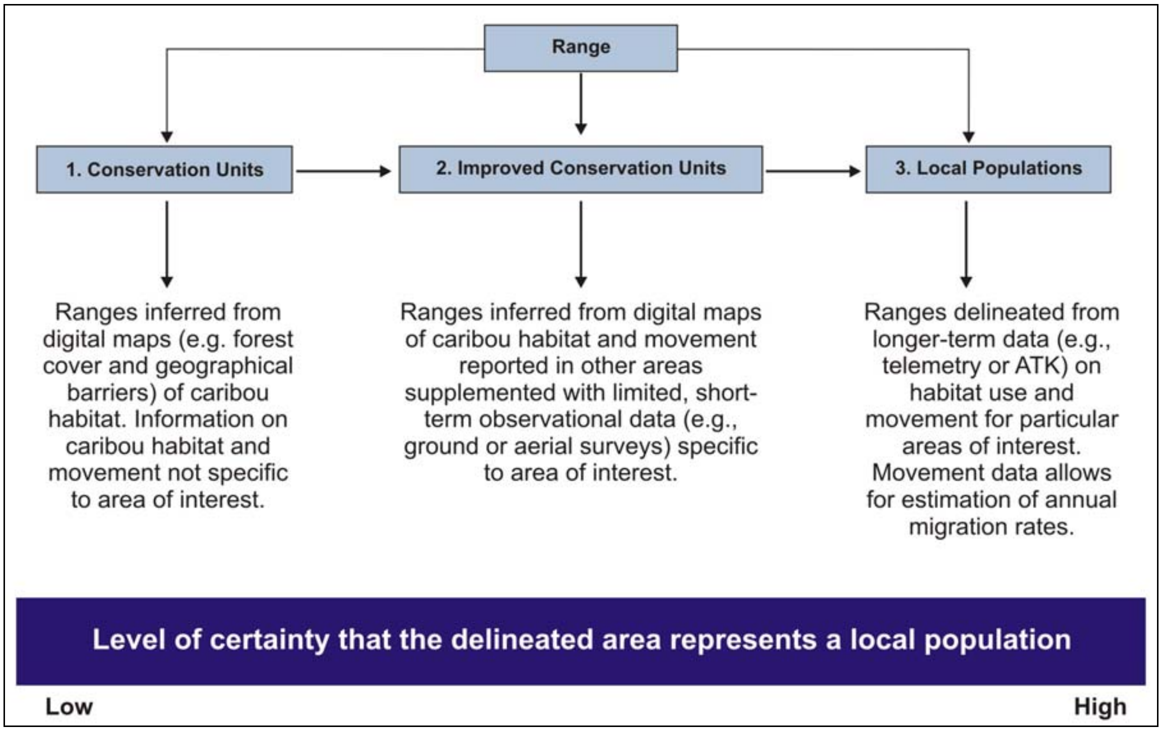


Figure 4. Range delineation types developed to reflect variation in the data and methods used to delineate boreal caribou ranges across Canada and the level of certainty in the delineated boundaries.

Revised national range delineation map

The boreal caribou range delineation map was updated using the best and most current information provided by jurisdictions. The map served as the basis for delimiting the spatial extent for the subsequent analyses of a range to maintain a self-sustaining population and ultimately the description of critical habitat.

Trans-boundary and large continuous ranges

Two special cases were highlighted as having important implications to the critical habitat analyses: trans-boundary ranges and very large continuous ranges. Few jurisdictions have coordinated efforts to harmonize information on trans-boundary ranges and range delineation often artificially stops at the political boundaries. The lack of joint monitoring and data-sharing between jurisdictions decreases the certainty of range delineations and subsequent critical habitat descriptions. For example, the cumulative disturbance across the trans-boundary range may exceed levels supporting population sustainability despite management efforts applied in either jurisdiction. Similarly, averaging habitat condition over a large, continuous area will mask spatial variation in disturbances, potentially resulting in range contraction where human development is concentrated (see Table 1 in Appendix 7.1).

2.4.3 Current habitat conditions

Two aspects of the 2008 Scientific Review focused on describing the habitat conditions influencing the survival and recovery of boreal caribou in Canada. First, a meta-analysis concluded that the percentage total disturbance (fire and 500m buffered anthropogenic disturbances) negatively affected the rates of caribou recruitment (EC 2008). Second, boreal caribou habitat use was described across different ecozones in Canada.

In the present update, a number of additional analyses quantifying the relative impact of different disturbance and habitat types and their configuration on caribou demography were undertaken to improve the certainty of the assessment of whether ranges could maintain self-sustaining local populations based on habitat condition. These included:

a. new digitized maps of anthropogenic disturbances and fires were created to facilitate analyses quantifying the impact of disturbance on caribou demography (Section 2.4.3.1);
b. an analysis of caribou habitat selection was conducted using radio-collar locations provided by jurisdictions to augment available information on the relative importance of different habitat types to caribou. The analysis was conducted at several scales (entire boreal caribou distribution and stratified by ecozones) to better understand how regional context might influence the description of critical habitat (Section 2.4.3.2);
c. new analyses were conducted to better understand how the spatial configuration of anthropogenic disturbance might influence caribou demography (Section 2.4.3.3); and
d. an enhanced meta-analysis of the relationship between habitat condition and population condition (hereinafter referred to as the recruitment-disturbance relationship, Section 2.4.3.4).

2.4.3.1 Disturbance mapping

a) Anthropogenic

A method for locating and classifying anthropogenic development according to the disturbance type was developed and implemented to create a nationally consistent, repeatable geospatial dataset of unbuffered estimates of anthropogenic disturbances. This update also increased the temporal correspondence between the disturbance data and the demographic data used in subsequent analyses to quantify the effect of habitat quality and configuration on the demography of boreal caribou.

Anthropogenic disturbance was defined as any human-caused disturbance to the natural landscape that could be identified visually from Landsat imagery at a scale of 1:50,000. Disturbances were classified into two broad categories, linear and polygonal features, which were further broken down into eight sub-categories each (Table 1). For each anthropogenic feature type, a clear description was established to maintain consistency in identifying the various disturbances in the imagery by different interpreters. Although ancillary data were used to guide interpretation and feature labelling, features themselves were only digitized if they were clearly visible on Landsat imagery. This general rule set the baseline for developing more specific rules of interpretation and digitizing of the disturbance events.

Table 1. Categories of anthropogenic disturbance digitized to inform the implementation of the boreal caribou critical habitat description framework.

Linear Features	Polygonal Features
Roads	Cut areas
Power lines	Mines
Railways	Reservoirs
Seismic Lines	Settlement
Pipelines	Well Sites
Dams	Agriculture
Airstrips	Oil and gas[1]
Unknown	Unknown[2]

1. Features associated with the oil and gas industry. This may include gas plant, batteries, pump station and compressor stations.
2. Areas believed to be anthropogenic disturbance, based on patterns and comparison to surrounding environment in the satellite imagery; however, the specific type of disturbance is unknown.

Two series of map products were produced. The first maps were to support the buffer analysis (see Section 2.4.3.3) and the meta-analysis of population and habitat condition (see Section 2.4.3.4). These data were collected from satellite imagery with dates that corresponded to the collection of demographic data for each local population (see Appendix 7.5), increasing the temporal correspondence between the disturbance and demographic data. In addition, current (2006-2010) mapping of each boreal caribou range as delineated by jurisdictions was performed to provide estimated areas of human disturbance required for the current and future range assessment (see Section 2.4.5). Only information on new anthropogenic disturbances was collected in areas that overlapped with the sample of ranges used in the meta-analysis (Section 2.4.3.4).

b) Fire

Estimates of fire used in the 2008 Scientific Review were calculated from the Canadian National Fire Database (CNFDB, maintained by the Canadian Forest Service (CFS)), augmented by additional coverage for Northwest Territories, that contained wildfires greater than 200 ha (CFS 2010, NWTCG 2010). A 50 year limit was used to identify areas disturbed by fire, and hence unsuitable for caribou, consistent with methodology applied by Sorenson et al. (2008).

For the present assessment, jurisdictional agencies were contacted to obtain the most complete and up-to-date information on fires. Information on fire within National Parks was provided from either Parks Canada, if available, or the CNFDB. The availability of fire data varied, in particular with respect to the first year of data collection, **and the maximum number of years for which fire data was available across jurisdictions**

was 40 years. As a result, the fire data were standardized by using a 40 year limit to identify areas disturbed by fire (i.e., less than 40 yrs). Due to the small amount of land in the 40-50 year age class for fires (for areas where the information was available), the change from 50 years to 40 years post-fire resulted in only minor discrepancies in measures of area disturbed by fire between the 2008 Scientific Review and the present assessment.

2.4.3.2 Habitat selection

It is well accepted that boreal caribou habitat use can vary spatially in response to regional and local environmental conditions and habitat availability (see Appendix 7.3). The current ranges of boreal caribou in Canada spans nine ecozones (Figure 5). Ecozones represent areas with roughly the same climatic conditions, land features, and floral and faunal species. They provide a logical starting point for controlling for some of the regional variation in abiotic and biotic conditions experienced by caribou across their boreal distribution.

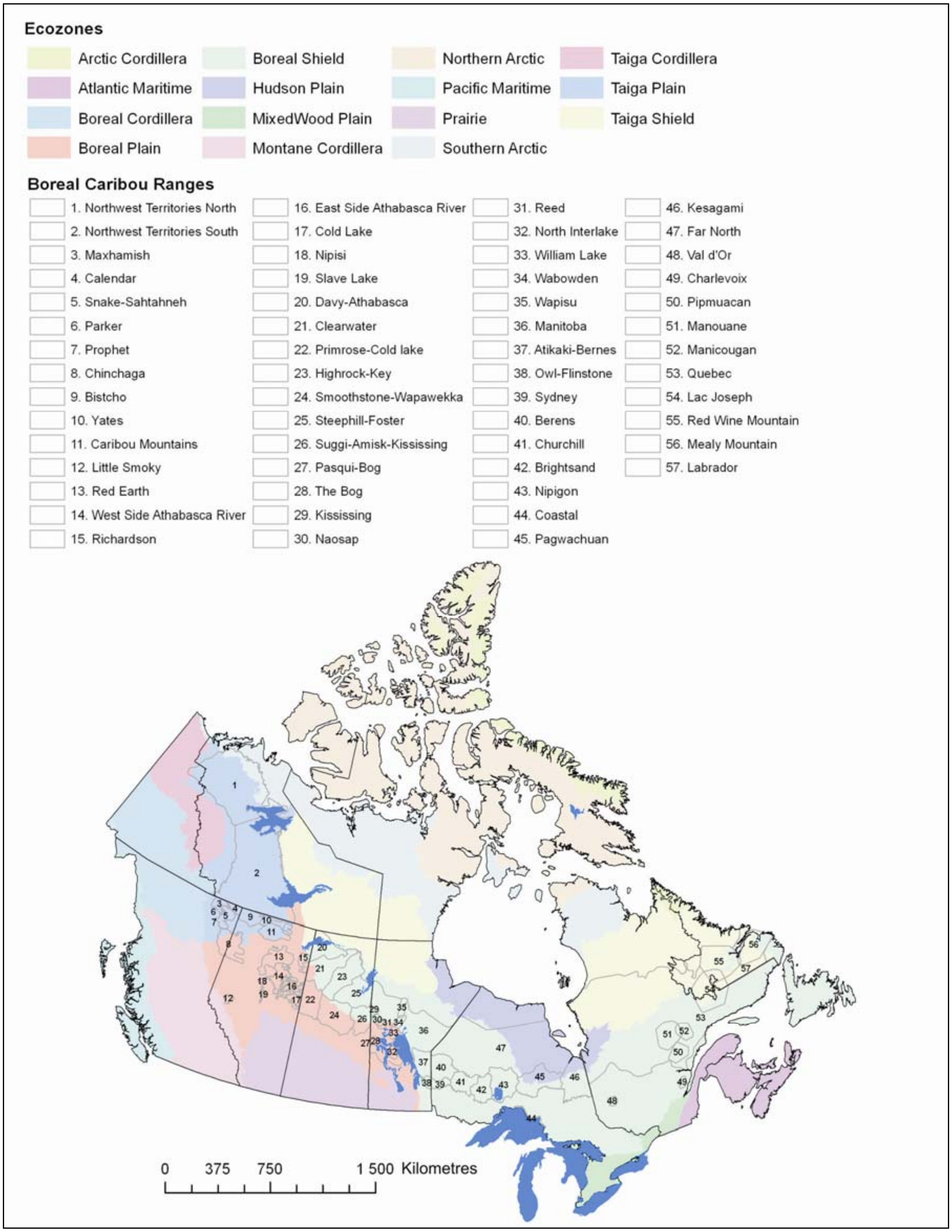


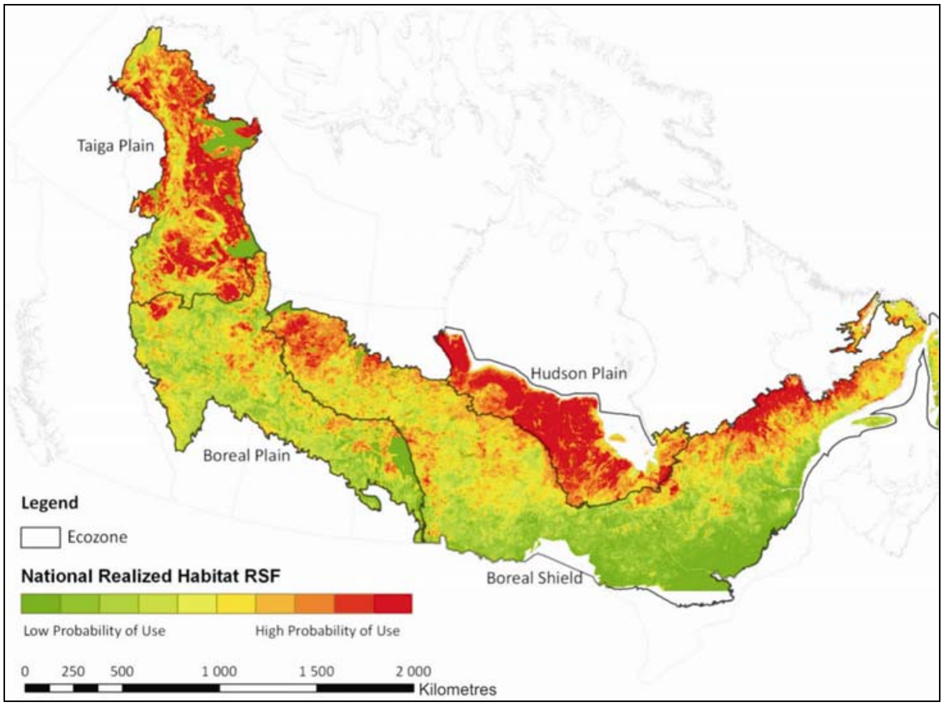
Figure 5. Location of current ranges of boreal caribou in relation to the ecozones in Canada.

Generally, resource selection (RSF) models are used to quantify a species' habitat use relative to its availability. RSFs were developed to describe caribou habitat use at two broad-scales: a national model describing habitat use across the extent of the species' occurrence and ecozonal models describing habitat use across the different ecozones found in the boreal forest of Canada (Figure 6; Appendix 7.3). These scale-dependent analyses allowed for a better understanding of how the variability in habitat selection at different spatial scales might affect the description of critical habitat, by testing whether or not controlling for ecozonal variation could strengthen inferences about the biotic and abiotic conditions influencing caribou demography.

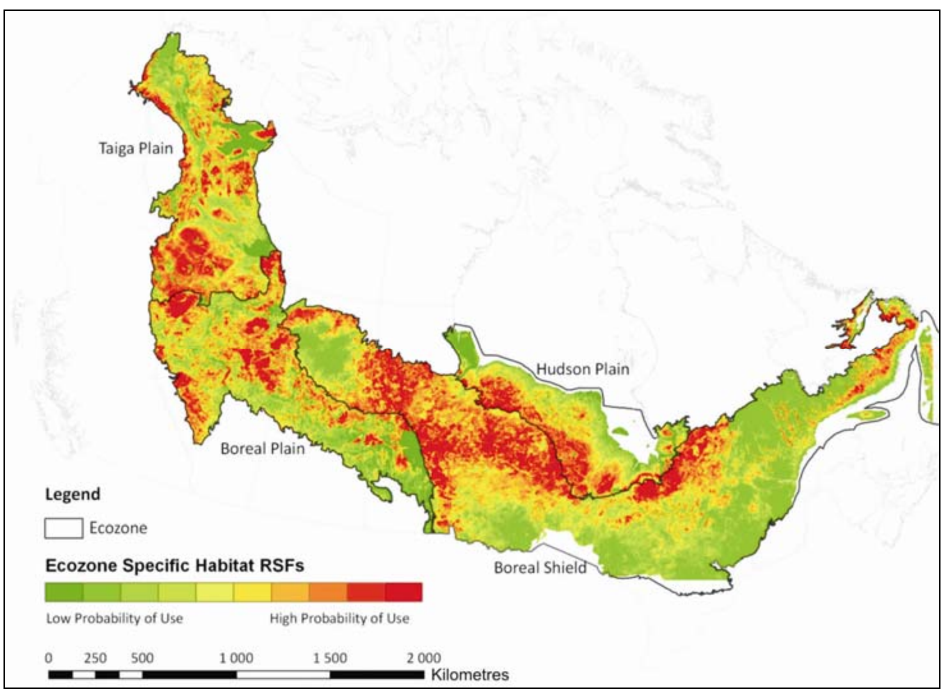
The RSF models were developed using animal location data from 581 radio-collared caribou distributed among 27 ranges, including 179,022 locations during 2000 to 2010 (Table 4.1 in Appendix 7.3). The caribou location data were provided by several jurisdictions. A nationally consistent digital database was developed to define the types of habitats available to boreal caribou across the country, including the identification of different types of forest, wetlands, disturbances (fires and roads), forage quality, slope, aspect and the roughness of the landscape (Table 5.1-5.2 in Appendix 7.3). The landcover data were derived from MODIS imagery, complemented with the Peatlands of Canada database. The fire data used was from a compilation generated by EC and acquired from individual provinces and territories along with data from the CNFD for the fires within National Parks. The fire data included burns from 1917 and 2010.

The RSF models corroborated many important habitat selection relationships of boreal caribou reported in the literature. For example, the models indicated that caribou consistently avoided areas with high road density and avoided recent burns (less than 40 years old), across all ecozones. In this context, avoidance is defined as a reduction in use compared to what would be expected based on availability. Previous research has shown that boreal caribou are associated with mature conifer stands and peatlands where terrestrial lichens are available for winter forage (Stuart-Smith et al. 1997, Neufeld 2006, O'Brien et al. 2006, Brown et al. 2007, Courtois et al. 2007). Thus, recent burns that destroy lichen and result in young seral stands are likely avoided by caribou across the boreal forest (Schaefer and Pruitt 1991, Vors et al. 2007, Sorensen et al. 2008). However, such results derived from coarse national or ecozonal datasets should be interpreted with further considerations of local environmental factors (i.e., frequency, size and severity of forest fires in a specific region). Fire regimes vary significantly across the national, and even, the ecozonal distribution of boreal caribou. Boreal caribou are adapted to the local environmental conditions defining each range. From a caribou habitat use perspective, a 40 year post-fire time period might be considered "old" in certain regions, while considered relatively "young" elsewhere. As such, regional idiosyncrasies in fire recovery time period should be investigated with more refined datasets prior to making decisions on the appropriate recovery time period relative to caribou habitat.

In general, the ecozone specific models were more discriminatory and had better predictive accuracy than the national model. A cross-validation analysis was performed using withheld caribou locations to assess the ability of the RSF models to successfully predict caribou habitat. The results indicated that, even at the national scale, high frequencies of the withheld caribou locations occurred within high use areas identified by the RSF models. There was, however, significant variation in ecozonal relationships that should be explored through more detailed analyses, based on more refined datasets.



(a)



(b)

Figure 6. (a) National and (b) ecozone specific resource selection functions (RSFs) for boreal woodland caribou across the extent of occurrence in Canada. The probability of selection is scaled between low (green) and high (red).

The relative ranking of habitat as predicted by the RSF models was used to identify high quality caribou habitat. High quality habitat was defined by the top three (3) quantiles of the predicted probability of occurrence of boreal caribou, and was incorporated into subsequent analyses examining the effects of habitat condition on caribou recruitment (see section 2.4.3.4).

2.4.3.3 Buffer analysis

The purpose of the buffer analysis was to quantify the ecological effects of human development on boreal caribou, relative to the extent by which human disturbances were buffered. It was also used to examine the impact of buffering on the configuration of anthropogenic disturbance and, in turn, the effect of configuration of disturbance in a range on caribou.

The effect of anthropogenic disturbances on boreal caribou was tested by comparing changes in the predictive power (R^2) of a model describing variation in caribou recruitment as a function of percent total disturbance of the range, an aggregate measure of fire and buffered human disturbance, for 24 boreal caribou ranges across Canada (see Section 2.4.3.4 or Appendix 7.5 for details). The ten models tested differed only in the buffer radius applied equally to all types of anthropogenic development with the exception of reservoirs (see rationale for removing reservoirs from the disturbance footprint in Section 2.4.3.4).

The relationship between the disturbance–recruitment model's predictive power and different buffer treatments on human disturbance was dome-shaped and was sub-divided into 3 zones: increasing, stable, and decreasing (Figure 7). The stable zone was defined as models with buffer treatments with an R^2-value that was within 2.5% of the best model (1000 m buffer; Appendix 7.4). The 2.5 % threshold was chosen to approximate a one-tailed significance test of $\alpha = 0.025$ with the tail of the distribution bound by the most extreme R^2-value (i.e., best model). The most conservative buffer (500 m) within the stable zone (Figure 7) was selected to represent the effective area of anthropogenic disturbance.

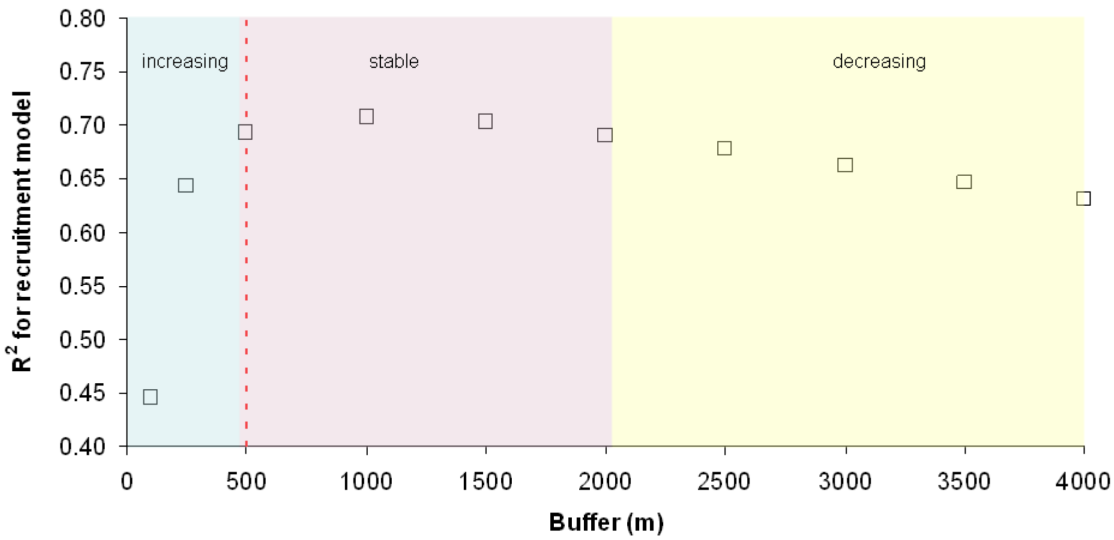


Figure 7. R^2-value of models describing recruitment as a function of percent total disturbance with different buffers applied to anthropogenic disturbance. The dashed line denotes the 500 m buffer selected to represent the effects of human disturbance. The three zones (increasing, stable, decreasing) represent trend in the relationship.

A sensitivity analysis indicated that the disturbance-recruitment relationship applied with a 500 m disturbance buffer width produced stable estimates of the effect of anthropogenic disturbance on caribou recruitment (see Appendix 7.4). Moreover, the 500 m width appeared to capture basic information about the effects of fragmentation or the spatial configuration of human disturbance on the landscape in addition to the effects of habitat loss. Only two of the six disturbance configuration metrics tested had a significant effect on caribou calf recruitment, after controlling for the percentage anthropogenic disturbance buffered by 500 m: edge density, a surrogate for quantifying the changes in the permeability of the landscape to predators, and the nearest-neighbour distance between disturbance patches, a surrogate measure of landscape connectivity. These two metrics of disturbance configuration were incorporated into the subsequent analysis to identify the relationship between population (recruitment) and habitat conditions (disturbance, see Section 2.4.3.4).

2.4.3.4 Meta-analysis of population and habitat condition

In addition to incorporating the results of the enhanced disturbance mapping, the scope of the meta-analysis of caribou calf recruitment in relation to disturbance was expanded to better explain and understand the influence of habitat quality (including the type and configuration of disturbance) on this relationship (see Appendix 7.5). The expanded version included the development of eleven (11) candidate models that quantified improvements in the disturbance mapping (M0 vs. M3; Table 2), tested the relative effects of different disturbance types (M1-8), incorporated the results of the effects of anthropogenic disturbance and the configuration of disturbance (M9), and evaluated the influence of undisturbed habitats (M10-12) including high quality caribou habitat (hqh) as derived from the habitat selection model (Model 12).

Table 2. Specification of candidate models for the national meta-analysis.

Model	Predictor variables	Description
M0	total_dist_2008	Total non-overlapping disturbance from 2008 (see EC 2008)
M1	anthro_2011	Anthropogenic disturbance (500m buffer; reservoirs removed)
M2	fire_2011	Fire proportion (unbuffered)
M3	total_dist_2011	Total non-overlapping disturbance (500m buffer; reservoirs removed)
M4	lnlinear_2011	Percent buffered linear disturbance (500m buffer)
M5	poly_2011	Polygonal anthropogenic disturbances (500m buffer; reservoirs removed)
M6	lnlinear + poly_2011	M4 + M5
M7	anthro + fire_excl_anthro_2011	M1 + fires exclusive of anthropogenic disturbances
M8	total_dist + fire_prop_dist_2011	M3 + fires as proportion of total disturbance
M9	total_dist + ln_nn_2011	M3 + area-weighted mean nearest neighbor distance (500m buffer)
M10	ifl_2011	Proportion intact forest landscape exclusive of anthropogenic disturbance
M11	ifl_nofire_2011	Proportion intact forest landscape exclusive of anthropogenic disturbance and fire
M12	total_dist + hqh_2011	M3 + proportion of high quality habitat

The top model (M3) explained 69% of the variation in calf recruitment across a sample of twenty-four (24) ranges based on the percent total disturbance (fire + 500 m buffered anthropogenic disturbance; Figure 8) on each range. This model was analogous to the top model used in the 2008 Scientific Review. However, the new disturbance maps, which allowed better temporal matching of demographic data with disturbance data, and exclusion of reservoirs from the disturbance estimates, resulted in a 12% gain in explanatory power over the 2008 model. Most of the negative effects of disturbance were attributed to human development (60% in isolation), while only 5% of the variation in recruitment could be attributed to fire alone (see Appendix 7.5). Nevertheless, their combined influence was greater than the sum of their individual contributions. Decomposing anthropogenic disturbance into linear and polygonal features did little to improve the predictive power of the recruitment model, but the negative effect of linear disturbance features was greater than the negative effect of polygonal disturbances (see Appendix 7.5).

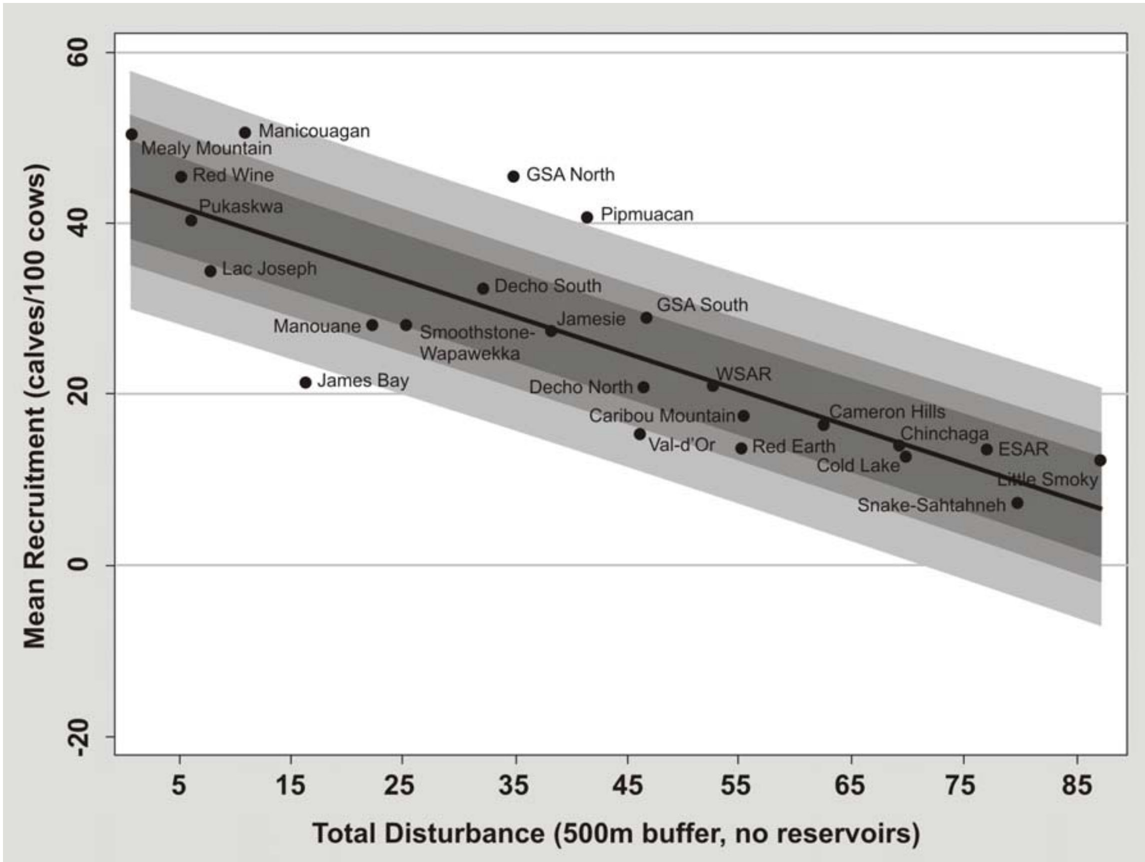


Figure 8. Graph showing 50, 70 and 90 % prediction bands for the best univariate regression model (M3) of caribou recruitment and landscape disturbance.

The disturbance–recruitment relationship from the meta-analysis was used to parameterize a model of habitat-based population growth (see Appendix 7.8) based on the percent total disturbance within each boreal caribou range, and this indicator was used for the integrated risk assessment (Section 2.4.6.1) and to derive the categories of risk for the disturbance thresholds (Section 2.4.6.2).

2.4.4 Current population condition

Jurisdictions were requested to share best available demographic data for the updated assessment. Data availability and type varied widely between ranges (Appendix 7.1; Appendix 7.11).

2.4.5 Current and future conditions

2.4.5.1 Current condition

The assessment of current range conditions evaluated the probability that current range conditions were sufficient to support self-sustaining caribou populations. As per Section 2.1., a "self-sustaining" population is one that experiences stable or positive growth (trend) over the short term (*first criterion*), and is large enough (size) to persist over the long-term (*second criterion*) without active management intervention (*third criterion*), such as predator control. Table 3 describes the indicators developed to evaluate the three criteria, namely:

1) the probability that caribou would experience stable or increasing population growth over the short-term, which was expressed as Pr ($\lambda \geq$ stable) over 20 years; and
2) the probability that the population was large enough to avoid quasi-extinction, defined as a population with less than 10 reproductively active females over the longer term without the need for ongoing active management intervention (e.g., predator management or translocation from other populations), which was expressed as Pr ($N_t \geq$ Qext) over 50 years (see Appendix 7.8 for details of the two indicators). This indicator was used to assess the increased risk of extinction for small population sizes such that lower values of Pr ($N_t \geq$ Qext) indicate a higher risk of extinction and vice versa.

Two types of analyses were required to estimate the probabilities that ranges could maintain a self-sustaining local population: a non-spatial population viability analysis (using a generic population model; Appendix 7.6), and a probabilistic decision-analysis tool, or Bayesian Decision Network (BDN[2]; Appendix 7.8). Two different sources of information were used to define range-specific demographic parameters. The disturbance–recruitment relationship from the meta-analysis was used to parameterize the population model based on habitat condition (see below under *Indicator from habitat condition*), whereas the information provided by jurisdictions on population size and trend were used to define demographic parameters based on population condition (see below under *Indicators from population condition*). The self-sustainability indicators from habitat and population conditions were used to inform the integrated risk

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[2] Bayesian decision networks (BDNs: also called probability networks) are statistical tools increasingly used in ecology and wildlife management to depict the influence of habitat or environmental predictor variables on ecological-response variables (Marcot et al. 2006).

assessment, which is a component of the scientific description of critical habitat (Section 2.4.6).

Table 3. Indicators of self-sustainability used in the Integrated Risk Assessment to assess current conditions.

Indicator of self-sustainability	Data used[1]	Description
1) Probability of population growth rate based on habitat condition, $Pr\ (\lambda \geq \text{stable})_{habitat}$	Population growth (λ) derived from the recruitment-disturbance relationship.	The proportion of times the mean projected population growth over 20 years (yr) was either stable or increasing on average over that time interval $Pr\ (\lambda \geq \text{stable})$, given a specified set of demographic estimates. The 20-yr time period corresponds to the IUCN criteria for evaluating rates of change and probabilities of population decline. Only extant populations, defined as populations greater than 10 animals at the end of the time interval, were used to calculate $Pr\ (\lambda \geq \text{stable})$.
2) Probability of population growth rate based on population condition, $Pr\ (\lambda \geq \text{stable})_{population}$	Population information reported from jurisdictions.	
3) Probability of population size exceeding quasi-extinction threshold, $Pr\ (N_t \geq Qext)$	Population size reported from jurisdictions. Estimates calculated assuming good demographic conditions (stable growth).	The proportion of times a population remained extant over 50 yrs ($Pr\ (Nt \geq Qext)$ given a set of specified demographic estimates. Extant populations were defined as those with greater than 10 reproductively active females, based on IUCN criteria for assessing extinction risk (IUCN 2010).

1. Decision rules were developed for addressing the variability in data availability across ranges (see Appendix 7.8).

Population model

The generic population model (referred to as “ensemble model” in Appendix 7.6) was developed to create a large database of potential outcomes from which range-specific probabilities could be derived. The demographic variables used in the model (Table 4) were estimated from a review of the published literature on boreal caribou and cover the range of demographic values reported from the jurisdictions. The model projected annual changes in initial population ($N_{t=1}$) over 20 and 50 years using all possible permutations of population parameters and assumed levels of error in each parameter (i.e., standard deviation, SD) to reflect different levels of annual stochastic variation. The projected changes in population size at each time (t) step ($N_{t=1}$, $N_{t=2}$,… $N_{t=20}$) over 20 years were used to calculate the annual realized lambda (λ, proportional change in population size at t+1) for each combination of parameters (Appendix 7.6). These were used to define the range of lambda values for which the population showed decreasing, stable and increasing growth, on average over the 20 years given stochastic variation (Table 5) and to estimate the self-sustainability indicator of stable and increasing population growth ($Pr\ (\lambda \geq \text{stable})$). The upper and lower bound for defining a self-sustaining population was defined by $\lambda = 1.01$ and $\lambda = 0.99$, respectively. Many populations under a variety of demographic conditions are likely to be self-sustaining using this definition, particularly given assumed annual stochastic variation in population parameters and the effects of demographic stochasticity. However, some may not be self-sustaining (e.g. smaller populations considered over longer time frames), therefore care is required when interpreting whether one or more management responses are likely to improve the chances of a population being self-sustaining in the future. The projected changes in population size ($N_{t=1}$, $N_{t=2}$,… $N_{t=50}$) over 50 years were used to calculate the self-sustainability indicator for assessing the increased risk of extinction for small population size (Pr ($N_t \geq Qext$)).

Table 4. Ranges of parameters and their incremental step sizes used in factorial projections for the generic population modelling.

Parameter	Range of Values	# levels (increments)
N_0 – initial population size (mature females)	20–10,000	18
Annual mean per capita recruitment – recruitment of females/female	0–0.3	13 (increments of 0.025)
Annual SD about recruitment	0.01–0.21	4 (increments of 0.07)
Annual potentially breeding female survival rate	0.70–1.0	16 (increments of 0.02)
Annual SD about survival	0.01–0.21	4 (increments of 0.07)
K	20 times N_0	3 (values of 3, 6, and 20)
r_{max}	1.1–1.3	2 (1.1 and 1.3)

Table 5. Range of lambda values corresponding to each of the population trend categories determined through population simulations.

Population Category	Range of λ
Decreasing	<0.99
Stable	0.99–1.01[1]
Increasing	>1.01

1. above a λ = 0.99, populations have a high probability of remaining, on average, stable for long-periods, given stochastic variation (Appendix 7.6).

Indicator from habitat condition

One self-sustainability indicator was calculated from habitat condition: the probability that the local population would experience stable or increasing population growth (λ) over a 20-year period, i.e., Pr ($\lambda \geq$ stable)$_{habitat}$, hereinafter referred to as the habitat indicator of population growth (Table 3). The percentage of total disturbance (fire and 500 m-buffered anthropogenic disturbance) within each range was used to estimate the recruitment rate (± SD) using the recruitment-disturbance relationship developed in section 2.4.3.4. The national average for adult survival (Sad = 0.85) was used in combination with the expected recruitment value and associated coefficients of variation for each range to calculate annual population growth used by the BDN to estimate range-specific Pr ($\lambda \geq$ stable)$_{habitat}$. This indicator was calculated as an expected mean over all possible population sizes observed nationally to isolate the effects of population growth from the effects of population size (see section *Indicators from population condition*).

Indicators from population condition

Two self-sustainability indicators were calculated for each range based on population condition information: Pr ($\lambda \geq$ stable)$_{population}$, hereinafter referred to as the population indicator of population growth and Pr ($N_t \geq$ Qext), hereinafter referred to as the indicator of quasi-extinction, a persistence measure used to assess the increased risk of extinction for small population size (Table 3).

The population indicator of population growth was estimated by the BDN for all ranges using the reported lambda values (λ ± SD) or population trend (decreasing, stable, or increasing; Table 5) reported by jurisdictions. A set of decision rules was developed to address the variability in partial data reported from jurisdictions for lambda. For example, the national average for adult survival (Sad = 0.85) was used in combination with observed recruitment values to estimate lambda if the reporting jurisdiction only provided recruitment estimates for a given range. As per the habitat indicator of population growth, the population indicator of population growth was calculated as an expected mean over all possible population sizes to reflect variability in expected outcomes based on observable population sizes at the national scale.

The indicator of quasi-extinction was estimated using population size for each range and assuming good demographic conditions (stable growth) to isolate the effect of population size from population growth. This provided an assessment of the increased risk of extinction for small populations due to stochastic events for the integrated risk assessment (see Section 2.4.6). This indicator was not calculated in the absence of population size data.

2.4.5.2 Future conditions

A semi-spatial habitat-dynamics model was developed (Appendix 7.7) to forecast future changes in the spatio-temporal patterns in habitat conditions and their impact on the assessment of a range's ability to maintain a self-sustaining population. These projections of natural disturbance were used as input data for the estimation of the habitat indicator of population growth through time (see Table 3) which in turn provided information to support the consideration of range-specific disturbance thresholds. The three (3) steps required to estimate the indicator were:

1. The current state of habitat conditions within each range was characterized by information about fire regimes, anthropogenic disturbances, water bodies, and different habitat types identified by the Moderate Resolution Imaging Spectroradiometer (MODIS, a sensor on the Terra satellite). All features within the range were time stamped to track their change through time. Time since last fire was used to determine the age of forests following fires. Anthropogenic disturbances were assumed to have been created in the same year of the Landsat imagery that was used to digitize the disturbance (section 2.4.3.1). An expected stable or equilibrium age structure for the different forest types was created using long-term simulations (see Appendix 7.7).
2. The current range maps (from step 1) were projected 100 years into the future using the Spatially Explicit Landscape Event Simulator (SELES; Fall and Fall 2001) according to four broadly contrasting scenarios:
    i. Static conditions: Current conditions remain unchanged (i.e., there are no new anthropogenic or natural disturbances, ecological succession or recovery of disturbed habitat). While this is not intended as a realistic scenario, it is an analogue of the 2008 Scientific Review "static" analysis and extends it to allow estimation of demographic stochasticity in the habitat-based PVA model (Appendix 7.6).
    ii. Recovery only: This projects the effect of passive (i.e., no active restoration) of disturbed areas over time on range condition (see Appendix 7.6 for rules of passive recovery). This allows for an assessment of the partial effect of reducing current levels of fire and anthropogenic disturbance on the range upon the population parameters irrespective of the confounding effects of other dynamics.
    iii. Natural disturbances only: This scenario was used to estimate the partial effect of natural habitat dynamics (see Appendix 7.6 for rules of natural habitat dynamics), given current levels of anthropogenic disturbance upon the population parameters.
    iv. Recovery + natural disturbance: This scenario was used to examine the combined effects of range dynamics assuming no further increase in anthropogenic disturbance upon the population parameters.

The spatial simulation maps were used to calculate annual estimates of the percent future total disturbance (fire and 500m buffered anthropogenic) for each of the four scenarios.

3. The future disturbance estimates were used to calculate an expected recruitment rate from the disturbance–recruitment relationship (see Section 2.4.3.4). Using the same approach as in Section 2.4.5.1, the expected recruitment was combined with a national mean adult survival rate (Sad = 0.85) and associated coefficients of variation for both to produce probability estimates of expected future growth rate (λ) of the population. The probability that the future range would experience stable or increasing growth Pr ($\lambda \geq$ stable) was estimated using the large database created by the Population Model and the BDN (Section 2.4.5.1) to produce range specific mean estimates of lambda (λ) for future levels of disturbance averaged over 0-20 years, 21-50 years and 51-100 years.

The results from the assessment of future conditions for each scenario and time interval are represented in the factsheets (Appendix 7.10) for each range as per Figure 9. Such information can be used to support the interpretation of the range-specific disturbance thresholds (see Section 2.4.6.2 and Appendix 7.9). However, they are not, and should not, be interpreted as projections of the actual condition of the range through time.

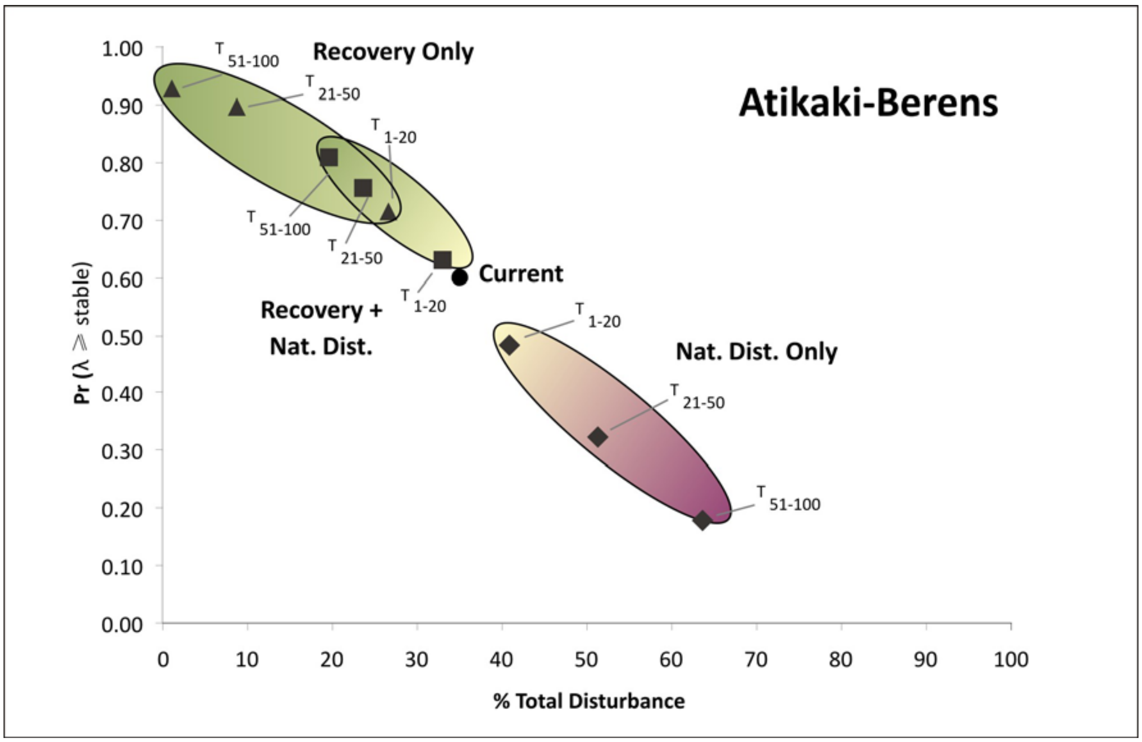


Figure 9. Probability that the population growth rate is either stable or positive (Pr ($\lambda \geq$ stable)) as a function of percent (%) total disturbance based on four (4) hypothetical habitat dynamic scenarios: (1) Current: static conditions; (2) Recovery Only: passive recovery of old disturbances; (3) Natural Disturbance Only (Nat. Dist. Only): new disturbances created by fire without passive recovery; and (4) Recovery + Nat. Dist.: the combined effects of new fires and passive recovery of old disturbances, averaged for three time intervals (1-20, 21-50, 51-100 yrs). Note: this example is for the Atikaki-Berens range.

2.4.6 Critical habitat description

2.4.6.1 *Integrated Risk Assessment*

"Risk" is defined here as the likelihood that a range can maintain a self-sustaining local population, and the uncertainty surrounding the indicators used in the assessment. The Integrated Risk Assessment for each local population had 2 main components (Tables 6 and 7):

1. A statement about the probability that current range conditions, described in terms of habitat and population conditions, are sufficient to support a self-sustaining population (Table 6). This involved a lines and weight of evidence approach to integrate the three indicators of self-sustainability (see Section *Decision rules for integration*) and assign each range to one of five likelihood categories of self-sustainability. These categories represent a gradient of risk based on a modified version of the likelihood scale developed by the Intergovernmental Panel on Climate Change (IPCC 2005.).
2. The uncertainty, or alternatively, the certainty in the Integrated Risk Assessment was assessed using two certainty measures: a statement of certainty that reflects the type of information used to estimate the indicators of self-sustainability (Table 7), and their consistency (described under Section *Decision rules for Integration*). A reported lambda measured over at least three years within the last 10 years was assigned a higher level of certainty in terms of the quality of information than a reported trend. A reported lambda measured over less than three years within the last 10 years was assigned the same level of certainty as a reported trend (Table 7).

Table 6. Likelihood scale for the Integrated Risk Assessment of current conditions.

Probability of the outcome (self-sustaining)	Category of likelihood that the range condition can support a self-sustaining local population	Self-sustainability outcome[1]
≥ 0.9	Very likely	SS
<0.9 to ≥ 0.6	Likely	SS
<0.6 to ≥ 0.4	About as likely as not	NSS/SS
< 0.4 to ≥ 0.1	Unlikely	NSS
< 0.1	Very unlikely	NSS

1. SS: Self-Sustaining; NSS/SS: Not Self-Sustaining / Self-Sustaining; NSS: Not Self-Sustaining.

Table 7. Level of certainty associated with the availability of demographic data for a range. Data on habitat condition was not included because it was available for and standardized across all ranges.

Certainty statement of evidence based on availability of demographic data	Demographic data available
Much evidence	Reported lambda[1] and population size
Considerable evidence	Reported trend and population size
Some evidence	Population size
Limited evidence	No demographic data

1. Lambda must be measured over ≥3 years within the last 10 years. A reported lambda that did not satisfy this criterion was treated like a reported trend.

Decision Rules for Integration

A set of decision rules, illustrated in Figure 10, was established for weighting the individual assessments of self-sustainability based on the three (3) indicators and providing one integrated risk assessment. First, a self-sustainability outcome was determined for each indicator using the probability intervals in Table 6. The three individual outcomes were compared to determine if the three indicators of self-sustainability were in agreement (Step 1). If all three indicators suggested the same self-sustainability outcome (i.e., *high* agreement as defined in Table 8), the later was considered as the integrated risk assessment (Step 8). For this situation, the associated likelihood category was based on the indicator suggesting the lowest, more conservative, likelihood of self-sustainability.

Additional steps were taken to resolve disagreement among the indicators and identify the most plausible outcome given available range-specific information. In cases where the three indicators were in complete disagreement (i.e., *low* agreement as defined in Table 8), the precautionary principle was applied such that the outcome from the indicator suggesting the lowest probability of maintaining a self-sustaining population was assigned the most weight of evidence, and selected (Step 2) with its associated likelihood category as the integrated risk assessment outcome. For all other cases, Steps 3-7 of the decisions rules were implemented to identify the indicator with the most weight.

Conflicting assessment outcomes resulting from *partial* agreement (Table 8) between the habitat and population indicators of population growth (Step 4) was resolved by:

4a. Determining whether there was active predator management on the range. Active predator management would bias the Pr $(\lambda \geq \text{stable})_{\text{population}}$ towards high likelihoods of self-sustainability despite poor habitat conditions. When available information suggests predator management, the Pr $(\lambda \geq \text{stable})_{\text{habitat}}$ was attributed the most weight and used as the indicator of population growth.

4b. Determining whether the Pr $(\lambda \geq \text{stable})_{\text{population}}$ was calculated using a lambda measured over at least three years within the last 10 years. This rule was devised to distinguish ranges for which the population indicator of population growth was based on a estimates of lambda (λ) that were based on intensive monitoring versus population indicators based on reported trends that are often inferred (see Appendix 7.11). Estimates of lambda can show considerable annual variation due to stochastic events. Three years was selected as the minimum data requirements to produce lambda (λ) estimates with some level of confidence given the assumed levels of error or stochasticity used in the population modelling to derive the indicators. The Pr ($\lambda \geq$ stable)$_{population}$ was assigned more weight and selected for the assessment in such cases, otherwise the Pr ($\lambda \geq$ stable)$_{habitat}$ was used.

The precautionary principle (Guiding Principle 5) was applied in situations where the outcome from the indicator of population growth (outcome of Step 4a-b) disagreed with the outcome from the indicator of quasi-extinction used to flag the increased risk of extinction for small population sizes (Step 6). The integrated risk assessment was based on (i.e., more weight was attributed to) the indicator that produced the highest risk or lowest probability of meeting the goal of maintaining a self-sustaining population. This was synonymous with adjusting the integrated risk assessment to indicate cases where there might be an increased risk of extinction due to small population size.

As stated previously, in addition to the certainty in the data used (Table 7), the certainty in the integrated risk assessment was further defined through assessing the consistency in the information provided by each indicator for a given range. Consistency was evaluated based on the number of indicators that were in agreement with the indicator assigned the most weight of evidence in the integrated risk assessment (Table 8). The evaluation was conducted only on ranges with all 3 indicators of self-sustainability. As above, the approach used for the certainty statement represents a modified version of that developed by IPCC (2005).

Table 8. Level of certainty in the consistency of information.

Indicator of self-sustainability attributed the most weight of evidence	Conditional consistency criteria	Certainty statement of consistency of information
Pr ($\lambda \geq$ stable)	Consistent with alternative Pr ($\lambda \geq$ stable) indicator	High agreement
Pr (Nt $\geq$ Qext)	Consistent with the two Pr ($\lambda \geq$ stable) indicators	
Pr ($\lambda \geq$ stable)	Consistent with Pr (Nt $\geq$ Qext)	Partial agreement
Pr (Nt $\geq$ Qext)	Consistent with one of the two Pr ($\lambda \geq$ stable) indicators	
Pr ($\lambda \geq$ stable) Pr (Nt $\geq$ Qext)	No consistency	Low agreement

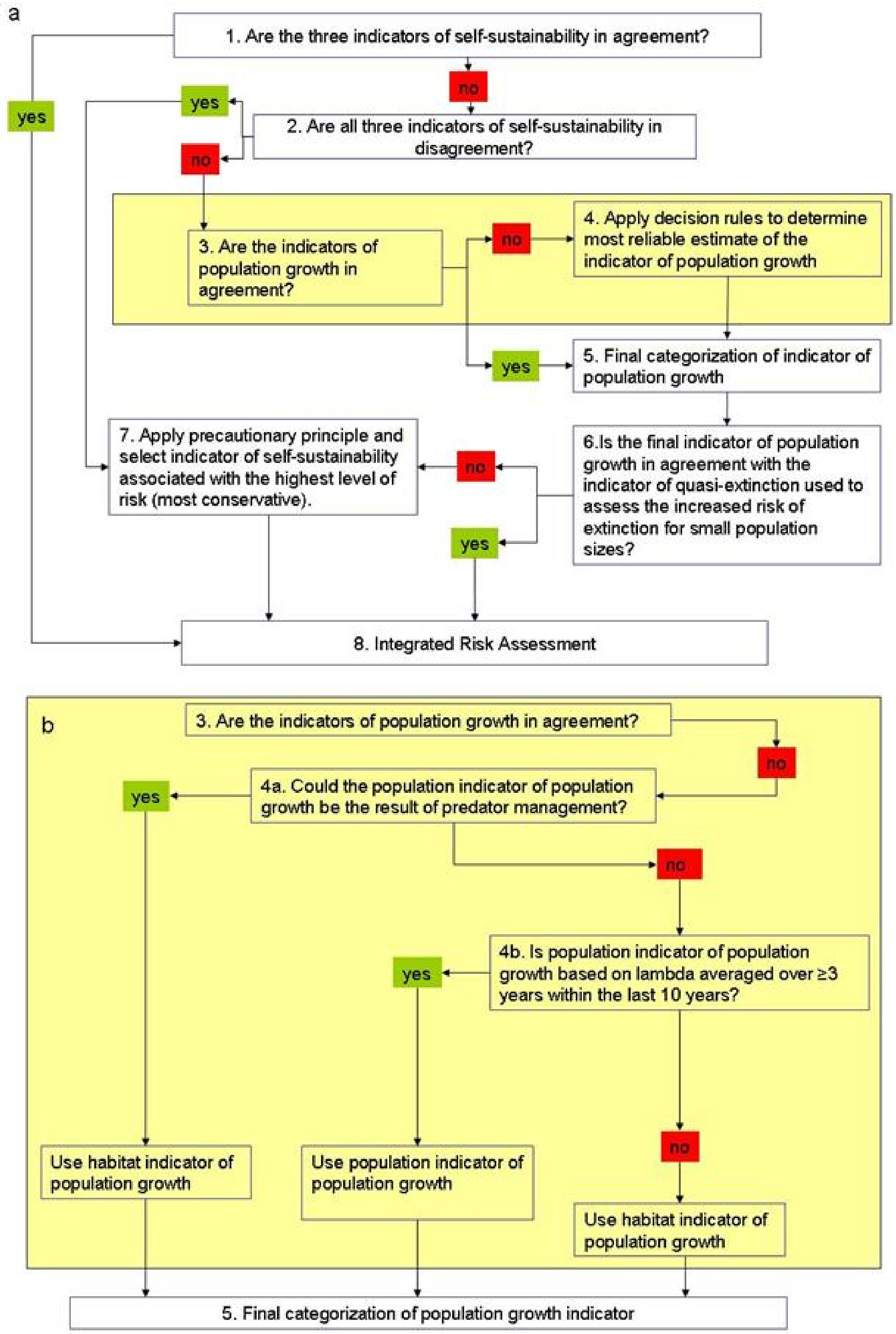


Figure 10. (a) Decision rules applied to inform integrated risk assessment. (b) Elaboration of rules used to resolve difference between the indicators of population growth.

2.4.6.2 *Range-specific management thresholds*

The integrated risk assessment is designed to evaluate a set of likelihoods related to the probability that current range conditions will support a self-sustaining population. Each likelihood statement is associated with a range of indicator values corresponding to different levels of confidence in the desired outcome; in this case, self-sustaining local populations (see Table 8). However, an assessment of current conditions does not answer the question: what must be conserved (for self-sustaining ranges) or recovered (for non-self-sustaining ranges) to achieve a desired level of certainty in meeting the recovery goal? In the context of the present assessment, this can be framed relative to risk and expressed through the identification of habitat-based management thresholds; specifically, disturbance thresholds. While it falls beyond the scope of a scientific assessment to determine management thresholds, information and methodologies to support this are presented here (see Appendix 7.9 for a full discussion of the approach).

Ecological thresholds can be identified when the relationship between an attribute of interest and the environmental driver of change, or stressor, is non-linear, suggesting an abrupt change across a small range of values (Groffman et al. 2006, Villard and Jonsson 2009, Samhouri et al. 2010). The existence of discrete ecological thresholds can inform management decisions, particularly when the threshold represents a clear boundary between two states that differ with respect to desired management outcome. However, when relationships between environmental stressors and ecological attributes are linear, or when transitions from one state to another are gradual, no ecological threshold can be defined, and consideration of management thresholds relies on the assignment of ecological risk along a continuum of conditions. In either case, establishment of management thresholds relies on management decisions regarding the level of acceptable risk. Such decisions can be informed by a probabilistic assessment of potential outcomes, relative to desired state, as represented here.

In the present assessment, range condition is a primary indicator related to the recovery criteria of stable or positive population growth, and is used here as the starting point for considering management thresholds related to critical habitat. Integration of the recruitment-disturbance relationship described in Section 2.4.3.4 with a mean annual adult female survival rate (Sad = 0.85), allows derivation of a lambda function for the habitat-based population growth indicator (Appendix 7.8). This relationship expresses the probability of observing a mean lambda over a 20-year period indicative of a stable or increasing population ($\lambda \geq$ stable), at varying levels of total range disturbance (Figure 11). While there are regions of greater certainty at the low and high ends of the disturbance gradient, there is no discrete threshold separating sustainable from unsustainable conditions. The likelihood of observing a non-declining population decreases, or risk of failure to achieve the recovery objective increases, with increasing levels of disturbance.

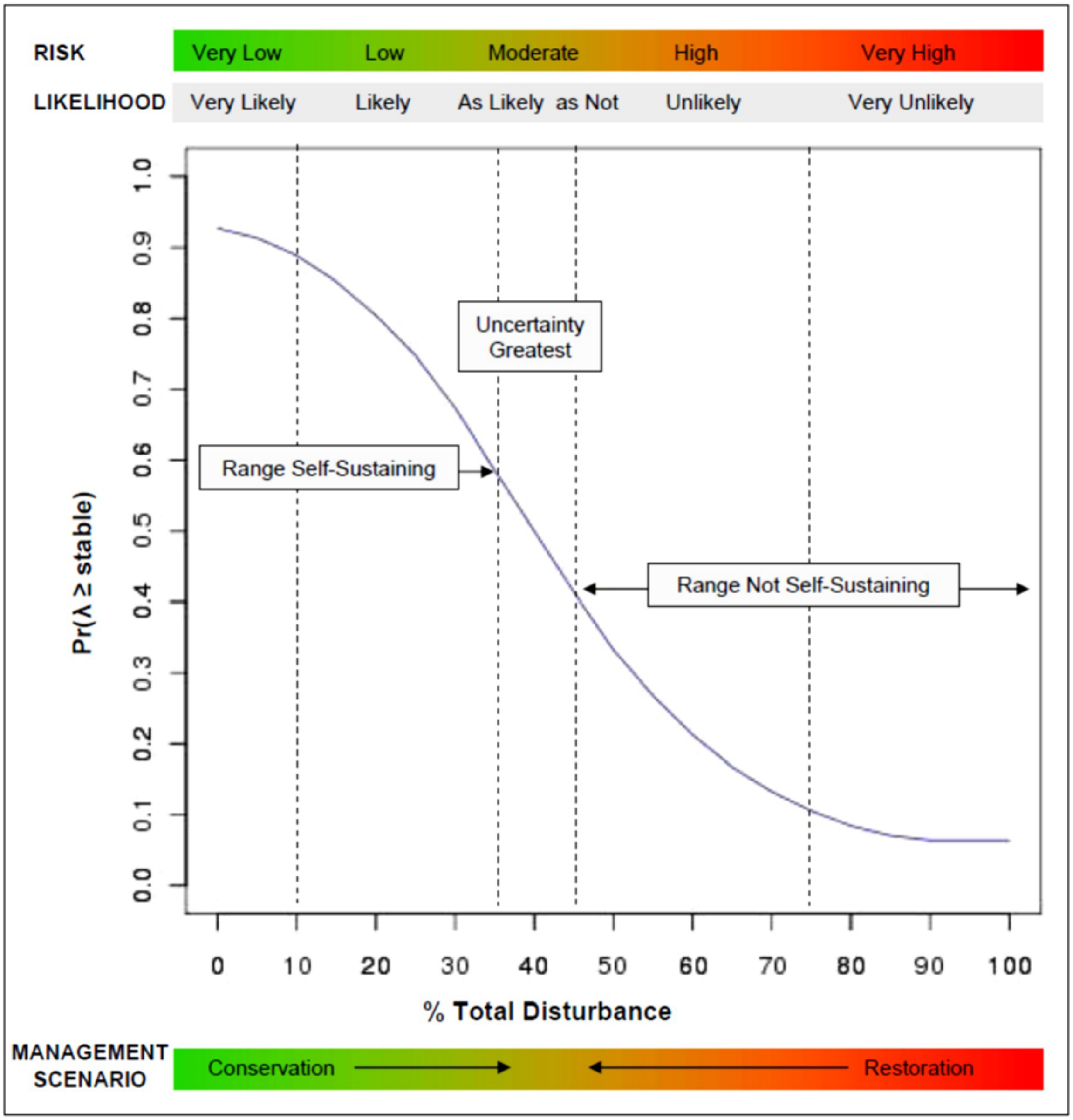


Figure 11. Probability of observing stable or positive growth ($\lambda \geq$ stable) of caribou populations over a 20-year period at varying levels of total range disturbance (fires $\leq$ 40 years + anthropogenic disturbances buffered by 500 m). Lambda (λ) was calculated using disturbance-specific recruitment values from the meta-analysis and a mean annual adult female survival rate of 0.85, consistent with other components of the critical habitat assessment (see Appendix 7.8). Certainty of outcome, ecological risk, and management scenarios are illustrated along a continuum of conditions.

The disturbance values associated with the likelihood categories for the habitat-based population growth indicator are presented in Table 9. The intervals associated with each likelihood statement reflect a range of indicator values, consistent with a probabilistic representation of certainty in outcome. Within the integrated risk assessment, an assignment of “self-sustaining” was reached when available information suggested a range was more likely than not to support a self-sustaining population, based on a probability of sustained stable or positive growth ≥ 0.60 (Table 8; Figure 11). Similarly, when it was more unlikely than not that a range would support a self-sustaining population (probability of sustained stable or positive growth ≤ 0.40), the range received an assignment of a probable outcome of "not self-sustaining". The assignments reflect a weight of evidence approach based on quantitative criteria. The high uncertainty in outcome associated with the intermediate likelihood category of "as likely as not" results in a joint assignment of probable outcomes.

Table 9. Intervals of total range disturbance associated with varying levels of certainty in outcome and risk relative to achieving the recovery objective of stable or positive population growth.

Probability of Sustained Stable or Positive Growth[1]	Likelihood of Desired Outcome	Disturbance Interval[2]	Level of Risk
≥ 90%	Very likely	≤ 10%	Very low
< 90 to ≥ 60%	Likely	> 10–35%	Low
< 60 to ≥ 40%	As likely as not	> 35–45%	Moderate
< 40 to ≥ %10	Unlikely	> 45–75%	High
< 10%	Very unlikely	>75%	Very high

1. Intervals adapted from IPCC 2005; time frame for assessing mean growth rate is 20 years.
2. See Figure 11.

The interpretation of risk has both objective and subjective components. The relative ranking of risk from very low to very high in Table 9 represents the continuum of conditions, and associated probabilities of outcomes, given a discrete ecological threshold has not been identified in the relationship of interest. This interpretation is thus objective, in that it represents a gradient in certainty of outcome based on the underlying ecological relationship. The assignment of risk to each likelihood category, and the likelihood intervals themselves, can also be interpreted as an expression of acceptance of varying levels of certainty in desired outcomes, and therefore subjective in nature. For example, acceptance of an "as likely as not" outcome as moderate risk from a management perspective is a value statement, and thus subject to change based on management objectives.

The present scientific assessment can speak to the likely outcomes and relative risk associated with current and future conditions, given a stated management objective, but it cannot determine the level of acceptable risk relative to realizing that objective. Specification of acceptable risk is necessary to establish management thresholds, because different levels of acceptable risk are expressed as different management thresholds. For example, if a "likely" outcome relative to the recovery objective of self-sustaining populations was considered acceptable from a management perspective, then the associated management threshold might be set at the upper end of the range of disturbance values associated with this likelihood category, with values below consistent with a desired state, and those above representing an undesirable or unacceptable state. A more or less conservative management approach would result in a lower or higher disturbance threshold. Because thresholds are typically used as a trigger for management actions, the use of incremental or tiered thresholds, representing a gradient of risk, can support graduated management responses along the recovery continuum.

Regardless of whether level of acceptable risk is expressed through a single or multiple thresholds, the associated disturbance intervals derived from Figure 11 reflect expected outcomes based on patterns evident at a national scale. They do not provide for range-specific assessments in the absence of additional information. Outcomes for individual populations will fall at different locations within these intervals, and may even fall outside them. Consistent with the integrated risk assessment, other indicators related to recovery criteria, also expressed relative to risk or likelihood of desired outcome, can be used to refine understanding of outcomes and interpretation of thresholds at a range-level (see Section 3.2 for the probability assignments associated with the two population indicators also used in the integrated risk assessment). The same decision rules applied in the integrated risk assessment would apply here (Figure 10, Section 2.4.6.1). Considerations of additional lines of evidence, such as projected extinction risk, based on the estimate of quasi-extinction derived from population size and trend (Table 6.8.1, Appendix 7.8), and potential future conditions, based on natural forest recovery of presently disturbed areas, and additional disturbance by fire (see Section 2.4.5.2), can also increase the overall certainty in outcome and consequently refine the interpretation of disturbance thresholds for individual populations relative to acceptable risk.

In general, the less information available, the less certainty there is in outcome. Multiple lines of evidence that suggest similar outcomes create greater certainty, as too does higher quality information. Certainty in outcome is the principal measure used to refine assessment of risk and inform the establishment and interpretation of disturbance thresholds for individual ranges. The steps necessary to support application of range-specific disturbance thresholds are illustrated in Figure 12, including a link to identification of appropriate management actions. In all cases where adjustment to interpretation of thresholds is considered, more information is required to make informed assessments of risk and certainty of outcomes.

Step 1

Establish acceptable level of risk relative to certainty in desired outcome, and identify disturbance thresholds based on the relationship between disturbance and population growth.

Step 2

Compare current level of range disturbance to identified threshold values and assess risk relative to achieving the desired management outcome.

Step 3

Consider additional assessment criteria and modify assignment of risk and threshold interpretation if certainty has increased or the probable outcome differs.

Step 4

Evaluate projected future conditions for habitat and population, re-assess risk, and modify threshold interpretation.

Step 5

Identify appropriate management actions based on final assessment of risk and associated threshold interpretation.

Figure 12. Generalized approach to the assessment of risk and establishment and interpretation of disturbance-based management thresholds for boreal caribou.

Further elaboration of the approaches described here is provided in Appendix 7.9. Examples of applications of these concepts are provided in the results section of the main document (see Section 3.3). The methodological framework presented provides a starting point for considering range-specific disturbance thresholds within a risk assessment framework. Their implementation requires determination of acceptable risk by managers.

2.4.6.3 Bio-physical attributes

Predation risk and forage availability are the primary factors that influence patterns of boreal caribou habitat use across Canada. In general, boreal caribou select mature and late seral-stage upland and lowland conifers and peatland complexes to spatially separate themselves from predators. These habitats often have an abundance of terrestrial and arboreal lichens, an important source of forage especially in winter. Grasses, sedges, herbaceous plants and lichens all become an important source of food from spring to fall when caribou broaden their diets. Similarly, caribou use habitats that facilitate escape from predators, such as shorelines and habitats with shallow snow, and many use islands for calving in spring. Caribou also show a general avoidance of shrub rich habitats, deciduous forests, and areas recently disturbed by fire and human activity (polygonal and linear disturbance). These habitats create favourable conditions for other ungulate species, which are the primary prey species for wolves and bears. In addition to creating sources of food for primary prey species, linear disturbance create travel corridors increasing the vulnerability of caribou to predators (James 1999; James and Stuart-Smith 2000; Nagy 2011).

The general characteristics of caribou habitat selection outlined above were described at the finer scale for seven ecozones and the five subregions of the Boreal Shield. The characteristics were compiled based on a literature review of boreal caribou habitat use in ecozones across their distribution in Canada (EC 2008), and from the results of the habitat selection analysis (see Section 2.4.3.2). No information was available for either the Southern Arctic ecozone or Taiga Cordillera ecozone (EC 2008). Within each ecozone, habitat selection was first described at a broad scale and then broken down according to the simple representation of the life history cycle of boreal caribou: calving, post-calving, the rut, winter and the habitats used as travel corridors. Habitats avoided by boreal caribou are described last. The latter framework is meant to facilitate interpretation with respect to describing the bio-physical attributes that allow caribou to carry out life processes necessary for species survival and recovery.

The interpretation of the habitat selection analysis requires the following considerations:

- There is variation in the habitats used by boreal caribou throughout their life history. It is the sum of all the habitats rather than any one component that contributes to the survival and recovery of boreal caribou populations.
- The information provided should be applied at the scale of the range to ensure that the objective of maintaining/recovering boreal caribou populations to self-sustaining levels (Section 2.1) is met.
- Habitat selection studies performed on specific ranges could further refine the description of caribou habitat use within each ecozone. Also, there are situations when selected habitats may be detrimental to the survival of a local population, i.e., an ecological trap (Appendix 7.3). An ecological trap refers to the phenomenon whereby animals mistake habitats that are detrimental to survival and reproduction for habitats that are beneficial. Alternatively, animals may have no choice but to select the best among unfavourable habitats because there is no favourable habitat available. An independent assessment of the value of selected habitats to survival and reproduction, such as the indicators of self-sustainability, should be used in conjunction with the population specific patterns of habitat use to ensure that selected habitats promote survival and reproduction.

3 RESULTS

The description of boreal caribou critical habitat consists in the delineation and location of the range and the certainty in range delineation (Section 3.1), the integrated range assessment (Section 3.2), information supporting the identification of disturbance-based management thresholds (Section 3.3), and a description of the key bio-physical attributes (Section 3.4). Factsheets regrouping range-specific results and supplemental information for critical habitat identification have also been developed (Appendix 7.10).

3.1 Range Delineation

Substantial changes to the delineation of boreal caribou ranges have been made since the 2008 Scientific Review, particularly in the Northwest Territories (NT), Alberta, and Ontario (Figure 13). Compared to the 2008 Scientific Review, a total of 57 ranges are still currently recognized by jurisdictions in Canada. However, significant changes occurred, with the number of ranges either decreasing (NT) or increasing (Ontario) in some jurisdictions. Table 10 summarizes the distribution of boreal caribou ranges within the 3 range delineation categories.

Based on the information provided to EC, the main changes to boreal caribou ranges in Canada since the Scientific Review 2008 are:

- Ontario: the province has identified preliminary population ranges as part of the implementation of the Ontario’s Woodland Caribou Conservation Plan (OMNR n.d.). The province reported nine ranges for the update, compared to four in the Scientific Review 2008.
- Northwest Territories: Although the jurisdiction considered that boreal caribou within NT (extending into northern Alberta) consist in a large continuous population, large wildfires have occurred in the central part of the range and a recent study suggests that this discontinuity in habitat has created two, temporary isolated, subpopulations (Nagy et al. 2011). As such, the ranges of the sub-populations were used for the purpose of the current assessment.
- British Columbia: given additional information collected by the province, the Prophet and Parker ranges are no longer considered as “core” habitat, but rather a fair delineation of each local population.
- Alberta: The range known as Deadwood has been merged with the Chinchaga range. Also, various changes to existing range boundaries were made.

Table 10. Number of boreal caribou ranges in Canada within the following three delineation types: Conservation Unit, Improved Conservation Unit, and Local Population.

Range Type	Number of Ranges
Conservation Unit	18
Improved Conservation Unit	13
Local Population	26

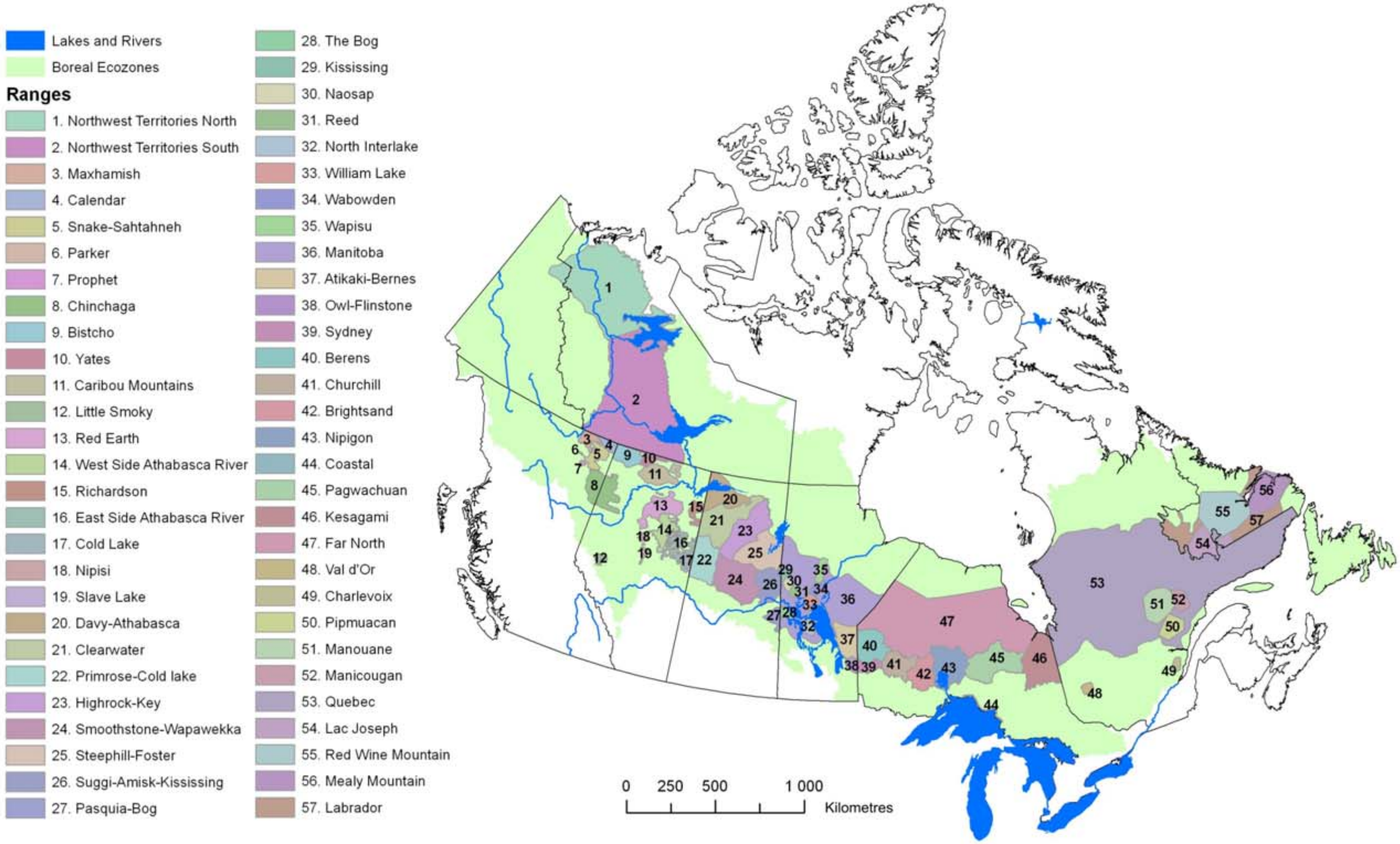


Figure 13. Boreal caribou ranges in Canada identified for the description of critical habitat.

3.2 Integrated Risk Assessment

Results obtained from applying the methodology for the risk assessment described in Section 2.4.6.1 are presented in Table 10.

Of the 57 currently delineated ranges in Canada, 17 (30%) were assessed in the “self-sustaining” (SS) category, 7 (12%) in the “not self-sustaining/self-sustaining” (NSS/SS) category, and 33 (58%) in the “not self-sustaining” (NSS) category. The repartition of likelihood statements for each self-sustaining outcome was as follow:

- For the 17 self-sustaining ranges: 3 were assigned to the “very likely”, and 14 to the “likely” categories;
- For the 33 not self-sustaining ranges: 14 were assigned to the “very unlikely”, and 19 to the “unlikely” categories;
- The 7 ranges assessed as NSS/SS were assigned to the “as likely as not” likelihood statement.

Results from the integrated risk assessment were also mapped in Figure 14. The distribution of the assessment outcomes demonstrates an East-West gradient of self-sustainability, with higher proportion of ranges not self-sustaining in the western portion of the caribou distribution. With the exception of Red Wine Mountain, the ranges in the eastern portion assessed as “not self-sustaining” are all in the southern limit of caribou distribution. The underlying causes include small, highly disturbed, isolated populations (Val d’Or, Charlevoix), rapid population decline (Kesagami), and high total disturbance (Sydney, Pipmuacan).

Table 11 Results for the Integrated Risk Assessment and for the supporting indicators assessing boreal caribou ranges based on two criteria of self-sustaining local population: 1) stable or positive population growth over the short term (≤ 20 years) estimated using Pr (λ ≥ stable), and 2) persistence over the long-term (≥ 50 years) estimated using the indicator of quasi-extinction (Pr (N≥Qext)).

Reference #	Range	Range Type [1]	Disturbance			Population size	Indicator of the range capacity to maintain a self-sustaining population			Integrated Risk Assessment		Notes on interpretation
							Stable or Positive Population Growth		Persistence			
			Fire (%)	Anthropogenic (%)	Total non-overlapping (%) buffered		Pr (λ ≥ stable) habitat	Pr(λ ≥ stable) population	Pr (N≥Qext)[2]	Likelihood	Assessment of Self-sustainability[3]	
Northwest Territories												
1	Northwest Territories North[4]	LP	18	5	22	n/a	0.80	n/a	n/a	likely	SS	• Delineated range represents a local population range (LP) as defined by the criteria used to identify a local population range in this report. Large fires have created a discontinuity in habitat that has created a North-South divide in NT. Animals from the North have traditionally moved into the South. This divide is considered temporary until the area affected by fire regenerates. • Current range conditions are *likely* to maintain a self-sustaining population over time. The risk assessment is based on *limited* evidence and primarily on the habitat indicator of population growth because it is the only indicator available. • Disturbance is dispersed throughout the range and a large portion originates from fire. • However, NT has detailed demographic data for study areas within the large continuous LP. For example, lambda estimates averaged over 2-3 years suggest that boreal caribou in the Gwich' in South (λ = 1.08) and Gwich' in North (λ = 1.20) study areas are experiencing positive growth (Nagy et al. 2011) consistent with risk assessment based on habitat information that the current range will likely maintain self-sustaining caribou.

Reference #	Range	Range Type [1]	Disturbance			Population size	Indicator of the range capacity to maintain a self-sustaining population			Integrated Risk Assessment		Notes on interpretation
			Fire (%)	Anthropogenic (%)	Total non-overlapping (%) buffered		Stable or Positive Population Growth: Pr (λ ≥ stable) habitat	Stable or Positive Population Growth: Pr(λ ≥ stable) population	Persistence: Pr (N≥Qext)[2]	Likelihood	Assessment of Self-sustainability[3]	
2	Northwest Territories South[4]	LP	29	10	38	n/a	0.55	n/a	n/a	As likely as not	NSS/ SS	• Delineated range represents a local population range (LP) as defined by the criteria used to identify a local population range in this report. Animals have been reported to move between NT, BC, and AB. Large fires have created a discontinuity in habitat that has created a North-South divide in NT. Animals from the North have traditionally moved into the South. This divide is considered temporary until the area affected by fire regenerates. • Current range conditions are *as likely as not* to maintain a self-sustaining population over time. The risk assessment is based on *limited* evidence and primarily on the habitat indicator of population growth because it is the only indicator available. • A large portion of the disturbance on this range is due to fire. Most of the anthropogenic disturbance is aggregated in the southern portion of the range. • However, NT has detailed demographic data for study areas within the large continuous LP. Lambda estimates averaged over 5 years suggest that boreal caribou in the Dehcho South (λ = 0.92) and Dehcho North (λ = 0.97) study areas are in decline (Larter and Allaire 2010). Lambda estimates averaged over 7 years in the South Slave (λ = 0.96) and over 5 years in the Cameron Hills (λ = 0.87) study areas are also in decline (Kelly and Cox 2011). The latter estimates suggest that the above risk assessment might be somewhat liberal, however more detailed analysis incorporating demographic data from a larger number of study areas would be necessary to ensure that the spatial variation in habitat conditions across the large continuous LP is adequately captured.

Reference #	Range	Range Type [1]	Disturbance			Population size	Indicator of the range capacity to maintain a self-sustaining population			Integrated Risk Assessment		Notes on interpretation
			Fire (%)	Anthropogenic (%)	Total non-overlapping (%) buffered		Stable or Positive Population Growth		Persistence	Likelihood	Assessment of Self-sustainability [3]	
							Pr (λ ≥ stable) habitat	Pr(λ ≥ stable) population	Pr (N≥Qext) [2]			
British Columbia												
3	Maxhamish	LP	0.5	57	58	306	0.23	n/a	0.85	unlikely	NSS	• Delineated range represents a LP. • Current range conditions are *unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *some* evidence and primarily on the habitat indicator of population growth that suggests poor habitat condition is having adverse effects on the population. • There are insufficient available data to estimate the population indicator of population growth; estimates of population growth would improve the certainty in and potentially change the assessment.
4	Calendar	LP	8	58	61	291	0.21	n/a	0.84	unlikely	NSS	• Delineated range represents a LP. However, there is evidence that animals move between BC and NT and AB. • Current range conditions are *unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *some* evidence and primarily on the habitat indicator of population growth that suggests poor habitat condition is having adverse effects on the population. • There are insufficient available data to estimate the population indicator of population growth; estimates of population growth would improve the certainty in and potentially change the assessment.
5	Snake-Sahtahneh	LP	6	86	87	365	< 0.09	0.09	0.87	very unlikely	NSS	• Delineated range represents a LP. • Current range conditions are *very unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence and primarily on the habitat indicator of population growth that suggests poor habitat condition is having adverse effects on the population. • There is *high* agreement among indicators supporting the assessment outcome. The population indicator of population growth also suggests the current range will not maintain a self-sustaining population based on estimates of λ averaged over 2 years that indicate the population is in decline (λ = 0.97).

Reference #	Range	Range Type [1]	Disturbance			Population size	Indicator of the range capacity to maintain a self-sustaining population			Integrated Risk Assessment		Notes on interpretation
			Fire (%)	Anthropogenic (%)	Total non-overlapping (%) buffered		Stable or Positive Population Growth: Pr (λ ≥ stable) habitat	Stable or Positive Population Growth: Pr(λ ≥ stable) population	Persistence: Pr (N≥Qext)[2]	Likelihood	Assessment of Self-sustainability[3]	
6	Parker	LP	0.5	34	34	25	0.63	n/a	0.31	unlikely	NSS	• Delineated range represents a LP. • Current range conditions are *unlikely* to maintain a self-sustaining population over time based on *some* evidence. The precautionary principle is used to flag the increased risk of quasi-extinction associated with small population size (N = 25). • Poor habitat condition does not appear to represent an additive risk; the habitat indicator of population growth indicates habitat condition is sufficient to maintain a self-sustaining population. Factors contributing to the small population size should be investigated. • There are insufficient available data to estimate the population indicator of population growth; estimates of population growth would improve the certainty in and potentially change the assessment.
7	Prophet	LP	0.4	79	79	54	< 0.09	n/a	0.54	very unlikely	NSS	• Delineated range represents a LP. • Current range conditions are *very unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *some* evidence and primarily on the habitat indicator of population growth that suggests poor habitat condition is having adverse effects on the population. • The quasi-extinction indicator suggests an additive risk of extinction due to small population size (N=54). • There are insufficient available data to estimate the population indicator of population growth; estimates of population growth would improve the certainty and potentially change the assessment.
Alberta												
8	Chinchaga (incl. BC portion)	LP	8	74	76	250	0.10	<0.09	0.82	very unlikely	NSS	• Delineated range represents a trans-boundary LP. AB and BC coordinate monitoring and share information on caribou in this range. • Current range conditions are *very unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *some* evidence and primarily on estimates of lambda averaged over the last 5 years that indicate that the population is in rapid decline (λ=0.91). • There is *high* agreement among the indicators supporting the assessment outcome. The habitat indicator of population growth also suggests that poor habitat condition is having adverse effects on the population, although this indicator produces a slightly more optimistic estimate than that based on the population indicator of population growth.

Reference #	Range	Range Type [1]	Disturbance			Population size	Indicator of the range capacity to maintain a self-sustaining population			Integrated Risk Assessment		Notes on interpretation
			Fire (%)	Anthropogenic (%)	Total non-overlapping (%) buffered		Stable or Positive Population Growth		Persistence	Likelihood	Assessment of Self-sustainability [3]	
							Pr (λ ≥ stable) habitat	Pr(λ ≥ stable) population	Pr (N≥Qext) [2]			
9	Bistcho	LP	20	61	71	195	0.13	<0.09	0.78	very unlikely	NSS	• Delineated range represents a LP. However, evidence suggests that animals move between AB, NT and BC. • Current range conditions are *very unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *much* evidence and primarily on estimates of lambda averaged over the last 4 years that indicate the population is in rapid decline (λ=0.89). • There is *high* agreement among the indicators supporting the assessment outcome. The habitat indicator of population growth also suggests that poor habitat condition is having adverse effects on the population, although this indicator produces a slightly more optimistic estimate than that based on the population indicator of population growth.
10	Yates	LP	43	21	61	350	0.21	0.90	0.87	unlikely	NSS	• Delineated range represents a LP. However, there is evidence that animals move between AB and NT. • Current range conditions are *unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence, but there is *low* agreement among the indicators. The precautionary principle was applied to resolve the discrepancy between habitat and population data. The risk assessment is based primarily on the habitat indicator of population growth that suggests poor habitat condition is having adverse effects on the population. A large portion of the disturbance on this range is due to fire. • Estimates of lambda averaged over two years suggest that the population is stable and very likely to be self-sustaining (λ = 1.02). Longer-term estimates of lambda would improve certainty in population indicator for population growth and potentially change the risk assessment.
11	Caribou Mountains	LP	44	23	57	315-394	0.23	<0.09	0.85-0.88	very unlikely	NSS	• Delineated range represents a LP. • Current range conditions are *very unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *much* evidence and primarily on estimates of lambda averaged over the last 5 years that indicate the population is in rapid decline (λ=0.87). • There is *high* agreement among the indicators supporting the assessment outcome. The habitat indicator of population growth also suggests that poor habitat condition is having adverse effects on the population, although this indicator produces a slightly more optimistic estimate than that based on the population indicator of population growth. A large portion of the disturbance on this range is due to fire.

Reference #	Range	Range Type [1]	Disturbance			Population size	Indicator of the range capacity to maintain a self-sustaining population			Integrated Risk Assessment		Notes on interpretation
			Fire (%)	Anthropogenic (%)	Total non-overlapping (%) buffered		Stable or Positive Population Growth		Persistence	Likelihood	Assessment of Self-sustainability [3]	
							Pr (λ ≥ stable) habitat	Pr(λ ≥ stable) population	Pr (N≥Qext) [2]			
12	Little Smoky	LP	0.2	95	95	78	< 0.09	0.21	0.62	very unlikely	NSS	• Delineated range represents a LP. • This range is currently under predator management. Accordingly, the risk assessment is based on the habitat indicator of population growth that indicates the current range condition is *very unlikely* to maintain a self-sustaining population over time in the absence of active management intervention.
13	Red Earth	LP	30	44	62	172-206	0.20	<0.09	0.76-0.80	very unlikely	NSS	• Delineated range represents a LP. • Current range conditions are *very unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *much* evidence and primarily on estimates of lambda average over 5 years that indicate the population is in rapid decline (λ=0.86). • There is *high* agreement among the indicators supporting the assessment outcome. The habitat indicator for population growth also suggests that poor habitat condition is having adverse effects on the population, although this indicator produces a slightly more optimistic estimate than that based on the population indicator of population growth.
14	West Side Athabasca River (WSAR)	LP	4	68	69	204-272	0.13	<0.09	0.80-0.83	very unlikely	NSS	• Delineated range represents a LP. • Current range conditions are *very unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *much* evidence and primarily on estimates of lambda average over the last 5 years that indicate the population is in rapid decline (λ=0.92). • There is *high* agreement among the indicators supporting the assessment outcome. The habitat indicator of population growth also indicates that poor habitat condition is having adverse effects on the population, although this indicator produces a slightly more optimistic estimate than that based on population information.
15	Richardson	LP	67	22	82	150	< 0.09	n/a	0.74	very unlikely	NSS	• Delineated range represents a LP. • Current range conditions are *very unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *some* evidence and primarily on the habitat indicator of population growth that suggests poor habitat condition is having adverse effects on the population. A large portion of the disturbance in this range is due to fire. • There are insufficient available data to estimate the population indicator of population growth; estimates of population growth would improve the certainty in and potentially change the assessment.

Reference #	Range	Range Type [1]	Disturbance			Population size	Indicator of the range capacity to maintain a self-sustaining population			Integrated Risk Assessment		Notes on interpretation
							Stable or Positive Population Growth		Persistence			
			Fire (%)	Anthropogenic (%)	Total non-overlapping (%) buffered		Pr (λ ≥ stable) habitat	Pr(λ ≥ stable) population	Pr (N≥Qext)[2]	Likelihood	Assessment of Self-sustainability[3]	
16	East Side Athabasca River (ESAR)	LP	26	77	81	90-150	< 0.09	<0.09	0.65-0.74	very unlikely	NSS	• Delineated range represents a LP. Current range conditions are *very unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *much* evidence and primarily on estimates of lambda average over the last 5 years that indicate the population is in rapid decline (λ=0.85). • There is *high* agreement among indicators supporting the assessment outcome. The habitat indicator of population growth also suggests that poor habitat condition is having adverse effects on the population.
17	Cold Lake	LP	32	72	85	150	< 0.09	<0.09	0.74	very unlikely	NSS	• Delineated range represents a LP. However, evidence suggests that animals move between AB and SK. • Current range conditions are *very unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *much* evidence and primarily on estimates of lambda average over the last 5 years that indicate the population is in rapid decline (λ = 0.77). • There is *high* agreement among the indicators that support the assessment outcome. The habitat indicator of population growth also suggests that poor habitat condition is having adverse effects on the population.
18	Nipisi	LP	6	66	68	55[5]	0.15	n/a	0.54	unlikely	NSS	• Delineated range represents a LP. • Current range conditions are *unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *some* evidence and primarily on the habitat indicator of population growth that suggests poor habitat condition is having adverse effects on the population. • The indicator of quasi-extinction suggests an additive risk of extinction due to small population size (N=55). • There are insufficient available data to estimate the population indicator of population growth; estimates of population growth would increase certainty in and potentially change the assessment.
19	Slave Lake	LP	37	63	80	65[5]	< 0.09	n/a	0.58	very unlikely	NSS	• Delineated range represents a LP. • Current range conditions are *very unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *some* evidence but primarily primarily on the habitat indicator of population growth that suggests poor habitat condition is having adverse effects on the population. • The quasi-extinction indicator suggests an additive risk of extinction due to small population size (N=65). • There are insufficient available data to estimate the population indicator of population growth and to assess the additive risk of extinction due to small population size. Estimates of population growth and size would increase certainty in and potentially change the assessment.

Reference #	Range	Range Type [1]	Disturbance: Fire (%)	Disturbance: Anthropogenic (%)	Disturbance: Total non-overlapping (%) buffered	Population size	Indicator of the range capacity to maintain a self-sustaining population: Stable or Positive Population Growth: Pr (λ ≥ stable) habitat	Stable or Positive Population Growth: Pr(λ ≥ stable) population	Persistence: Pr (N≥Qext)[2]	Integrated Risk Assessment: Likelihood	Integrated Risk Assessment: Assessment of Self-sustainability[3]	Notes on interpretation
Saskatchewan												
20	Davy-Athabasca	CU	60	2	61	310	0.21	n/a	0.85	unlikely	NSS	• Delineated range represents a conservation unit. Range boundaries may change with additional information. • Current range conditions are *unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *some* evidence and primarily on the habitat indicator of population growth that suggests poor habitat condition is having adverse effects on the population. A large portion of the disturbance on this range is due to fire. • There are insufficient available data to estimate the population indicator of population growth; estimates of population growth would increase certainty in and potentially change the assessment.
21	Clearwater	CU	69	3	70	425	0.14	n/a	0.89	unlikely	NSS	• Delineated range represents a conservation unit. Range boundaries may change with additional information. • Current range conditions are *unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *some* evidence and primarily on the habitat indicator of population growth that suggests poor habitat condition is having adverse effects on the population. A large portion of the disturbance on this range is due to fire. • There are insufficient available data to estimate the population indicator of population growth; estimates of population growth would increase certainty in and potentially change the assessment.
22	Primrose-Cold Lake	CU	40	20	54	350	0.27	n/a	0.87	unlikely	NSS	• Delineated range represents a conservation unit. Information is available suggesting that animals move between SK and AB. Range boundaries may change with additional information. • Current range conditions are *unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *some* evidence and primarily on the habitat indicator of population growth that suggests poor habitat condition is having adverse effects on the population. A large portion of the disturbance on this range is due to fire. • There are insufficient available data to estimate the population indicator of population growth; estimates of population growth would increase certainty in and potentially change the assessment.

Reference #	Range	Range Type [1]	Disturbance			Population size	Indicator of the range capacity to maintain a self-sustaining population			Integrated Risk Assessment		Notes on interpretation
			Fire (%)	Anthropogenic (%)	Total non-overlapping (%) buffered		Stable or Positive Population Growth		Persistence	Likelihood	Assessment of Self-sustainability[3]	
							Pr (λ ≥ stable) habitat	Pr(λ ≥ stable) population	Pr (N≥Qext)[2]			
23	Highrock-Key	CU	62	4	64	1060	0.19	n/a	0.95	unlikely	NSS	• Delineated range represents a conservation unit. Range boundaries may change with additional information. • Current range conditions are *unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *some* evidence and primarily on the habitat indicator of population growth that suggests poor habitat condition is having adverse effects on the population. A large portion of the disturbance on this range is due to fire. • There are insufficient available data to estimate the population indicator of population growth; estimates of population growth would increase certainty in and potentially change the assessment.
24	Smoothstone-Wapawekka	CU	17	20	33	700	0.66	0.37	0.94	unlikely	NSS	• Delineated range represents a conservation unit. Range boundaries may change with additional information. • Current range conditions are u*nlikely* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence, but there is *low* agreement among the indicators. The precautionary principle was applied to resolve the discrepancy between habitat and population data. The risk assessment is based on the population indicator of population growth that suggests the population is in decline (trend). • The habitat indicator of population growth suggests that habitat condition is likely sufficient to maintain a self-sustaining population. A large portion of the disturbance on this range is due to fire. • Factors contributing to the declining population trend should be investigated.
25	Steephill-Foster	CU	49	2	50	1075	0.33	n/a	0.95	unlikely	NSS	• Delineated range represents a conservation unit. Range boundaries may change with additional information. • Current range conditions are *unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *some* evidence and primarily on the habitat indicator of population growth that suggests poor habitat condition is having adverse effects on the population. A large portion of the disturbance on this range is due to fire. • There are insufficient available data to estimate the population indicator of population growth; estimates of population growth would increase certainty in and potentially change the assessment.

Reference #	Range	Range Type [1]	Disturbance			Population size	Indicator of the range capacity to maintain a self-sustaining population			Integrated Risk Assessment		Notes on interpretation
			Fire (%)	Anthropogenic (%)	Total non-overlapping (%) buffered		Stable or Positive Population Growth		Persistence	Likelihood	Assessment of Self-sustainability [3]	
							Pr (λ ≥ stable) habitat	Pr(λ ≥ stable) population	Pr (N≥Qext) [2]			
26	Suggi-Amisk-Kississing	CU	18	8	25	430	0.74	n/a	0.89	likely	SS	• Delineated range represents a conservation unit. Range boundaries may change with additional information. • Current range conditions are *likely* to maintain a self-sustaining population over time. The risk assessment is based on *some* evidence and primarily on the habitat indicator of population growth that suggests habitat condition is sufficient for boreal caribou. A large portion of the disturbance in this range is due to fire. • There are insufficient available data to estimate the population indicator of population growth. Estimates of population growth would increase certainty in and potentially change the assessment.
27	Pasquia-Bog	CU	12	33	44	30	0.44	0.37	0.37	unlikely	NSS	• Delineated range represents a conservation unit. Range boundaries may change with additional information. • Current range conditions are *unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence. The precautionary principle is used to flag the increased risk of quasi-extinction associated with small population size (N=30). • There is *partial* agreement among the indicators supporting the assessment outcome. The population indicator for population growth yielded the same risk assessment to that based on population size. The population is in decline (trend). • The habitat indicator of population size suggests that habitat condition is as likely as not to be sufficient for self-sustainability. • Factors contributing to the small population size and the declining population trend should be investigated.

Reference #	Range	Range Type [1]	Disturbance: Fire (%)	Disturbance: Anthropogenic (%)	Disturbance: Total non-overlapping (%) buffered	Population size	Stable or Positive Population Growth: Pr (λ ≥ stable) habitat	Stable or Positive Population Growth: Pr(λ ≥ stable) population	Persistence: Pr (N≥Qext)[2]	Integrated Risk Assessment: Likelihood	Integrated Risk Assessment: Assessment of Self-sustainability[3]	Notes on interpretation
Manitoba												
28	The Bog	ICU	4	12	16	50-75	0.89	0.55	0.52-0.61	as likely as not	NSS/ SS	• Delineated range represents an improved conservation unit. Range boundaries may change with additional information. • Current range conditions are *as likely as not* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence. The precautionary principle is used to flag the increased risk of quasi-extinction associated with small population size (N=50-75). • There is *partial* agreement supporting the assessment outcome. The population indicator of population growth yielded the same risk assessment to that based on population size. The population is stable (trend). • The habitat indicator of population growth suggests that habitat condition is likely sufficient to maintain a self-sustaining population. • Factors contributing to the small population size should be investigated.
29	Kississing	ICU	39	13	52	50-75	0.31	0.55	0.52-0.61	unlikely	NSS	• Delineated range represents an improved conservation unit. Range boundaries may change with additional information. • Current range conditions are *unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence, but there is low agreement among the indicators. The precautionary principle was applied to resolve the discrepancy between habitat and population data. The risk assessment is based primarily on the habitat indicator of population growth that suggests poor habitat condition is having adverse effects on the population. A large portion of the disturbance on this range is due to fire. • The indicator of quasi-extinction suggests an additive risk of extinction associated with small population size (N = 50-75). The reported stable population trend suggests that the current range would be as likely as not to maintain a self-sustaining population. • Discrepancy between habitat and population information should be investigated; improved estimates of population growth (lambda) would increase certainty in the assessment.

Reference #	Range	Range Type[1]	Disturbance			Population size	Indicator of the range capacity to maintain a self-sustaining population			Integrated Risk Assessment		Notes on interpretation
							Stable or Positive Population Growth		Persistence			
			Fire (%)	Anthropogenic (%)	Total non-overlapping (%) buffered		Pr (λ ≥ stable) habitat	Pr(λ ≥ stable) population	Pr (N≥Qext)[2]	Likelihood	Assessment of Self-sustainability[3]	
30	Naosap	ICU	28	26	50	100-200	0.33	0.55	0.68-0.80	unlikely	NSS	• Delineated range represents an improved conservation unit. Range boundaries may change with additional information. • Current range conditions are *unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence, but there is *low* agreement among the indicators. The precautionary principle was applied to resolve the discrepancy between habitat and population data. The risk assessment is based primarily on the habitat indicator of population growth that suggests poor habitat condition is having adverse effects on the population. A large portion of the disturbance on this range is due to fire. • The reported trend of stable yields a more optimistic assessment, although it still suggests that the range would be as likely as not to maintain a self-sustaining population. • Discrepancy between habitat and population information should be investigated; improved estimates of population growth (lambda) would increase certainty in and potentially change the assessment.
31	Reed	ICU	7	20	26	100-150	0.62	0.55	0.68-0.74	likely	SS	• Delineated range represents an improved conservation unit. Range boundaries may change with additional information. • Current range conditions are *likely* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence but primarily on the habitat indicator of population growth. • There is *partial* agreement among the indicators supporting the assessment outcome. The indicator of quasi-extinction produces a similar assessment to that based on the habitat information and suggests that there is no additive risk of extinction associated with small population size. However, the reported trend of stable yields a more conservative assessment that suggests the range is as likely as not to maintain a self-sustaining population; improved estimates of population growth (lambda) would increase certainty in and potentially change the assessment.

Reference #	Range	Range Type [1]	Disturbance: Fire (%)	Disturbance: Anthropogenic (%)	Disturbance: Total non-overlapping (%) buffered	Population size	Indicator of the range capacity to maintain a self-sustaining population: Stable or Positive Population Growth: Pr (λ ≥ stable) habitat	Stable or Positive Population Growth: Pr(λ ≥ stable) population	Persistence: Pr (N≥Qext)[2]	Integrated Risk Assessment: Likelihood	Integrated Risk Assessment: Assessment of Self-sustainability[3]	Notes on interpretation
32	North Interlake	ICU	4	14	17	50-75	0.87	0.55	0.52-0.61	as likely as not	NSS/ SS	• Delineated range represents an improved conservation unit. Range boundaries may change with additional information. • Current range conditions are *as likely as not* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence. The precautionary principle is used to flag the increased risk of quasi-extinction associated with small population size (N = 50-75). • There is *partial* agreement among the indicators supporting the assessment outcome. The reported trend of stable produces a similar risk assessment to that based on the indicator of quasi-extinction. However, poor habitat condition does not appear to represent an additive risk; the habitat indicator of population growth indicates habitat condition is sufficient to maintain a self-sustaining population. • Factors contributing to the small population size should be investigated; improved estimates of population growth (lambda) would increase certainty in and potentially change the assessment.
33	William Lake	ICU	24	10	31	25-40	0.63	0.55	0.31-0.46	unlikely	NSS	• Delineated range represents an improved conservation unit. Range boundaries may change with additional information. • Current range conditions are *unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence, but there is *low* agreement among the indicators. The precautionary principle was applied to resolve the discrepancy between habitat and population data. The risk assessment is based on the increased risk of quasi-extinction associated with small population size (N = 25-40). • The habitat information and reported trend of stable yields more optimistic assessments, although these two types of information do not yield the same results. Poor habitat condition does not appear to represent an additive risk; the habitat indicator of population growth indicates habitat condition is sufficient to maintain a self-sustaining population. The reported stable population trend suggests that the range is as likely as not to maintain a self-sustaining population. • A large portion of the disturbance on this range is due to fire. • Factors contributing to small population size should be investigated; improved estimates of population growth (lambda) would increase certainty in and potentially change the assessment.

Reference #	Range	Range Type [1]	Disturbance			Population size	Indicator of the range capacity to maintain a self-sustaining population			Integrated Risk Assessment		Notes on interpretation
			Fire (%)	Anthropogenic (%)	Total non-overlapping (%) buffered		Stable or Positive Population Growth		Persistence	Likelihood	Assessment of Self-sustainability[3]	
							Pr (λ ≥ stable) habitat	Pr(λ ≥ stable) population	Pr (N≥Qext)[2]			
34	Wabowden	ICU	10	19	28	200-225	0.63	0.55	0.80-0.81	likely	SS	• Delineated range represents an improved conservation unit. Range boundaries may change with additional information. • Current range conditions are *likely* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence and primarily on the habitat indicator of population growth. • There is *partial* agreement among the indicators supporting the assessment outcome. The indicator of quasi-extinction produces a similar assessment to the habitat indicator for population growth. However, the reported trend of stable produces a more conservative assessment that indicates the population is as likely as not to be self-sustaining. • Improved estimates of population growth (lambda) would increase certainty in and potentially change the assessment.
35	Wapisu	ICU	10	14	24	100-125	0.83	0.55	0.68-0.70	likely	SS	• Delineated range represents an improved conservation unit. Range boundaries may change with additional information. • Current range conditions are *likely* to maintain a self-sustaining population. The risk assessment is based on *considerable* evidence but primarily on the habitat indicator of population growth. • There is *partial* agreement among the indicators supporting the assessment outcome. The indicator of quasi-extinction produces a similar assessment to the habitat indicator for population growth. However, the reported population trend of stable produces a more conservative assessment that indicates the population is as likely as not to be self-sustaining. • Improved estimates of population growth (lambda) would increase certainty in and potentially change the assessment.

Reference #	Range	Range Type [1]	Disturbance			Population size	Indicator of the range capacity to maintain a self-sustaining population			Integrated Risk Assessment		
							Stable or Positive Population Growth		Persistence			
			Fire (%)	Anthropogenic (%)	Total non-overlapping (%) buffered		Pr ($\lambda \geq$ stable) habitat	Pr($\lambda \geq$ stable) population	Pr ($N \geq Qext$)[2]	Likelihood	Assessment of Self-sustainability[3]	Notes on interpretation
36	Manitoba	CU	22	8	28	775-1585	0.70	0.55	0.94-0.97	likely	SS	• Delineated range represents a conservation unit. Range boundaries may change with additional information. • Current range conditions are *likely* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence but primarily on the habitat indicator of population growth. • There is *partial* agreement among the indicators supporting the assessment outcome. The indicator of quasi-extinction produces a similar assessment to the habitat indicator of population growth. However, the reported population trend of stable produces a more conservative assessment that indicates the population is as likely as not to be self-sustaining. • Improved estimates of population growth (lambda) would increase certainty in and potentially change the assessment. • Averaging habitat conditions over a large continuous area may mask spatial variation in disturbance. A large portion of the disturbance on this range is due to fire. Disturbance created by fire is dispersed across the range. Anthropogenic disturbance is also dispersed across the range with a higher concentration in the western versus eastern portion of the range.
37	Atikaki-Berens	ICU	32	5	35	300-500	0.61	0.55	0.85-0.91	likely	SS	• Delineated range represents an improved conservation unit. Available information suggests that animals move between MB and ON (Berens range). Range boundaries may change with additional information. • Current range conditions are *likely* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence primarily on the habitat indicator of population growth that suggests habitat condition is sufficient to maintain caribou. A large portion of the disturbance on this range is due to fire. • There is *partial* agreement among the indicators supporting the outcome assessment. The indicator of quasi-extinction produces a similar assessment to that based on the habitat information and suggests that there is no additive risk of extinction associated with small population size. However, the reported trend of stable produces a slightly more conservative assessment that suggests the population is as likely as not to be self-sustaining. • Improved estimates of population growth (lambda) would increase certainty in and potentially change the assessment.

Reference #	Range	Range Type [1]	Disturbance			Population size	Indicator of the range capacity to maintain a self-sustaining population			Integrated Risk Assessment		Notes on interpretation
			Fire (%)	Anthropogenic (%)	Total non-overlapping (%) buffered		Stable or Positive Population Growth		Persistence	Likelihood	Assessment of Self-sustainability[3]	
							Pr (λ ≥ stable) habitat	Pr(λ ≥ stable) population	Pr (N≥Qext)[2]			
38	Owl-Flinstone	LP	25	18	39	78	0.52	0.55	0.62	as likely as not	NSS/ SS	• Delineated range represents a LP. • Current range conditions are *as likely as not* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence but primarily on the habitat indicator of population growth. A large portion of the disturbance on this range is due to fire. • There is *high* agreement among the indicators supporting the assessment outcome. The population indicator of population growth produces a similar risk assessments to that based on habitat information. The population is reported as stable (trend). • Improved estimates of population growth (lambda) would increase certainty in and potentially change the assessment.
Ontario												
39	Sydney	ICU	28	33	58	n/a	0.23	n/a	n/a	unlikely	NSS	• Delineated range represents an improved conservation unit. Range boundaries may change with additional information. • Current range conditions are *unlikely* to maintain a self-sustaining population. The risk assessment is based on *limited* evidence but primarily on the habitat indicator of population growth because it is the only indictor available for this range. • There are insufficient available data to estimate the population indicator of population growth and the additive risk of quasi-extinction associated with small population size; estimates of population growth and size would increase certainty in the assessment.
40	Berens	ICU	34	7	40	n/a	0.52	n/a	n/a	as likely as not	NSS/ SS	• Delineated range represents an improved conservation unit. • Available information suggests that animals move between ON and MB (Atikaki-Berens range). Range boundaries may change with additional information. • Current range conditions are *as likely as not* to maintain a self-sustaining population. The risk assessment is based on *limited* evidence but primarily on the habitat indicator of population growth because it is the only indicator available for this range. A large portion of the disturbance on this range is due to fire. • There are insufficient available data to estimate the population indicator of population growth and the additive risk of quasi-extinction associated with small population size; estimates of population growth and size would increase certainty in and potentially change the assessment.

Reference #	Range	Range Type [1]	Disturbance			Population size	Indicator of the range capacity to maintain a self-sustaining population			Integrated Risk Assessment		Notes on interpretation
			Fire (%)	Anthropogenic (%)	Total non-overlapping (%) buffered		Stable or Positive Population Growth		Persistence	Likelihood	Assessment of Self-sustainability[3]	
							Pr (λ ≥ stable) habitat	Pr(λ ≥ stable) population	Pr (N≥Qext)[2]			
41	Churchill	ICU	6	28	31	n/a	0.67	n/a	n/a	likely	SS	• Delineated range represents an improved conservation unit. Range boundaries may change with additional information. • Current range conditions are *likely* to maintain a self-sustaining population. The risk assessment is based on *limited* evidence but primarily on the habitat indicator of population growth because it is the only indicator available for this range. • There are insufficient available data to estimate the population indicator of population growth and the additive risk of quasi-extinction associated with small population size; estimates of population growth and size would increase certainty in and potentially change the assessment.
42	Brightsand	ICU	18	28	42	n/a	0.46	n/a	n/a	as likely as not	NSS/ SS	• Delineated range represents an improved conservation unit. Range boundaries may change with additional information. • Current range conditions are *as likely as not* to maintain a self-sustaining population. The risk assessment is based on *limited* evidence but primarily on the habitat indicator of population growth because it is the only indicator available for this range. • There are insufficient available data to estimate the population indicator of population growth and the additive risk of quasi-extinction associated with small population size; estimates of population growth and size would increase certainty in and potentially change the assessment.
43	Nipigon	LP	7	25	31	300	0.67	0.55	0.85	likely	SS	• Delineated range represents a LP. • Current range conditions are *likely* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence but primarily on the habitat indicator of population growth • There is *partial* agreement among the indicators supporting the assessment outcome. The indicator of quasi-extinction produces a similar assessment to that based on the habitat information and suggests that there is no additive risk of extinction associated with small population size. However, the reported stable trend for population growth produces a more conservative assessment that suggests the population is as likely as not to be self-sustaining; improved estimates of population growth (lambda) would increase certainty in and potentially change the assessment.

Reference #	Range	Range Type [1]	Disturbance			Population size	Indicator of the range capacity to maintain a self-sustaining population			Integrated Risk Assessment		Notes on interpretation
							Stable or Positive Population Growth		Persistence			
			Fire (%)	Anthropogenic (%)	Total non-overlapping (%) buffered		Pr (λ ≥ stable) habitat	Pr(λ ≥ stable) population	Pr (N≥Qext)[2]	Likelihood	Assessment of Self-sustainability[3]	
44	Coastal	CU	0	16	16	492	0.87	n/a	0.90	likely	SS	• Delineated range represents a conservation unit consisting of 3 occupied islands and shorelines including Pukaskwa Park. Range delineation is currently being refined. • Current range conditions are *likely* to maintain a self-sustaining population over time. The risk assessment is based on *some* evidence but primarily on the habitat indicator of population growth and is supported by the indicator used to assess the increased risk of quasi-extinction associated with small population size. • Estimates of population growth would increase certainty in and potentially change the assessment.
45	Pagwachuan	ICU	0.9	26	27	n/a	0.72	n/a	n/a	likely	SS	• Delineated range represents an improved conservation unit. Range boundaries may change with additional information. • Current range conditions are *likely* to maintain a self-sustaining population. The risk assessment is based on *limited* evidence but primarily on the habitat indicator of population growth because it is the only indicator available. • There are insufficient available data to estimate the population indicator of population growth and the additive risk of quasi-extinction associated with small population size. Estimates of population growth and size would increase certainty in and potentially change the assessment.
46	Kesagami	ICU	3	36	38	492	0.54	<0.09	0.90	very unlikely	NSS	• Delineated range represents an improved conservation unit. Range boundaries may change with additional information. • Current range conditions are *very unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence, but there is *low* agreement among the indicators. The precautionary principle was applied to resolve the discrepancy between habitat and population data. The risk assessment is based on estimates of lambda averaged over 1998-2001 that suggest the population in rapid decline (λ = 0.88). • Poor habitat condition does not appear to be contributing to the rapid population declines. The habitat indicator of population growth suggests that the habitat condition is *as likely as not* to support a self-sustaining population. • Factors contributing to population decline should be investigated.

Reference #	Range	Range Type [1]	Disturbance			Population size	Indicator of the range capacity to maintain a self-sustaining population			Integrated Risk Assessment		Notes on interpretation
			Fire (%)	Anthropogenic (%)	Total non-overlapping (%) buffered		Stable or Positive Population Growth		Persistence	Likelihood	Assessment of Self-sustainability [3]	
							Pr (λ ≥ stable) habitat	Pr(λ ≥ stable) population	Pr (N≥Qext) [2]			
47	Far North	CU	14	1	15	n/a	0.88	n/a	n/a	likely	SS	• Delineated range represents a conservation unit. Range delineation is currently being refined. • Current range conditions are *likely* to maintain a self-sustaining population. The risk assessment is based on *limited* evidence but primarily on the habitat indicator of population growth. • There is insufficient available data to estimate the population indicator of population growth and the additive risk of quasi-extinction associated with small population size; estimates of population growth and size would increase certainty in the assessment. • Averaging habitat conditions over a large continuous area may mask spatial variation in disturbance. Fire is the predominant disturbance type within the range. Fires affect and are dispersed over the western portion of the range.
Quebec												
48	Val d'Or	LP	0.1	60	60	30	0.21	0.37	0.37	unlikely	NSS	• No updated demographic information was provided for this risk assessment. • Delineated range represents a LP. • Current range conditions are *unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence but primarily on the habitat indicator of population growth that suggests poor habitat condition is having adverse effects on the population. • There is *high* agreement among the indicators supporting the assessment outcome. The indicator of quasi-extinction produces a similar assessment to that based on the habitat information and suggests that there is an additive risk of extinction associated with small population size (N = 30). Similarly, the reported declining trend also suggests the current range is not self-sustaining. • Improved estimates of population growth (lambda) would increase certainty in and potentially change the assessment.

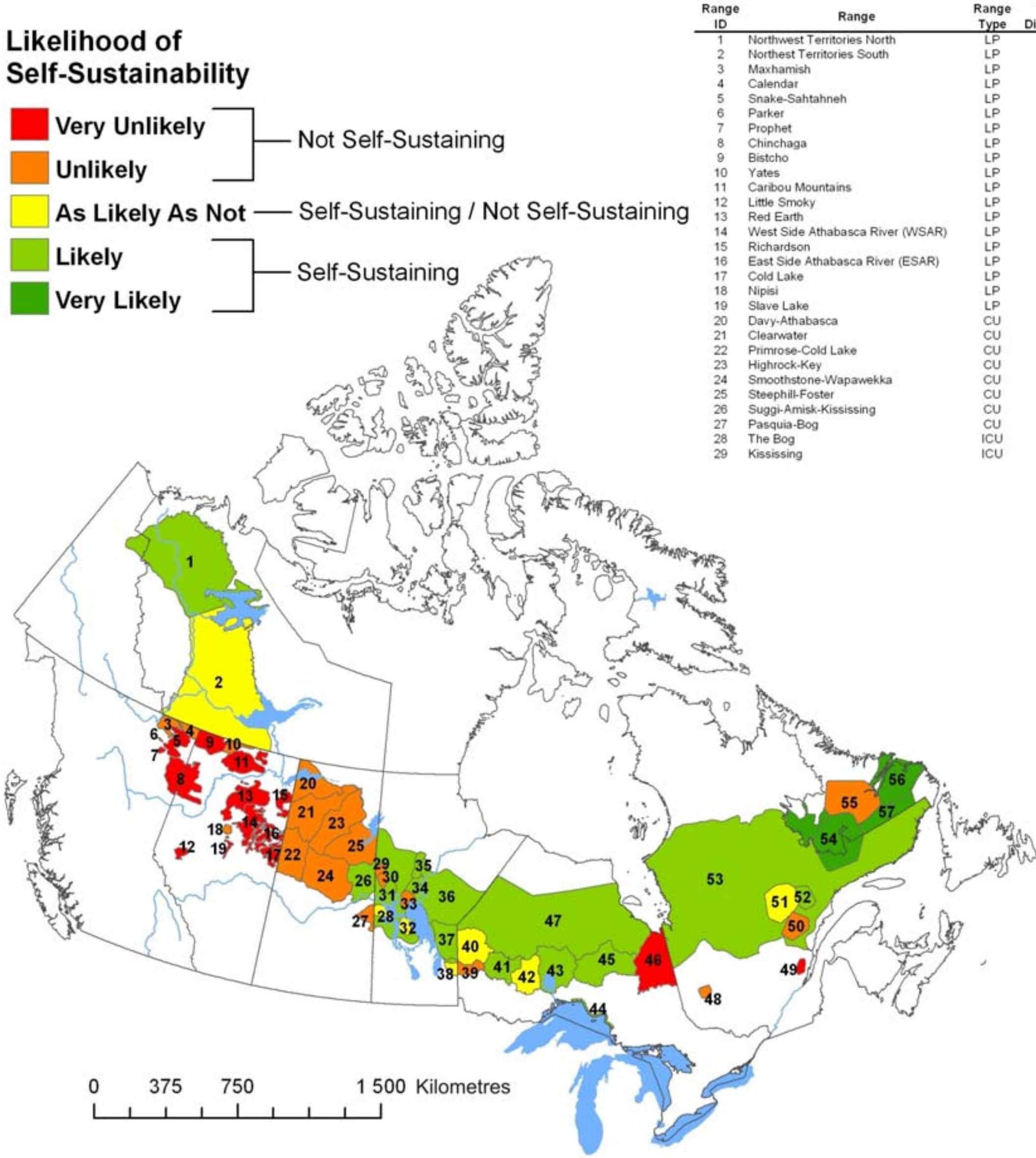
Reference #	Range	Range Type [1]	Disturbance			Population size	Indicator of the range capacity to maintain a self-sustaining population			Integrated Risk Assessment		Notes on interpretation
							Stable or Positive Population Growth		Persistence	Likelihood	Assessment of Self-sustainability[3]	
			Fire (%)	Anthropogenic (%)	Total non-overlapping (%) buffered		Pr (λ ≥ stable) habitat	Pr(λ ≥ stable) population	Pr (N≥Qext)[2]			
49	Charlevoix	LP	4.0	77	80	75	< 0.09	0.55	0.62	very unlikely	NSS	• No updated demographic information was provided for this risk assessment. • Delineated range represents a LP. • Current range conditions are *very unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence, but there is *low* agreement among the indicators. The precautionary principle was applied to resolve the discrepancy between habitat and population data. The risk assessment is based primarily on the habitat indicator of population growth that suggests poor habitat condition is having adverse effects on the population. • The reported stable population trend estimate produces a more optimistic assessment that the population is as likely as not to be self-sustaining; improved estimates of population growth (lambda) would increase certainty in and potentially change the assessment.
50	Pipmuacan	ICU	11.1	51	59	134	0.22	0.55	0.71	unlikely	NSS	• No updated demographic information was provided for this risk assessment. • Delineated range represents an improved conservation unit. Range boundaries may change with additional information. • Current range conditions are *unlikely* to maintain a self-sustaining population. The risk assessment is based on *considerable* evidence, but there is *low* agreement among the indicators. The precautionary principle was applied to resolve the discrepancy between habitat and population data. The risk assessment is based primarily on the habitat indicator of population growth that suggests poor habitat condition is having adverse effects on the population. • The reported stable population trend estimate produces a more optimistic assessment than that based on the habitat indicator of population growth that suggests the population is as likely as not to be self-sustaining; improved estimates of population growth (lambda) would increase certainty in and potentially change the assessment.

Reference #	Range	Range Type [1]	Disturbance			Population size	Indicator of the range capacity to maintain a self-sustaining population			Integrated Risk Assessment		Notes on interpretation
			Fire (%)	Anthropogenic (%)	Total non-overlapping (%) buffered		Stable or Positive Population Growth		Persistence	Likelihood	Assessment of Self-sustainability [3]	
							Pr (λ ≥ stable) habitat	Pr(λ ≥ stable) population	Pr (N≥Qext) [2]			
51	Manouane	ICU	17.9	23	39	358	0.53	0.55	0.87	as likely as not	NSS/ SS	• No updated demographic information was provided for this risk assessment. • Delineated range represents an improved conservation unit. Range boundaries may change with additional information. • Current range conditions are *as likely as not* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence but primarily on the habitat indicator of population growth. • There is *high* agreement among the indicators that supporting the assessment outcome. The reported stable trend produces a similar assessment to that based on the habitat indicator of population growth • Improved estimates of population growth (lambda) would increase certainty in and potentially change the assessment.
52	Manicouagan	ICU	3.2	32	33	181	0.66	0.71	0.77	likely	SS	• No updated demographic information was provided for this risk assessment. • Delineated range represents an improved conservation unit. Range boundaries may change with additional information. • Current range conditions are *likely* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence but primarily on the habitat indicator of population growth. • There is *high* agreement among the indicators that the current range will maintain a self-sustaining population. The reported stable trend produces a similar assessment to that based on the habitat indicator of population growth. • Improved estimates of population growth (lambda) would increase certainty in and potentially change the assessment.

Reference #	Range	Range Type [1]	Disturbance			Population size	Indicator of the range capacity to maintain a self-sustaining population			Integrated Risk Assessment		Notes on interpretation
							Stable or Positive Population Growth		Persistence			
			Fire (%)	Anthropogenic (%)	Total non-overlapping (%) buffered		Pr (λ ≥ stable) habitat	Pr(λ ≥ stable) population	Pr (N≥Qext)[2]	Likelihood	Assessment of Self-sustainability[3]	
53	Quebec	CU	19.9	12	30	9000	0.68	0.55	1.00	likely	SS	• No updated demographic information was provided for this risk assessment. • Delineated range represents a conservation unit. Range boundaries may change with additional information. • Current range conditions are *likely* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence but primarily on the habitat indicator of population growth. • There is *partial* agreement among the indicators supporting the assessment outcome. The indicator of quasi-extinction produces a similar assessment to that based on the habitat information and suggests that there is no additive risk of extinction associated with small population size. However, the reported trend of stable yields a more conservative assessment that suggests the range is as likely as not to maintain a self-sustaining population. • Improved estimates of population growth (lambda) would increase certainty in and potentially change the assessment. • Averaging habitat conditions over a large continuous area may mask spatial variation in disturbance. Disturbance created by fire is dispersed across the range. The majority of anthropogenic disturbance is aggregated in the southern portion of this range.
Labrador (Newfoundland)												
54	Lac Joseph	LP	7.3	1	8	1101	0.90	n/a	0.95	very likely	SS	• No updated demographic information was provided for this risk assessment. • Delineated range represents a LP. • Current range conditions are *very likely* to maintain a self-sustaining population over time. This risk assessment is based on *limited* evidence but primarily on the habitat indicator of population growth. A large portion of the disturbance on this range is due to fire. • There are insufficient available data to estimate the population indicator of population growth; estimates of population growth would increase certainty in and potentially change the assessment.

Reference #	Range	Range Type [1]	Disturbance			Population size	Indicator of the range capacity to maintain a self-sustaining population			Integrated Risk Assessment		Notes on interpretation
							Stable or Positive Population Growth		Persistence	Likelihood	Assessment of Self-sustainability[3]	
			Fire (%)	Anthropogenic (%)	Total non-overlapping (%) buffered		Pr (λ ≥ stable) habitat	Pr(λ ≥ stable) population	Pr (N≥Qext)[2]			
55	Red Wine Mountain	LP	5.1	3	8	97	0.90	0.37	0.67	unlikely	NSS	• No updated demographic information was provided for this risk assessment. • Delineated range represents a LP. • Current range conditions are *unlikely* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence, but there is *low* agreement among the indicators. The precautionary principle was applied to resolve the discrepancy between habitat and population data. The risk assessment is based primarily on the population indicator of population growth that suggests the population is declining (trend). • Poor habitat condition does not appear to be contributing to the population decline; the habitat indicator of population growth suggests that habitat condition is sufficient to maintain a self-sustaining population. A large portion of the disturbance on this range is due to fire. • Factors contributing to population decline should be investigated.
56	Mealy Mountain	LP	0.4	1	2	2106	0.91	0.55	0.98	very likely	SS	• No updated demographic information was provided for this risk assessment. • Delineated range represents a LP. • Current range conditions are *very likely* to maintain a self-sustaining population over time. The risk assessment is based on *considerable* evidence but primarily on the habitat indicator of population growth. • There is *partial* agreement among the indicators supporting the assessment outcome. The indicator of quasi-extinction produces a similar assessment to the habitat indicator for population growth. However, the reported population trend of stable produces a more conservative assessment that indicates the population is as likely as not to be self-sustaining. • Longer-term estimates of λ would increase certainty in and potentially change the assessment.
57	Labrador	CU	6.5	2	9	n/a	0.90	n/a	n/a	very likely	SS	• No updated demographic information was provided for this risk assessment. • Delineated range represents a conservation unit. Range boundaries may change with additional information. • Current range conditions are *very likely* to maintain a self-sustaining population over time. The assessment is based on *limited* evidence but primarily on the habitat indicator of population growth because it is the only indicator available. A large portion of the disturbance on this range is due to fire. • There are insufficient available data to estimate the population indicator of population growth and the indicator of quasi-extinction; estimates of population growth and population size would improve the certainty in and potentially change the assessment.

1. Range type as per Figure 4: CU: Conservation Unit; ICU: Improved Conservation Unit; LP: Local Population.
2. This column reports on the indicator of quasi-extinction used to flag the increased risk of extinction associated with small population size. This indicator is estimated using range-specific population sizes and assuming good demographic conditions (stable growth), i.e., isolating the effect of population size on persistence. No quasi-extinction estimate was calculated in the absence of population size data.
3. Categories for the assessment of self-sustainability include: SS: Range Self-Sustaining; NSS: Range Not Self-Sustaining; NSS/SS: Range as likely to be Self-Sustaining as Not Self-Sustaining.
4. The jurisdiction recognizes Northwest Territories North and South as two subpopulations based on Nagy et al. (2011), and estimates a total population size in the NT of 6500.
5. The ratio between the population sizes for Nipisi and Slave Lake reported in the 2008 EC scientific review were used to derive updated population size estimates for each range from the 2010 estimate of 120 boreal caribou for both ranges combined (ASRD & ACA 2010).



Range ID	Range	Range Type	Total % Disturbance
1	Northwest Territories North	LP	22
2	Northest Territories South	LP	38
3	Maxhamish	LP	58
4	Calendar	LP	61
5	Snake-Sahtahneh	LP	87
6	Parker	LP	34
7	Prophet	LP	79
8	Chinchaga	LP	76
9	Bistcho	LP	71
10	Yates	LP	61
11	Caribou Mountains	LP	57
12	Little Smoky	LP	95
13	Red Earth	LP	62
14	West Side Athabasca River (WSAR)	LP	69
15	Richardson	LP	82
16	East Side Athabasca River (ESAR)	LP	81
17	Cold Lake	LP	85
18	Nipisi	LP	68
19	Slave Lake	LP	80
20	Davy-Athabasca	CU	61
21	Clearwater	CU	70
22	Primrose-Cold Lake	CU	54
23	Highrock-Key	CU	63
24	Smoothstone-Wapawekka	CU	33
25	Steephill-Foster	CU	50
26	Suggi-Amisk-Kississing	CU	25
27	Pasquia-Bog	CU	44
28	The Bog	ICU	16
29	Kississing	ICU	51

Range ID	Range	Range Type	Total % Disturbance
30	Naosap	ICU	50
31	Reed	ICU	26
32	North Interlake	ICU	17
33	William Lake	ICU	31
34	Wabowden	ICU	28
35	Wapisu	ICU	24
36	Manitoba	CU	28
37	Atikaki-Berens	ICU	35
38	Owl-Flinstone	LP	39
39	Sydney	ICU	58
40	Berens	ICU	39
41	Churchill	ICU	31
42	Brightsand	ICU	42
43	Nipigon	LP	31
44	Coastal	CU	16
45	Pagwachuan	ICU	27
46	Kesagami	ICU	38
47	Far North	CU	15
48	Val d'Or	LP	60
49	Charlevoix	LP	80
50	Pipmuacan	ICU	59
51	Manouane	ICU	39
52	Manicouagan	ICU	33
53	Quebec	CU	30
54	Lac Joseph	LP	8
55	Red Wine Mountain	LP	8
56	Mealy Mountain	LP	2
57	Labrador	CU	8

LP = Local Population
CU = Conservation Unit
ICU = Improved Conservation Unit

Figure 14. Integrated Risk Assessment for boreal caribou ranges in Canada. Self-sustainability outcomes (i.e., self-sustaining, not self-sustaining, or not self-sustaining/self-sustaining) for each range were assigned based on the likelihood statement describing the range's capacity to maintain a self-sustaining local population of boreal caribou.

3.3 Assessment of Risk and Identification of Management Thresholds

The methodology described in Section 2.4.6.2 was implemented for a sample of ranges to demonstrate the potential application and interpretation of a risk-based framework to support recovery planning, including but not limited to the use of management thresholds. As indicated in Section 2.4.6.2 the consideration of management threshold is informed by science but determined by managers in accordance with decisions regarding the acceptable level of risk. To illustrate the approach, the level of acceptable risk necessary for threshold determination was set concordant with the probability interval from the integrated risk assessment associated with a likely outcome, which corresponds to the weight of evidence indicating that a range was *likely* to support a self-sustaining population, and interpreted as relatively low risk (see Figure 11). The interval includes a range of estimated probabilities from greater or equal to 60 to 90%, corresponding to a total range-level disturbance values from 10 to 35%, inclusive of a 500 m buffer on all anthropogenic disturbances. The upper end of the disturbance interval was imposed as the "*disturbance threshold*" for demonstration purposes (Figure 15).

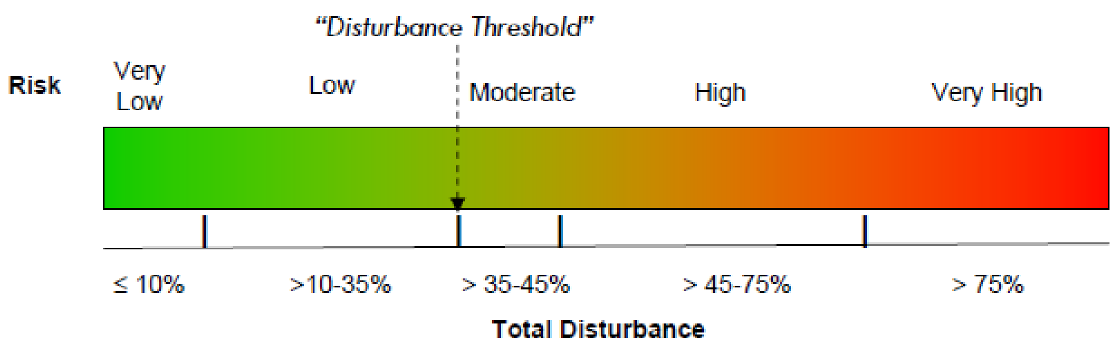


Figure 15. Intervals of disturbance reflecting relative levels of risk associated with achieving a desired outcome of maintaining range conditions necessary to support a self-sustaining population of boreal caribou. The assignment of "Disturbance Threshold" is for illustrative purposes only.

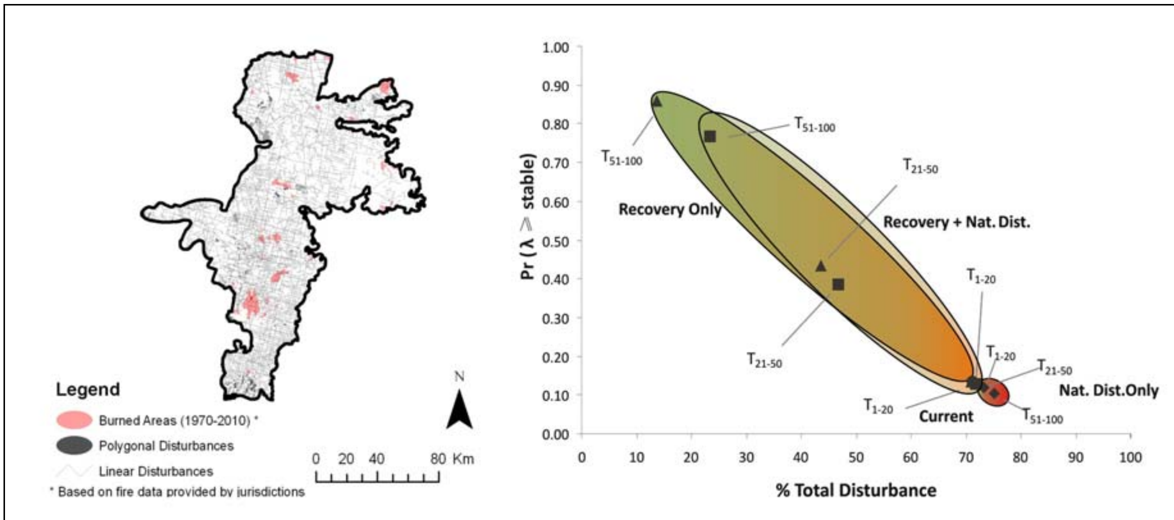
Three caribou ranges were evaluated using the stepwise approach summarized in Figure 12: West-side Athabasca River, Alberta; Smoothstone-Wapawekka, Saskatchewan, and North Interlake, Manitoba.

West-side Athabasca River: Alberta

At 69% total disturbance (Figure 16a), this range falls in the high risk category and is unlikely to support a self-sustaining population based on habitat condition. This level of disturbance is also well in excess of the "*disturbance threshold*". The reported average population trend over five years is rapidly declining ($\lambda = 0.92$; last reported value 0.78). While the reported population size of 204-272 indicates high potential for persistence, given a low risk of quasi-extinction under good habitat and population conditions (Pr ($N \geq Qext$) = 0.80-0.83), the projected quasi-extinction risk based on current population and habitat conditions indicates the population is highly unlikely to persist over the next 50 years.

Assessment of potential future scenarios (Figure 16b) indicates some potential for the range condition to improve through passive recovery of presently disturbed areas. However, it could take between 51 and 100 years for the range to recover to a condition consistent with the low risk category (also for illustrative purposes, the disturbance threshold), assuming no new anthropogenic or natural disturbances. Given the very high risk of local extirpation under current conditions, and natural recovery rates that are insufficient to offset short term extinction risk, the management scenario for this population suggests that active recovery efforts are required to reduce risk.

Monitoring of population condition should continue to assess response to recovery actions and associated changes in range condition.



(a) (b)

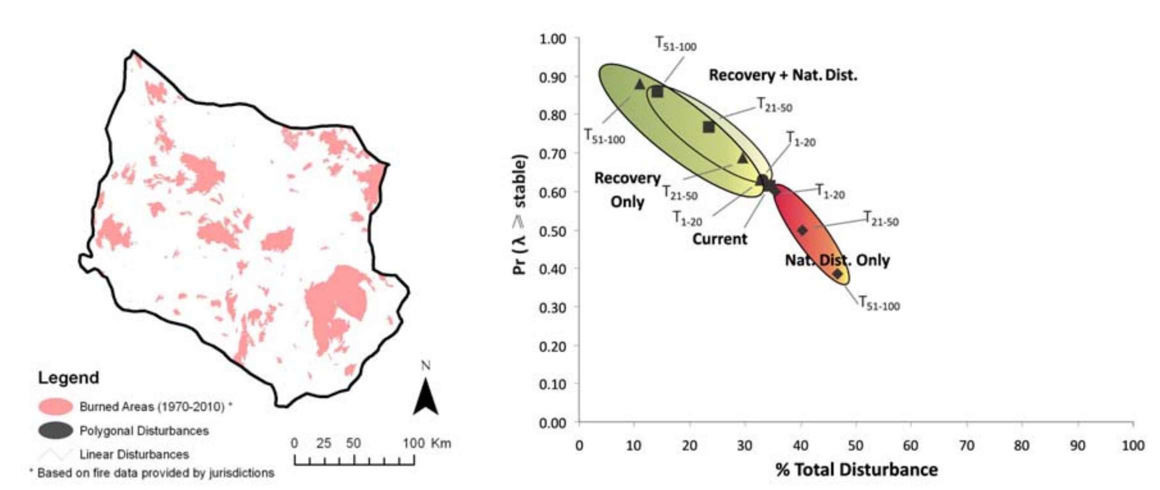
Figure 16. Current disturbance (a) and potential future population and range conditions (b) on the West-side Athabasca River caribou range.

Smoothstone–Wapaweka: Saskatchewan

At 33% total disturbance (Figure 17a), the range falls in the low risk category, which suggests it is likely to support a self-sustaining population based on habitat condition. The "*disturbance threshold*" has not been surpassed. However, the reported population trend is "declining". In addition, while the reported population size of 700 indicates a very low risk of extinction under good habitat and population conditions ($Pr(N \geq Qext)$ = 0.94), the projected quasi-extinction risk inferred from population trend under the observed habitat conditions is estimated at 0.38, indicating that the population faces high risk, and is unlikely to persist above a critical number of 10 individuals if current conditions are maintained. Visual inspection of mapped disturbance on the range (Figure 19a) suggests the highly dispersed nature of the disturbance, in conjunction with significant water bodies (not illustrated here), have contributed to a paucity of large, undisturbed areas within the range.

Assessment of future scenarios (Figure 17b) indicates potential for range condition to be improved within the low risk category through passive recovery of presently disturbed areas, 17% of which (47% of the total) consist of recent burns (≤ 40 years). While the likelihood of persistence is low if current conditions were maintained, natural recovery appears sufficient to offset short term extinction risk, assuming other threats are managed. Although the range is currently below the "*disturbance threshold*", the management scenario for this population is for conservation of remaining undisturbed habitat, to avoid increases in risk.

Monitoring should be implemented to confirm expected improvements to population condition in association with recovery of disturbed areas.



(a) (b)

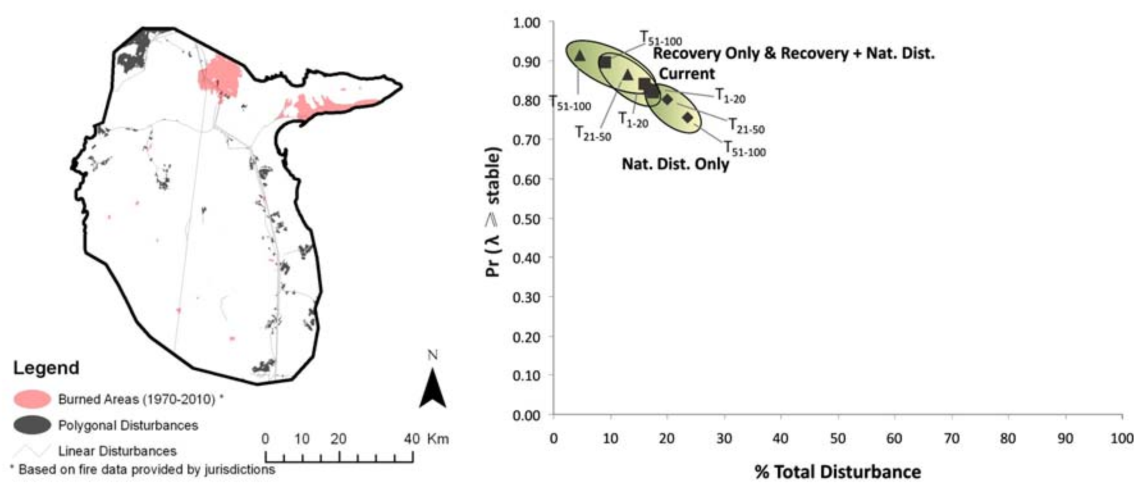
Figure 17. Current disturbance (a) and potential future population and range conditions (b) on the Smoothstone-Wapawekka caribou range.

North Interlake: Manitoba

At 17% total disturbance (Figure 18a), the range falls in the low risk category, which suggests it is likely to support a self-sustaining population based on habitat condition. The "*disturbance threshold*" has not been surpassed. However, the reported population size of 50-75 indicates a moderate risk of local extinction under good habitat and population conditions (Pr (N≥Qext) = 0.52-0.61), due to small population size.

Assessment of future scenarios (Figure 18b) indicates that range condition is likely to remain within the low risk category. The likelihood of persistence will remain uncertain and continue to represent moderate risk unless population size increases. Although the range is currently below the "*disturbance threshold*", the risk associated with the small population size suggests a cautious management approach to consideration of additional disturbance to avoid increasing risk. The location of the range on a peninsula, surrounded by water on 3 sides (not illustrated here) suggests isolation that also contributes to risk.

Monitoring should be implemented to confirm population condition and evaluate response to any changes within the range.



(a) (b)

Figure 18. Current disturbance (a) and potential future population and range conditions (b) on the North Interlake caribou range.

For purposes of illustrating application of the risk-based framework to thresholds interpretation, it was necessary to assign a disturbance-based management threshold. It is clear from the examples presented that there is considerable utility in the systematic approach to building on the integrated risk assessment to more fully interpret potential outcomes and guide recovery planning, through enhanced understanding of range-specific attributes. This is an objective process that does not require the determination of management thresholds. However, application of disturbance-based management

thresholds provides specific direction relative to management objectives and acceptable risk.
In the examples presented, the disturbance threshold was commensurate with the disturbance interval representing a likely outcome with respect to maintaining a self-sustaining population. The selection of higher or lower thresholds would have different interpretations with respect to likelihood of achieving the recovery objective. The results also suggest there may be considerable value in identifying graduated thresholds, to support a variety of conservation and restoration actions given different management scenarios and range-specific circumstances. Indiscriminate application of a single, fixed threshold may not achieve desired outcomes, particularly in the absence of range-specific interpretation.

3.4 Biophysical Attributes Necessary for the Survival and Recovery of Boreal Caribou across their Distribution in Canada

Table 12. Biophysical attributes of boreal caribou habitat in the Taiga Shield ecozone.

Scale of selection	Description
Broad scale	Upland tundra dominated by ericaceous shrubs (*Ericaceae* spp.), lichen, grasses and sedges. Lowland tundra composed of peatland complexes (muskeg and string bogs), lakes, rivers and riparian valleys. Dense mature conifer and open conifer forests with abundant lichens.[1, 2]
Calving	String bogs, treed bogs, small open wetlands (<1 km^2) and large muskeg.[1, 3] Calving on peninsulas and islands increases with amount of open water. [1, 4]
Post-calving	Forested wetlands. [1]
Rutting	Open wetlands. [1]
Winter	Forested areas are used in years of low snow accumulation, otherwise winter habitat selection reflects general avoidance of deep snow, including use of tundra habitat at higher elevations in mountainous regions and bogs along lakes or oceans.[5, 6] Forested wetlands. [6] Tundra uplands and sand flats in proximity to water. [6] Bog edges, glacial erratics and bedrock erratics with lichen, and lakes for loafing or ruminating. [4, 6, 7] Some use of mature white spruce and fir stands as alternative to habitat with arboreal lichens. [8]
Travel	Connectivity between selected habitat types important given reported patterns of movement among caribou. Some females travel 200 to 500 km from winter areas to calving sites. [1] Females show fidelity to post-calving sites returning to within 6.7 km of a given location in consecutive years. [8]
Avoidance	Avoidance of roads and areas recently burned (< 40 yrs). [9]

1. Brown et al. (1986); 2. Courtois et al. (2004); 3. Brown and Theberge (1985); 4. Schmelzer et al. (2004);
5. Brown and Theberge (1990); 6. Schmelzer et al. (2004); 7. I. Schmelzer (pers. comm.); 8. Schaefer et al. (2000);
9. Appendix 7.3.

Table 13. Biophysical attributes of boreal caribou habitat in the Hudson Plains ecozone.

Scale of selection	Description
Broad scale	Habitats selected generally to reduce predation risk. [1] Shrub rich treed muskeg and mature conifer forests. [1, 2] Poorly drained areas dominated by sedges, mosses and lichens, as well as open black spruce and tamarack forests. [3] Elevations of 150m.[4] Intermediate levels of ruggedness and NDVI. [4]
Calving	Mature conifer stand with and without lichens and wetlands. Preference for higher altitudes compared to habitat use during other periods. [1]
Post-calving	Fens, bogs and lakes.[5]
Rutting	Wetlands and conifer stands with lichen. Mature and regenerating conifer stands are also used, albeit to a lesser degree. [1]
Winter	Dense and mature conifer forests with lichens and wetlands. [1, 5] Peatlands dominated by open bogs and terrestrial lichens. [6] Large patches of intermediate and mature black spruce, shrub-rich treed muskeg and mixed conifer stands all used in late winter. [7]
Travel	Movements greatest in fall/winter when caribou transition from calving to winter habitat. [8] Long range movements are greater in areas with high moose densities, presumably to reduce predation risk. [2]
Avoidance	Avoid herbaceous areas and areas burned within 40 yrs. [4] Deciduous-dominated forests, lichen woodlands and lichen heaths avoided during winter. [6] Avoidance of human development (e.g. roads) provided sufficient caribou habitat remains.[1, 4] Habitats in proximity to human development are used in highly disturbed landscapes, presumably because there is no alternative. [1]

1. Courtois (2003); 2. Brown (2005); 3. Magoun et al. (2005); 4. Appendix 7.3; 5. Pearce and Eccles (2004); 6. Brokx (1965); 7. Brown et al. (2007); 8. Brown et al. (2003).

The Boreal Shield ecozone has been divided into 5 sub-regions (Tables 16-20) as per EC 2008 (Appendix 7.3):

Table 14. Biophysical attributes of boreal caribou habitat in the Boreal Shield East.

Scale of selection	Description
Broad scale	Conifer-feather moss forests on poorly-drained sites and mature conifer uplands with abundant terrestrial lichen. [1,2] Water bodies and wetlands are also selected. [2] Elevations of 300 m.[3] Intermediate values of NDVI. [3] Selection for regenerating burns >40 yrs old. [3]
Calving	Open wetlands, peninsulas and islands for calving in northeastern Québec. [4] Sedges, ericaceous species, bryophytes, alder and larch selected in spring in eastern regions (NF&L).[5] Balsam fir, dense black spruce stands, spruce-fir forests older than 40 yrs, and dry bare land with high lichen densities selected in the western regions. [6] Mature conifer stands, as well as wetlands selected in the southern regions. Higher altitudes used for calving in this area rather than lake or water bodies. [2]
Post-calving	Open and forested wetlands and continued use of peninsulas and islands in northeastern Québec. [4] Aquatic plants, dwarf birch (*Betula glandulosa*), deciduous shrubs, ericaceous species and moss in NF&L. [5]
Rutting	Open wetlands selected in northeastern Québec. [4] Terrestrial and arboreal lichens, forbs, sedges, mosses and coniferous and deciduous shrubs selected in NF&L. [5] Balsam fir stands, dense spruce stands, mature and regenerating conifer stands, other forest stands with abundant lichens, wetlands and dry bare lands preferred in southern extent. [2, 6, 7]
Winter	Forested wetlands selected in Labrador and northern Québec.[3] Some use of upland-tundra for loafing [3] Dry bare land, wetlands, mature conifer forests with lichen, balsam fir stands, dense spruce stands, and mixed spruce-fir forests older than 40 yrs selected in southern areas, up to 80 yrs old in other areas. [2, 6, 7] Use of mature forests protected from harvesting increases probability of encounters with wolves that select the same habitats in winter. [7] Shallow snow depths selected in late winter. [7]
Travel	Caribou move greater distances during the rutting season. [4]
Avoidance	Avoid deciduous and mixed forests, jack pine forests less than 40 yrs old and heaths without lichens all year round. [6, 7, 8] Avoid disturbed habitats, including roads, recreational areas, burns and clear-cuts or harvested areas used by wolves. [2, 3, 6, 7, 8]

1. Arsenault et al. (1997); 2. Courtois (2003); 3. Appendix 7.3; 4. Brown et al. (1986); 5. Bergerud (1972); 6. Crête et al. (2004); 7. Courbin et al. (2009); 8. Courtois et al. (2007).

Table 15. Biophysical attributes of boreal caribou habitat in the Boreal Shield Southeast.

Scale of selection	Description
Broad scale	Late seral-stage black spruce-dominated lowlands and jack pine-dominated uplands. [1] Elevations of 300 m. [2] Intermediate values of NDVI. [2] Selection for old (>40 yrs) burns. [2]
Calving	Open, medium-closed conifer forests. [3]
Post-calving	Not available.
Rutting	Dense and open mature conifer forests of spruce, tamarack, jack pine and young conifer forests between 30 to 50 yrs old. [3]
Winter	Charlevoix caribou select open stands of balsam fir, balsam fir-black spruce, black spruce, black-spruce-tamarack and jack pine stands older than 70 yrs. Dry bare lands, 30 to 50 yrs old stands of balsam fir or fir-black spruce, as well as 50 yr old jack pine stands, and arboreal and terrestrial lichens are also selected. [3, 5]
Travel	Not available.
Avoidance	Avoidance of roads and burns <50 yrs old. [2,4]

1. Duchesne et al. (2000); 2. Appendix 7.3; 3. Lefort et al. (2006); 4. Schaefer and Pruitt (1991); 5. Sebbane et al. (2002)

Table 16. Biophysical attributes of boreal caribou habitat in the Boreal Shield Central.

Scale of selection	Description
Broad scale	Late seral-stage black spruce-dominated lowlands and jack pine dominated uplands.[1, 2, 3] Open black spruce lowlands are selected near the Québec/Ontario border.[3] Low-density late seral-stage jack pine or black spruce forests and black spruce/tamarack-dominated peatlands with abundant terrestrial and moderate arboreal lichens are selected in areas of Ontario.[3, 4, 5, 6] Caribou also use areas with dry to moist sandy to loamy soils and shallow soils over bedrock. [6] Elevations of 300 m.[7] Intermediate values of NDVI. [7] Selection for regenerating burns >40 yrs old. [7]
Calving	Open canopies of mature black spruce and mesic peatland with ericaceous species for calving are selected for calving in the Claybelt region. [3] Females with calves selected areas with more abundant ericaceous shrubs and terrestrial lichens during the summer compared to females without calves. [3]
Post-calving	Not available.
Rutting	Not available.
Winter	Large areas of contiguous forests dominated by black spruce. [8] Open conifer forests or forests with lower tree densities where terrestrial and arboreal lichen are abundant and there is significant less snow (e.g. shorelines) are also selected. [4, 6]
Travel	Not available.
Avoidance	Avoid recently downed woody debris, dense shrubs and larch during the calving season in the Claybelt region. [3] Avoid mixed conifer and deciduous forests in winter. [8] Areas of deep snow are also avoided during winter. [4] Avoidance of roads and recent burns (<40 yrs old). [7]

1. Arseneault et al. (1997); 2. Courtois et al. (2003); 3. Lantin et al. (2003); 4. Bergerud (1985); 5. Vors (2006); 6. Wilson (2000); 7. Appendix 7.3; 8. Brown et al. (2007).

Table 17. Biophysical attributes of boreal caribou habitat in the Boreal Shield West Central.

Scale of selection	Description
Broad scale	Mature conifer uplands and conifer/tamarack dominated lowlands. [1, 2, 3, 4] Conifer/tamarack-dominated peatlands with abundant arboreal lichens, upland mature conifer forests stands with abundant terrestrial lichen and rocky areas with sparse trees. [5, 6, 7] Elevations of 300 m.[8] Intermediate values of NDVI. [8] Selection for regenerating burns >40 yrs old. [8]
Calving	Forested wetlands/treed bog, old burns, sparse conifer and dense spruce selected in areas of northwestern Ontario.[9] Peatlands, raised hillrocks with large muskeg areas, forested islands and shorelines of large lakes selected during calving. [1, 2, 10, 11, 12] Jack pine or jack pine/black spruce forests also used for calving in Manitoba. [5]
Post-calving	Peatland with forested islands, islands, and shorelines selected during summer. [10, 12] Mature, dense forest stands also selected. [5, 13]
Rutting	Semi-open and open bogs and mature conifer uplands selected during rutting. Terrestrial lichens and arboreal lichens, sedges and bog ericoids (*Andromeda glaucophylla, Chamaedaphne calyculata, Kalmia polifolia, Ledum groenlandicum*) are important sources of forage. [5]
Winter	Mature coniferous stands. [10, 14] Areas with a high proportion of lakes (>5-100 ha) with convoluted shorelines. [15] Caribou forage in areas with high lichen abundance and fewer shrubs in jack pine and black spruce stands with low tree densities, low basal areas and short heights. [16] Caribou select open bogs, intermediate to mature jack pine rock ridges, jack pine habitats with lichens and lakes, but move to jack pine ridges in mature conifer stands with lichen when winter conditions prevent foraging in bogs in Manitoba in winter. [5, 6, 17] Arboreal lichens, terrestrial lichens, sedges and ericaceous species are an important source of forage. [18]
Travel	Caribou in Ontario travel mainly in conifer forests, avoiding open habitats (e.g., lakes, disturbed areas, etc.) when migrating from summer to winter habitat. [2] Use frozen lakes for travel during winter/spring, in some instances to reach islands for calving. [1,5, 8, 11] Spring migration is not restricted to specific travel routes. [12] Caribou moved 8 to 60 km away after logging operations were begun. [20]
Avoidance	Shrub-rich fens are avoided during calving. [9] Tamarack fens avoided during post-calving. [12] Early successional stands, mixed softwood stands and areas with wind felled trees avoided in winter. [14, 18] Vesicular ice, areas with snow depths greater than 65 cm and snow crusted areas with a hardness >400g/cm^2 were also avoided during winter. [17] Caribou used areas immediately post fire, but then gradually avoided these areas as more time elapsed. [8, 18] Areas where active logging is taking place are avoided. [19, 20] Avoidance of roads. [8]

1. Bergerud et al. (1990); 2. Ferguson and Elkie (2004a); 3. Ferguson and Elkie (2004b); 4. Vors (2006); 5. Darby and Pruitt (1984); 6. Schaefer (1988); 7. O'Brien et al. (2006); 8. Appendix 7.3; 9. Hillis et al. (1998); 10. Armstrong et al. (2000); 11. O'Flaherty et al. (2007); 12. Cumming and Beange (1987); 13. Pearce and Eccles (2004); 14. Martinez (1998); 15. Ferguson and Elkie (2005); 16. Antoniak and Cumming (1998); 17. Stardom (1975); 18. Schaefer and Pruitt (1991); 19. Cumming and Hyer (1998); 20. Schindler et al. (2007).

Table 18. Biophysical attributes of boreal caribou habitat in the Boreal Shield West.

Scale of selection	Description
Broad scale	Conifer/tamarack-dominated peatland complexes and upland moderate to dense mature conifer forests with abundant lichens. [1, 2, 3] Elevations of 300 m.[4] Intermediate values of NDVI. [4] Selection for old (>40 yrs) burns. [4]
Calving	Peatlands, stands dominated by black spruce and treed muskeg all used for calving. [5, 6] Some caribou will use islands and lakeshores during calving. [3, 7]
Post-calving	Wooded lakeshores, islands, sparsely treed rock, upland conifer-spruce and treed muskeg are used in summer. [8, 7] Sites with a high abundance of arboreal lichen are important for foraging in some areas. [9] Dense conifer and mixed forests are also used. [3]
Rutting	Dense and sparse conifer and mixed forests. [3] Open riparian habitats are also used during the rut. [10]
Winter	Mature upland spruce, pine stands and treed muskeg. [8] Jack pine dominated forests. [2] In areas of Ontario, caribou select sparse and dense conifer, mixed forests and treed bogs. [3] In some areas caribou will select habitat with greater visibility and further away from forest edges. [9]
Travel	Some males move >100 km during the rutting season. [10] Traditional travel routes between summer and winter ranges occur in large peatland complexes in the Wabowden and Gormley area. [11]
Avoidance	Avoid shrub-rich habitats and hardwood-dominated stands. [1,2, 8] Avoidance of conifer stands that are not black spruce, deciduous stands, shrub-rich fens and wetlands during calving. [3, 6] Avoid recent burns and disturbed/fragmented areas, including roads. [3, 4, 8]

1. Arseneault et al. (1997); 2. O'Brien et al. (2006); 3. Hillis et al. (1998); 4. Appendix 7.3; 5. Rettie (1998); 6. Hirai (1998); 7. Shoesmith and Storey (1977); 8. Metsaranta and Mallory (2007); 9. Lander (2006); 10. V. Chrichton (pers. comm.); 11. Brown et al. (2000).

Table 19. Biophysical attributes of boreal caribou habitat in the Boreal Plains ecozone.

Scale of selection	Description
Broad scale	Caribou in Boreal Plains of Alberta select late seral-stage (>50 yrs old) conifer forest and treed peatlands with abundant lichens. [1, 2, 3, 4, 5] In northeastern Alberta, caribou habitat use restricted primarily to peatland complexes. [1] Elevations of 1135 m.[6] Intermediate levels of NDVI. [6] Selected old (>40 yrs) burns. [6]
Calving	Bogs and mature forests selected for calving in Alberta. [3, 4] In Saskatchewan, peatlands and stands dominated by black spruce and lowland black spruce stands within muskeg are used for calving. [7, 9]
Post-calving	Forest stands older than 50 yrs. [11] Upland black spruce/jack pine forests, lowland black spruce, young jack pine and open and treed peatlands and muskeg are also selected during summer. [7, 12, 13] In some areas, sites with abundant arboreal lichen are selected during summer. [14]
Rutting	Mature forests. [3] Upland black spruce/jack pine forests, lowland black spruce, young jack pine and open and treed peatlands and muskeg during summer. [7, 12]
Winter	Treed peatlands, treed bog and treed fen and open fen complexes with >50% peatland coverage with high abundance of lichens. [15, 16, 17] Mature forest > 50 yrs old. [3, 11] Upland black spruce/jack pine forests, lowland black spruce, young jack pine and open and treed peatlands. [7, 12, 13]
Travel	Not available.
Avoidance	Avoid upland and fen habitats, aspen dominated stands, immature stands and large rivers all year round. [3, 4, 6, 9] Avoid matrix-type habitat, including areas with abundant shrubs, disturbed/fragmented habitats, hardwood/deciduous dominated forest stands, and edge habitat. [1, 2, 8] Avoid recent burns, main roads, seismic lines, well sites and areas with a high density of cut blocks. [6, 10] Avoidance of water. [6]

1. Stuart-Smith et al. (1997); 2. Smith (2004); 3. Neufeld (2006); 4. James (1999); 5. McLoughlin et al. (2003); 6. Appendix 7.3; 7. Rettie (1998); 8. Arsenault (2003); 9. Hirai (1998); 10. Dyer (1999); 11. Dalerum et al. (2007); 12. Rettie and Messier (2000); 13. Metsaranta and Mallory (2007); 14. Lander (2006); 15. Anderson (1999); 16. Bradshaw et al. (1995); 17. Anderson et al. (2000).

Table 20. Biophysical attributes of boreal caribou habitat in the Montane Cordillera ecozone.

Scale of selection	Description
Broad scale	Little Smoky population spends the entire year in subalpine and upper foothill regions in upland lodge pole pine, mixed conifer lodgepole pine/black spruce and treed muskeg.[1, 4, 5] Open, pine dominated stands of 80 yrs or more. [2, 3]
Calving	Areas closer to cut-blocks with a high proportion of larch are selected during calving. [6]
Post-calving	Homogeneous areas of conifer dominated stands. [6]
Rutting	Not available.
Winter	Caribou use areas with a high proportion of larch and pine forests during winter. [6]
Travel	Not available.
Avoidance	Avoid areas with a large proportion of cut blocks. [6] Avoidance of seismic lines greatest during calving season. [6] Avoid white spruce stands which generally have a low abundance of lichens [7], aspen stands and large rivers. [6]

1. Edmonds (1988); 2. Thomas et al. (1996); 3. Szkorupa (2002); 4. Edmonds (1993); 5. Johnson (1980);
6. Neufeld (2006); 7. Saher (2005).

Table 21. Biophysical attributes of boreal caribou habitat in the Taiga Plains ecozone.

Scale of selection	Description
Broad scale	In NWT caribou prefer open coniferous habitat in all seasons of the year and in the Dehcho prefer using forest stand ages of 100 years or older. [1] Large patches of spruce peatland with reference for bogs over fens and upland and lowland black spruce forests with abundant lichens. [2, 3]
Calving	Open conifer forests, tussock tundra, low shrub, riparian, and recent burns in northern extreme of the NWT range. [4] In the Snake-Sahtaneh watershed of BC, caribou observed on small islands of mature black spruce or mixed forests within peatlands, in old burns at the edge of wetlands, in alder thickets with abundant standing water and on lake shores. [2]
Post-calving	Open coniferous forests with abundant lichen, low shrub, riparian, tussock tundra, sparsely vegetated habitat, and recent burns in the northern extreme of the NT range. [4] Old burns and neighbouring remnant unburned forests selected in late spring, early summer in Snake-Sahtaneh watershed. [2]
Rutting	Open coniferous and mixedwood forests, low shrub, riparian tussock tundra, and recent burns in northern extreme of NWT range. [4] Regenerating burns and sparsely vegetated habitat. [4]
Winter	Open coniferous forest with abundant lichen and riparian areas. [1, 2, 4]
Travel	In NWT some female caribou have little fidelity to calving areas between years, especially in the northern portions of the range, while others show considerable fidelity over successive (2-3) years. [5, 6] In NWT Mean daily rates of movement increase during the rut. They are greatest in the late-winter prior to pre-calving period. [6, 7]
Avoidance	Avoid edge habita. [8] During calving at northern extreme of range in NWT avoid closed mixed forests and water. [4] In northern extreme of range in NWT avoid closed deciduous and mixed forests in summer, fall, and winter. Water also avoided in fall, closed coniferous forest avoided in winter. [4] Avoid forest stand <10 years old during summer. [9]

1. Nagy and Larter, unpublished data; 2. Culling et al. (2006); 3. McLoughlin et al. (2005); 4. Nagy et al. (2006); 5. Larter and Allaire (2007); 6. Nagy et al., unpublished data; 7. Larter and Allaire (2010); 8. McLoughlin et al. (2005); 9. Dalerum et al. (2007).

Table 22. Biophysical attributes of boreal caribou habitat in the Boreal Cordillera ecozone.

Scale of selection	Description
Broad scale	Large patches of spruce peatland and lowland and upland black spruce forests with abundant lichens. [1]
Calving	Open conifer forests, tussock tundra, low shrub, riparian, recent burns and south and west aspects. [2]
Post-calving	Open conifer forests with abundant lichens, low shrub, tussock tundra, sparsely vegetated habitat, recent burns and west aspects. [2]
Rutting	Open coniferous and mixedwood forests, low shrub, riparian, tussock tundra, recent burns and west aspects. [2]
Winter	Open coniferous forests with abundant lichens and riparian habitats. [2]
Travel	Not available.
Avoidance	Avoid closed mixed forests, and water during calving and parts of the winter. [2] Avoid closed spruce forests and conifer forests without lichens in mid-winter. [2] Avoid closed deciduous forests year round and avoid mixed forests during post calving and rut. Water is also avoided during the rut. [2]

1. Culling et al. (2006); 2. Nagy et al. (2006).

No information was available for either the Southern Arctic ecozone or Taiga Cordillera ecozone (EC 2008).

4 DISCUSSION

The purpose of this assessment was to provide a scientific description of critical habitat for boreal caribou to inform critical habitat identification within the recovery strategy for this species at risk. A central premise of this assessment was that local populations and associated ranges are the appropriate biological and geographic units for critical habitat identification. Also important to framing this exercise is the goal of achieving self-sustaining populations, which has both a short-term (≤20 years) population trend component and a longer term (≥50 years) persistence component.

In the 2008 Scientific Review, the approach to critical habitat identification was focused on a probabilistic assessment of the adequacy of the current range conditions to support a self-sustaining population. A range assessment based on three lines of evidence (% total disturbance, population growth and population size) resulted in classification of critical habitat for each local population into one of three states: maintain current conditions, improve current conditions, or assess resilience to further disturbance. The present assessment extends the 2008 approach and addresses several key areas of uncertainty in the earlier assessment. However, it does not represent a fundamental shift from the premise that range is the appropriate geographic delineation. Further, the amount of total disturbance within a range remains the primary criteria for identifying critical habitat to meet a goal of self-sustaining local populations of caribou.

Significant advances were made in the conceptual and methodological design that underpins this 2011 Scientific Assessment. The first advance consists of reconsideration of the ecological representation of the objective of self-sustaining populations. This resulted in explicit recognition of two components encompassed by this population objective statement – stable and increasing population growth and long term persistence. The 2008 Scientific Review approach applied an integrated methodology that *a priori* combined these two components into one measure labeled as persistence, represented using three, equally-weighted lines of evidence. In the present assessment, indicators were identified that clearly distinguished these components of self-sustainability. Where discrepancies among indicators arose, decision rules were applied to help understand causes and resolve differences within the integrated assessment. This approach yielded better information to guide recommendations than simple averaging of contributing values.

The second major advance was the development of a conceptual framework and methodology to identify range-specific, disturbance-based management thresholds and support their interpretations. In the 2008 Scientific Review, the final range assessment led to designations of range self-sustaining (SS), not self-sustaining (NSS), or either (NSS/SS), based on available information. The critical habitat identification derived from these designations was limited to general statements about the condition of a given range relative to where it should be to support a self-sustaining population. In this 2011 Science Assessment, guidance is provided for use of a disturbance-based population growth function in conjunction with range specific information to extend the critical habitat description for the consideration of disturbance-based management thresholds. The present assessment articulates the clear dependence of the identification of disturbance-based management thresholds on specification of acceptable risk by decision makers. Once defined, these analyses could support action planning by informing decisions around several key questions, such as; "is habitat recovery needed?"; "how much habitat recovery is needed?"; "is there potential for further development in a range?"; and "how much more development could be tolerated?" at the specified level of risk.

As part of the 2011 Scientific Assessment, a significant update to the meta-analysis of recruitment in relation to disturbance was also undertaken, to assess the relative impacts of different disturbance types, and the effects of measures of habitat quality and configuration, on the underlying relationship. Substantial improvements in disturbance mapping were undertaken to support these analyses. Analyses examining the effects of different assumptions about the functional zone of influence of disturbances were used to clarify relationships between caribou recruitment and habitat condition. The updated, combined disturbance model explained nearly 70% of the variation in estimated calf recruitment across the study areas included in the analyses, most of which could be attributed to the negative effects of anthropogenic disturbance. Little statistical support was found for decomposing anthropogenic disturbances into finer classes to improve the predictive power of the recruitment model. However, the negative effect of linear disturbances on caribou demography was greater than the negative effect of polygonal disturbances, consistent with the results of the resource selection analyses examining caribou use. Unfortunately, the assessment of recruitment response to the hypothesized interaction between the amount of high quality habitat remaining in a range and total disturbance was limited by the very coarse habitat quality information available for the national resource selection function model. Several of the recruitment models evaluated suggest that better understanding of potential regional variation in response, including refined habitat selection models, could enhance range-specific applications. As well, further investigation of the ways that spatial configuration of different disturbance types could influence caribou demography is recommended. Regardless, the overall national relationship between total disturbance and calf recruitment was robust.

The methods for assessing self-sustainability were extended through the use of enhanced population modelling which enabled estimation of continuous probabilities, rather than discrete categories, and more explicit inclusion of uncertainty in both parameter estimation and outcomes. Probabilities describe the expected state of a criteria based upon the evidence gathered (e.g., statistical evidence from similar cases, modelling evidence, or expert opinion), but should not be interpreted as a prediction. A given probability that a local population is stable or increasing represents a relative likelihood in realizing a desired outcome that decision-makers can use to inform assessment of risk and determine management actions. Accounting for uncertainty offers the potential for more proactive, precautionary and innovative decision responses to assessing recovery than might otherwise be possible. Assessing uncertainty is also consistent with the application of an adaptive approach to caribou recovery.

A sensitivity analysis conducted as part of the population modelling demonstrated that population trend predictions were strongly influenced by adult mortality rates. There is little available information on adult mortality rates across boreal caribou ranges in Canada, and what is available is biased with respect to disturbance (i.e., there are generally more data available for highly disturbed ranges). In this assessment, a national average for female adult survival, derived from available data, was used. While expert opinion indicated that this estimate was reasonable, derivation of a disturbance-dependent female adult survival rate relationship would increase the certainty associated with population trend predictions. This highlights the need for more extensive monitoring programs that include adult female mortality assessments.

In contrast to the 2008 Scientific Review, the use of a set of hierarchical decision rules to combine different lines of evidence about the ability of ranges to maintain self-sustaining populations accounted for the types and quality of data available for each range, and dictated the relative contribution of each factor (including time scale) to the integrated risk assessment. The relative certainty associated with the integrated assessment can be used to inform monitoring needs, as well as the types of recovery actions that might be appropriate**.**

Similar to the 2008 Scientific Review, this assessment of the effects of range condition on self-sustainability was based on composite measures of disturbance and indicators from demographic modelling. Integration of new information or different sources of information is possible within the same framework, with the decision rules expanded to explicitly weight these additional sources of information.

Simple models of the key boreal ecosystem dynamics (regeneration or recovery of disturbed areas and new disturbance by fire) were developed and provided as information to support consideration of range-specific disturbance thresholds. The use of this approach is consistent with the need to consider species recovery in the context of the extent and rate at which critical habitat may change in response to environmental factors. This represents a key component of a precautionary approach to the goal of self-sustainability.

Critical Habitat Description

The final critical habitat descriptions derived by application of the critical habitat framework, and informed by the components described above, are provided in fact sheets for each of the 57 ranges assessed. The elements of the critical habitat description for each range are:

- range boundary and location;
- integrated risk assessment;
- information to support identification and interpretation of range-specific disturbance thresholds; and
- bio-physical attributes of habitat within a range.

Range boundary and location

Ranges used in this assessment were delineated by local jurisdictions based on a variety of methods and types of data. Some range delineations are more robust than others based on the type and quantity of data available. Most ranges in Canada have not been fully described owing to a lack of standardized animal location data and poor understanding of movement between adjacent or nearby ranges. Several ranges were delineated as conservation units, because animal location data were insufficient to support delineation of a local population. In these cases, the assessment represents an assessment of the condition of the conservation unit to support a self-sustaining local population. In a number of cases, the current range boundaries also do not consider trans-boundary movement of caribou between jurisdictions. In the case of Quebec and Labrador, updated range delineation and demographic data were not provided, therefore the 2011 assessment was completed using the 2008 information as the best available. As new information is obtained, the capacity of ranges to support self-sustaining populations of caribou will have to be re-assessed**.** Addressing the need for more animal location and movement information, as well as greater inter-jurisdictional collaboration, are important requirements to more fully describe ranges for local populations of boreal caribou and support continuous improvement of critical habitat description over time.

Integrated Risk Assessment

Consideration of different lines of evidence resulted in a statement of likelihood for each range as to its current ability to support a self-sustaining population. Of the 57 ranges evaluated, 17 were assessed as likely or very likely to be self-sustaining (SS), 33 as unlikely or very unlikely to be self-sustaining (NSS), and seven ranges to be as likely as not be self-sustaining (NSS/SS). These results differ from those presented in the 2008 Scientific Review for nine ranges.

In the present evaluation, the use of decision rules rather than averaging of probabilities across all indicators resulted in evidence with higher certainty carrying greater weight in the integrated assessment. As well, population size could override the population growth indicators, recognizing the additional risks associated with small populations. This consideration resulted in one range moving from SS (2008) to NSS/SS (2011). In the remaining eight cases, the habitat-based population growth indicator carried more weight than population information, either because no population information was available or a general population trend was reported that was inconsistent with the habitat-based indicator. Four of these ranges were in Saskatchewan, where total disturbance placed the ranges in NSS (as compared to NSS/SS in 2008). Population trend was not available. However, a large proportion of the disturbance was fire, thus it is possible that improved demographic data may suggest that the ranges are currently supporting self-sustaining populations. The weight of evidence of the remaining four ranges with different assessments from 2008 was placed on the habitat indicator of population growth due to the lack of population data; this resulted in a more optimistic assessment in two cases and a more pessimistic assessment in the other two cases. Again, improved demographic data may suggest a different outcome for these ranges, however in these last four cases total disturbance was not dominated by fire.

Additional changes to range assessment outcomes at the national level were a result of new range delineations including 1) Ontario, where eight new ranges were delineated, including the combination of three ranges from the 2008 assessment, and 2) NT, where two ranges are recognized for the 2011 assessment, as compared to six management units assessed in 2008.

A designation of "not self-sustaining" should not be interpreted as a conclusion that a range cannot be recovered, or that the local population cannot be maintained. The current range assessment does not explore the potential for recovery of a range through the application of management activities designed to mitigate disturbance or accelerate recovery, but rather it provides the likelihood of a range supporting a self-sustaining population given the current amount of total disturbance and the current condition of the population. The integrated risk assessment further supports critical habitat description by providing information used to locate each range within intervals of disturbance associated with varying levels of risk (see threshold discussion below).

Many ranges lack information on population trend and population size, which forced a reliance on estimated population trend based on the habitat indicator, and prevented the assessment of extinction risk where population size was unknown. There is an urgent need to implement monitoring and assessment programs for these ranges, as well as to continue monitoring programs where they currently exist.

Range Specific Disturbance Thresholds

For the lines of evidence approach used in this assessment, habitat condition was a primary indicator related to the recovery criteria of stable or positive population growth, and is presented as the starting point for considering range specific management thresholds related to critical habitat. The intervals associated with each likelihood statement reflect a range of indicator values, consistent with a probabilistic representation of risk relative to the information considered. The assignment of relative risk is informed by science but its qualitative interpretation reflects the acceptance of varying levels of certainty in desired outcome. Further, the probability intervals themselves could be altered to express different breakpoints in desired certainty. In recognition that level of acceptable risk must be specified by managers, range- specific disturbance thresholds were not identified for each of the 57 ranges. However, a consistent methodology for determining range-specific disturbance thresholds is presented and examples of the application of the approach provided.

The disturbance intervals associated with the generalized relationship between range condition and population growth reflect variability in expected outcomes based on patterns evident at a national scale. Consistent with the integrated risk assessment, other indicators related to recovery criteria, also expressed relative to risk or likelihood of desired outcome, are used to refine interpretation of thresholds at a range-level. This approach can be further extended to consider potential future conditions. To this end, future range condition projections are provided for each range for consideration in the interpretation of range specific management thresholds. The projections were restricted to simple models of effects of additional natural disturbances (fire only) and passive recovery from both natural and anthropogenic disturbances. Interpretation of the results of the future range condition projections supports the need for greater (or lesser) caution in the determination of range specific disturbance thresholds, and the urgency for management actions to offset the risk of local extinction. The future condition models applied here do not, however, integrate additional anthropogenic disturbance. The model framework could be used for this purpose but projecting future anthropogenic developments was beyond the scope of this assessment.

In general, the less information available, the less certainty there will be in outcomes, and the more precautious the management approach should be with respect to conservation. Multiple lines of evidence that suggest similar outcomes create greater certainty, as does high quality information. Certainty in outcome is the principal measure recommended for range-specific refinement of disturbance thresholds relative to acceptable risk.

Bio-physical Attributes

The general biophysical attributes of woodland caribou habitats have been reasonably well-studied in much of Canada. However, given that use of features can vary depending on their relative availability, and also across ecological regions, it is important to understand attributes of potential significance within each range. Clearly some generality is possible, for example, with respect to habitats supporting ground and arboreal lichens, but most attributes have been found to vary across caribou distribution (e.g., Thomas and Gray 2002). Certain habitat components and the response by caribou remain poorly understood, including forage availability and diet selection, while others such as the significance of large expanses of bogs and old upland conifer are well documented. The bio-physical attributes provided for each range in this science assessment should be considered as a starting point and should be augmented with more detailed and range specific information from jurisdictions and other information sources, such as Aboriginal Traditional Knowledge (ATK), at the recovery strategy and action planning stage.

Application of the Science Assessment to Boreal Caribou Recovery

The focus for this science assessment was the provision of a scientific description of critical habitat for each boreal caribou range to inform critical habitat identification in the National Recovery Strategy. However, the range assessment and associated modelling results will also be useful at the action planning stage, by providing an evaluation of the status of range conditions relative to critical habitat requirements, and therefore informing the need for, and urgency of, management actions. The conceptual approach

and modelling tools can also be applied to the evaluation of effective protection of critical habitat, as part of recovery and action plan implementation.
The future condition modelling completed in this science assessment provides general trend information for future disturbance conditions given natural disturbance patterns and passive recovery rates for a range. The primary application of this information was to inform the threshold interpretation (as described above) as a component of critical habitat identification, as well as to indicate management urgency in cases where current conditions were not sufficient to support a self-sustaining population. There was no attempt to integrate prediction of future development or management activities designed to accelerate the time to recovery for specific disturbance types. However, the tools for modelling future conditions were developed as a flexible framework to support action planning through the assessment of management scenarios. The integration of the habitat model with the population model can be used as a decision support tool for exploring population response to additional development and/or habitat recovery activities, thus providing an assessment of the probability of maintaining or achieving range conditions required to support self-sustaining populations. The population model also allows manipulation of population parameters based on information (if available) that quantifies changes in, for example, recruitment and/or adult survival in response to management actions that are not targeted at habitat changes (e.g., predator control).

A National Assessment – Strengths and Limitations

Like the 2008 review, the 2011 assessment is a national assessment designed to ensure a consistent methodology is applied to boreal caribou ranges across Canada. For example, to ensure consistent data inputs for disturbance mapping for the meta-analysis and assessment of each of the 57 ranges, data sources were utilized that were available across all boreal caribou ranges. Analyses undertaken using different data sources may yield different total disturbance results. Similarly, the resource selection analysis utilized variables describing land cover that were standardized across the distribution of boreal caribou in Canada. A nationally consistent approach allows for direct comparison of results across all areas considered, and when evaluating relationships, permits inclusion of data covering a broader range of conditions than available at narrower extents, such as regional scales. As such, it improves the identification and understanding of general relationships, where they exist. The robustness of the national meta-analysis of the relationship between caribou calf recruitment and total disturbance supports the strength of this approach. However, while this provides a strong foundation for this assessment, additional demographic and habitat information can significantly augment current understanding, particularly where uncertainty is high.

Application of Adaptive Management

The related goals of assessing the self-sustainability of ranges, and establishment of management thresholds for disturbance, must both acknowledge uncertainties resulting from availability and reliability of information about current population condition, as well as from limited knowledge about how populations will respond to additional and often interacting stressors. The probabilistic approach taken in this assessment, together with the application of a set of decision rules that relate the contribution of the information in each indicator to the strength of evidence about whether ranges are likely to maintain a self-sustaining local population, explicitly incorporates effects of uncertainties and data quality in the assessment process. This approach is consistent with the concept of adaptive management, which expresses likelihood (certainty) of outcomes as hypotheses. Disturbance thresholds and associated management actions are then implemented as carefully-designed experiments to reduce uncertainty and improve knowledge over time. A particular focus is to identify and avoid actions that carry a high risk of unintended outcomes or irreversible harm. Under this approach, substantial gains in knowledge can accrue from coordinated management and monitoring activities, or learning by doing, if the commitment to those activities remains strong.

The process of adaptive management can be represented as a continuous learning cycle, involving the key components of planning, doing, evaluating and adjusting (Figure 19). Associated with each of these are a number of activities to support the identification and reduction of uncertainties, in order to improve decision-making (e.g., the application of management thresholds). Central to the concept is the close integration of management, research and monitoring, where systems are not only carefully monitored, but management responses are nimble enough to change course in response to the weight of evidence. Adaptive management involves controlled management experiments guided by current understanding of system dynamics. Highly uncertain outcomes associated with different policy options become strong candidates for experimentation. The results of experiments are then used to inform adjustments to management strategies as necessary, in light of improved understanding.

Implementation of disturbance thresholds for caribou through active adaptive management could yield the greatest knowledge gains by prescribing a range of recovery actions and development activities, at varying levels of risk, in a way that does not preclude future management options. The range of current conditions across boreal caribou local populations suggests that sufficient contrast exists to support this approach. Where certainty in the likelihood of outcomes is high, the policy options are clearer relative to risk. However, there exists an intermediate range of disturbance levels over which outcomes for caribou local populations are highly uncertain. Understanding what factors contribute, and why, to a more or less desirable outcome with respect to caribou conservation, would significantly improve management effectiveness and reduce risk.

In conclusion, the purpose of this 2011 Scientific Assessment was to inform the description of critical habitat for a federal recovery strategy for boreal caribou in Canada by assessing the ability of current boreal caribou ranges to support self-sustaining local populations. The approach and framework developed for this assessment built upon and extended that presented in Environment Canada's 2008 *Scientific Review for the Identification of Critical Habitat for Woodland Caribou (Rangifer tarandus caribou), Boreal Population, in Canada*. While improved data and enhanced understanding would help address remaining uncertainties as a component of adaptive management, this report concludes that sufficient information exists to support a scientifically-grounded assessment of critical habitat for populations of boreal caribou across Canada, and provides a scientific description of critical habitat for each of the 57 identified ranges that comprise the full extent of occurrence of boreal caribou in Canada.

The breadth of information and knowledge compiled for this assessment exemplifies the comprehensive nature of, and interrelationships between, types of evidence available to provide a scientifically-based description of critical habitat for informing recovery planning for boreal caribou. Significant advances were made to the conceptual and methodological design during this assessment to address some key uncertainties or limitations identified in the 2008 Scientific Review. These advances improved the robustness of the results with respect to providing a scientific description of critical habitat for boreal caribou across Canada.

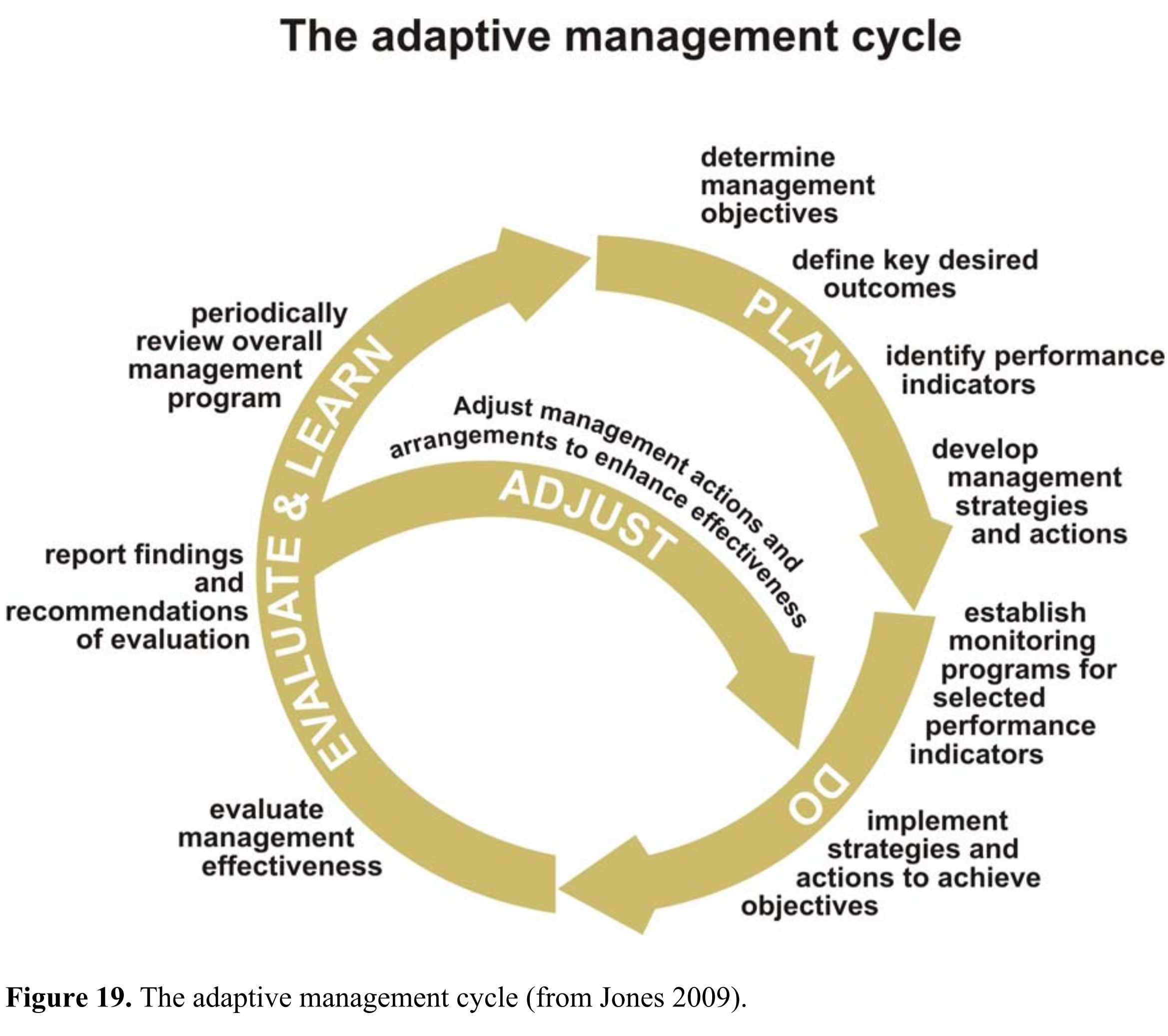


Figure 19. The adaptive management cycle (from Jones 2009).

5 ACKNOWLEDGMENTS

This report is founded on the extensive body of scientific research conducted by provincial, territorial and federal jurisdictions, academia and non-governmental organizations. The outcome is a testimony to the on-going dedication, enthusiasm and collaboration amongst experts involved directly or indirectly in the recovery of boreal caribou in Canada.

Specifically, the work presented in this report greatly benefited from guidance, advice, and reviews provided by the following science advisors: Dr. Fiona Schmiegelow (Chair), Dr. Vince Crichton, Dr. Marie-Josée Fortin, Dr. Daniel Fortin, Dr. Mark Hebblewhite, Mr. Dave Hervieux, Dr. Nicholas (Nic) Larter, Dr. John Nagy, Dr. Tom Nudds, Dr. Richard Pither, Mr. Gerry Racey, Dr. Justina Ray, Dr. Jim Schaefer, Dr. Dale Seip, Dr. Ian Thompson, Mr. Tim Trottier.

EC is also grateful to the *Boreal Caribou Science Management Committee*, responsible for providing strategic direction and overall coordination of the development of the report. The group also acted as the core writing team and editorial body for the report and underlying documents. It was composed of: Ms. Cathy Nielsen (Chair), Mr. Stephen Virc (Co-Chair), Mr. Jason Duffe, Dr. Cheryl Johnson, Mr. Christian Malouin, Dr. Fiona Schmiegelow, Dr. Glenn Sutherland, Dr. Ian Thompson. Previous members: Dr. David Browne and Mr. Dean Nernberg.

The contribution of Ms. Jean Polfus and Dr. Mark Hebblewhite for leading the development of the habitat selection analyses and resulting report was also greatly appreciated.

A number of individuals also contributed in various capacities throughout the development of the project, as follows:

Geomatics and mapping: EC/National Wildlife Research Centre Geomatics lab (Ms. Rebecca Baker, Ms. Bhavana Chaudhary, Mr. Thomas Giles, Ms Jeannine Paquette, Dr. Jon Pasher, Mr. Chris Patterson, Mr. Evan Seed, Ms. Valerie Torontow, Ms. Huili Wang) and Global Forest Watch Canada (Ms. Colleen Curan, Mr. Matthew Hanneman, Mr. Peter Lee).

Administrative: Ms. Aileen-Marie Schatz and Ms. Doris Aoun

Participation in workshops, analytical support and other expertise: Ms. Melissa Vance, Mr. Paul Johanson, Ms. Kim Lisgo, Ms. Jean Polfus, Mr. Robert Jagodzinski, Ms. Sue Cotterill, Mr. Pierre Vernier.

Finally, this work would not have been possible without the jurisdictions and organizations involved in boreal caribou recovery that shared their wealth of boreal caribou data. They consisted of: Government of the Northwest Territories (Environment and Natural Resources), Ministry of Environment of British Columbia, Alberta Sustainable Resource Development, Alberta Caribou Committee, Saskatchewan Environment, Manitoba Conservation, and Ontario Ministry of Natural Resources.

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