Environment Canada Environnement Canada

Scientific Review

for the Identification of Critical Habitat for Woodland Caribou *(Rangifer tarandus caribou)*, Boreal Population, in Canada

Canada

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

978-1-100-10680-9
En14-7/2008E-PDF

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Preface

The *Scientific Review for the Identification of Critical Habitat for Woodland Caribou (*Rangifer tarandus caribou*), Boreal Population, in Canada* was initiated to inform the development of a recovery strategy for this population of caribou. Although the review provides an analysis of the state of knowledge of boreal woodland caribou habitat and proposes a framework to support decision making, it does not provide enough guidance as to the amounts or spatial distribution of habitat disturbance that can be tolerated. Further, it has not incorporated Aboriginal traditional knowledge in a systematic way. The information provided is inadequate to enable the identification of critical habitat. Environment Canada is committed to identifying critical habitat for the boreal caribou in the recovery strategy. To that end, a series of western science studies are planned. These studies will form the basis, with other landscape information, to identify critical habitat. Expected completion date for this work is December 2010.

These western science studies will be informed by Aboriginal traditional knowledge that Environment Canada plans to collect through a series of regional workshops with Aboriginal peoples, culminating in a national workshop. The goal of these workshops will be to inform recovery planning and implementation. Environment Canada will work closely with national Aboriginal organizations to develop and hold these workshops.

Environment Canada is also planning consultations on key elements of a recovery strategy, including recovery goals and objectives, potential threat mitigation activities including land management regimes, industry best management practices, Aboriginal traditional practices, and other potential recovery activities. Consultation activities will include provinces and territories, wildlife management boards, Aboriginal groups, environmental non-governmental organizations, industry associations, and the public.

It is planned that the recovery strategy will be released in 2011. While these various streams of work are underway to inform its development, the information gathered to date on populations and threats will be widely shared to enable land managers to prudently manage the landscape in the interim.

Regular updates on progress of the work described above will be provided on the SARA Public Registry.

Scientific Review for the identification of Critical Habitat for Woodland Caribou (*Rangifer tarandus caribou*), Boreal Population, in Canada

EXECUTIVE SUMMARY

Woodland Caribou (*Rangifer tarandus caribou*), Boreal Population (herein referred to as boreal caribou), are formally listed as Threatened under the federal *Species at Risk Act (SARA)*. The Act requires the Minister of Environment to prepare a Recovery Strategy for the species that includes, to the extent possible and based upon the best available information, an identification of its Critical Habitat and/or, if there is insufficient information available, a Schedule of Studies to determine that information. In August 2007, Environment Canada (EC) launched a science-based review with the mandate to identify Critical Habitat to the extent possible, using the best available science and/or prepare a Schedule of Studies.

This science-based review was framed as one of transparent decision-analysis and adaptive management. Thus, the Schedule of Studies produced is a key requirement of the process, designed to produce continuous improvement of results over time. The proposed Critical Habitat Identification for the spatial units associated with each boreal caribou local population is based on available quantitative data and published science, and the assumptions associated with the methodology applied. Other factors, such as the incorporation of Aboriginal traditional knowledge, and the extent to which assumptions taken in this report align with Environment Canada policy directives on Critical Habitat, may influence any potential final identification of Critical Habitat in the National Recovery Strategy.

Leading experts in landscape ecology, caribou biology, spatial habitat modeling, and population analysis were engaged to provide scientific advice on the identification of Critical Habitat for boreal caribou. Of these leading experts, 18 were part of a formal Science Advisory Group established to provide EC ongoing peer review throughout the process. An expanded group of experts contributed to the science review through a workshop held in Toronto in November 2007. A set of guiding principles was established to clearly identify the fundamental elements of the evaluation process.

SARA S.2 defines Critical Habitat as "*... 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 a recovery strategy or in an action plan for the species.*" As such, to identify Critical Habitat (CH), a recovery target must first be established. In this case, the target was expressed in the draft *National Recovery Strategy for Boreal Caribou* (Environment Canada, 2007) and provided to the EC team leading the science review. By definition therefore, for the purposes of the CH science review the Recovery Goal was that : "*boreal caribou are conserved and recovered to self-sustaining levels, throughout their current distribution (extent of occurrence) in Canada*"; and the more specific Population and Distribution Objective was: "*to maintain existing local populations of boreal caribou that are self-sustaining and achieve population growth of local populations that are not currently self-sustaining, to the extent possible, throughout the current distribution (extent of occurrence) of boreal caribou in Canada*."

Critical Habitat for boreal caribou was therefore defined as the resources and environmental conditions required for persistence of local populations of boreal caribou throughout their current distribution in Canada. Identifying Critical Habitat for local populations was framed as an exercise in decision analysis and adaptive management. Establishment of a systematic, transparent and repeatable process was a central element of the approach. The report is structured around three major questions to be addressed in the identification of critical habitat: 1) What is the current distribution of boreal caribou in Canada; 2) Where are the local populations within the current distribution of boreal caribou in Canada; and 3) What habitat conditions are required for persistence of local populations of boreal caribou in Canada?

Consideration of scale is fundamental to identifying the resources and environmental conditions required for persistence of local populations of boreal caribou throughout their current distribution. 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, 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 local population ranges affect the demography of boreal caribou (e.g., survival and reproduction), which ultimately determines whether or not a population will persist. Therefore, in context of the Recovery Goal for this species, **local population range is the relevant spatial scale for the identification of critical habitat that includes the habitat conditions (quantity, quality and spatial configuration) required by caribou.** This is not equivalent to saying that every element within the range is critical to support a self-sustaining boreal caribou population, in all instances. However, it does provide a spatial delineation of the area of consideration when assessing the current conditions and quantifying risk relative to the recovery goal of maintaining or restoring self-sustaining local populations, for assigning potential Critical Habitat outcomes, and for planning for the management of the habitat conditions necessary to support population persistence (e.g. maintaining the functional attributes of the range).

General conclusions from the review include:

1) Critical Habitat for boreal caribou is most appropriately identified at the scale of local population range, and expressed relative to the probability of the range supporting a self-sustaining local population;

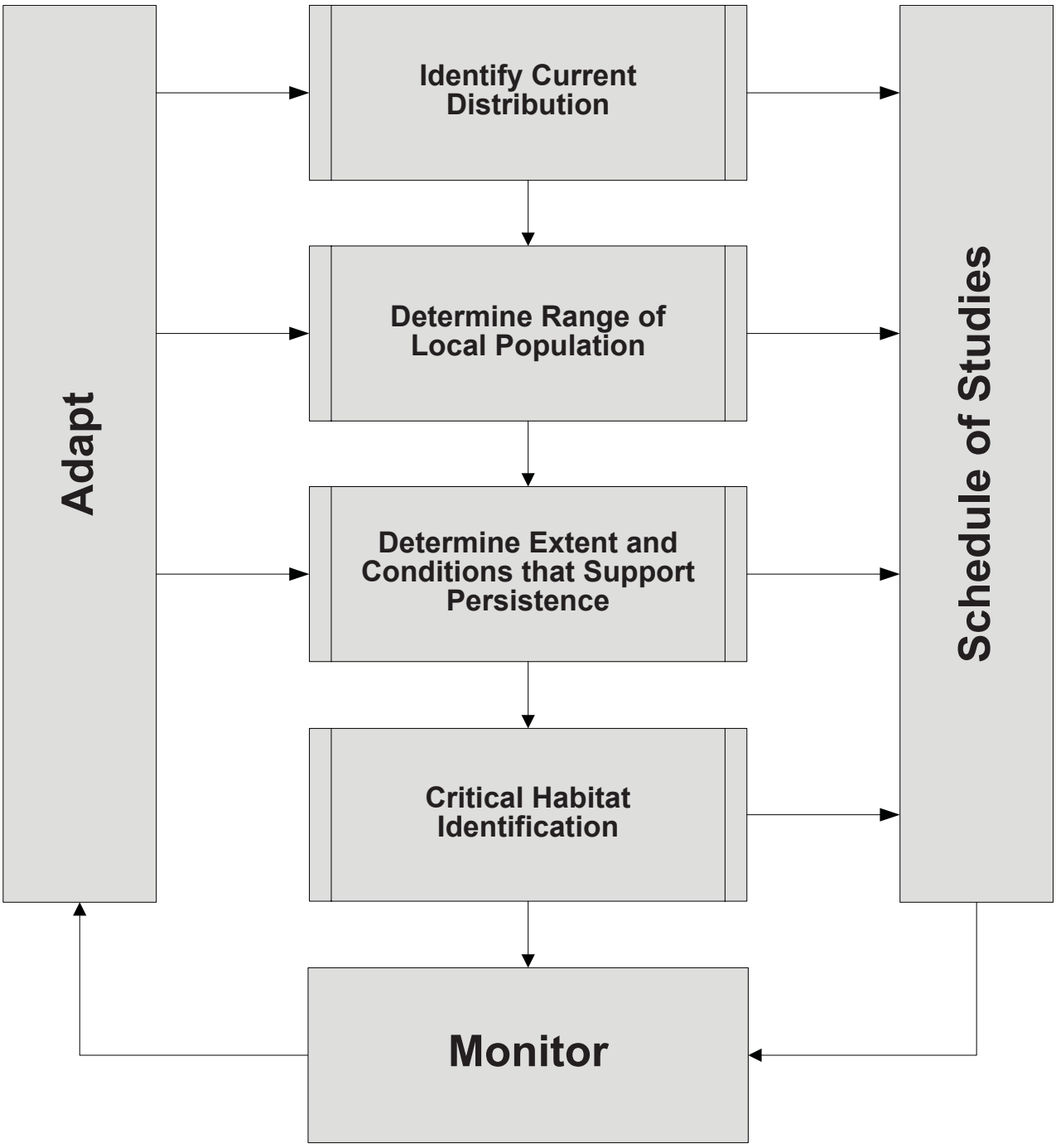
2) Range is a function of the extent and condition of habitat, where habitat includes the suite of resources and environmental conditions that determine the presence, survival and reproduction of a population;

3) Application of the Critical Habitat Identification Framework, for the 57 recognized local populations or units of analysis for Boreal caribou in Canada, yielded 3 proposed outcomes: Current Range, Current Range and Improved Conditions, or Current Range and Consider Resilience;

4) Like habitat selection by caribou, 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 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, present findings should be monitored and assessed for the purposes of refinement and adjustment over time, as new knowledge becomes available (e.g., a Schedule of Studies as part of Adaptive Management).

A major product of this science review is a Critical Habitat Framework that can support decision analysis, focus future research efforts, and frame critical habitat identification in the context of adaptive management (Executive Summary Figure 1). It was anchored by synthesis and analysis of available quantitative data and published scientific information on boreal caribou population and habitat ecology, including population distribution, trends, habitat use, and conditions for persistence. Aboriginal knowledge was considered when accessible in published documents. However, a separate process to gather Aboriginal traditional knowledge was not undertaken as part of this review. The Framework was structured around the major questions identified above, and designed to incorporate the important stages of adaptive management. Application of the framework and associated decision analysis involved clear identification of knowledge gaps, necessary assumptions, and key uncertainties throughout the process, which were directed to a Schedule of Studies, as appropriate. As in any adaptive management framework, its strength lies not only in its specific output(s) at a given time, but its ability to accommodate different assumptions or new data, including but not limited to Aboriginal and Traditional Knowledge, that can be used in the framework to yield continuously improved outputs.



Executive Summary Figure 1: Critical Habitat Framework

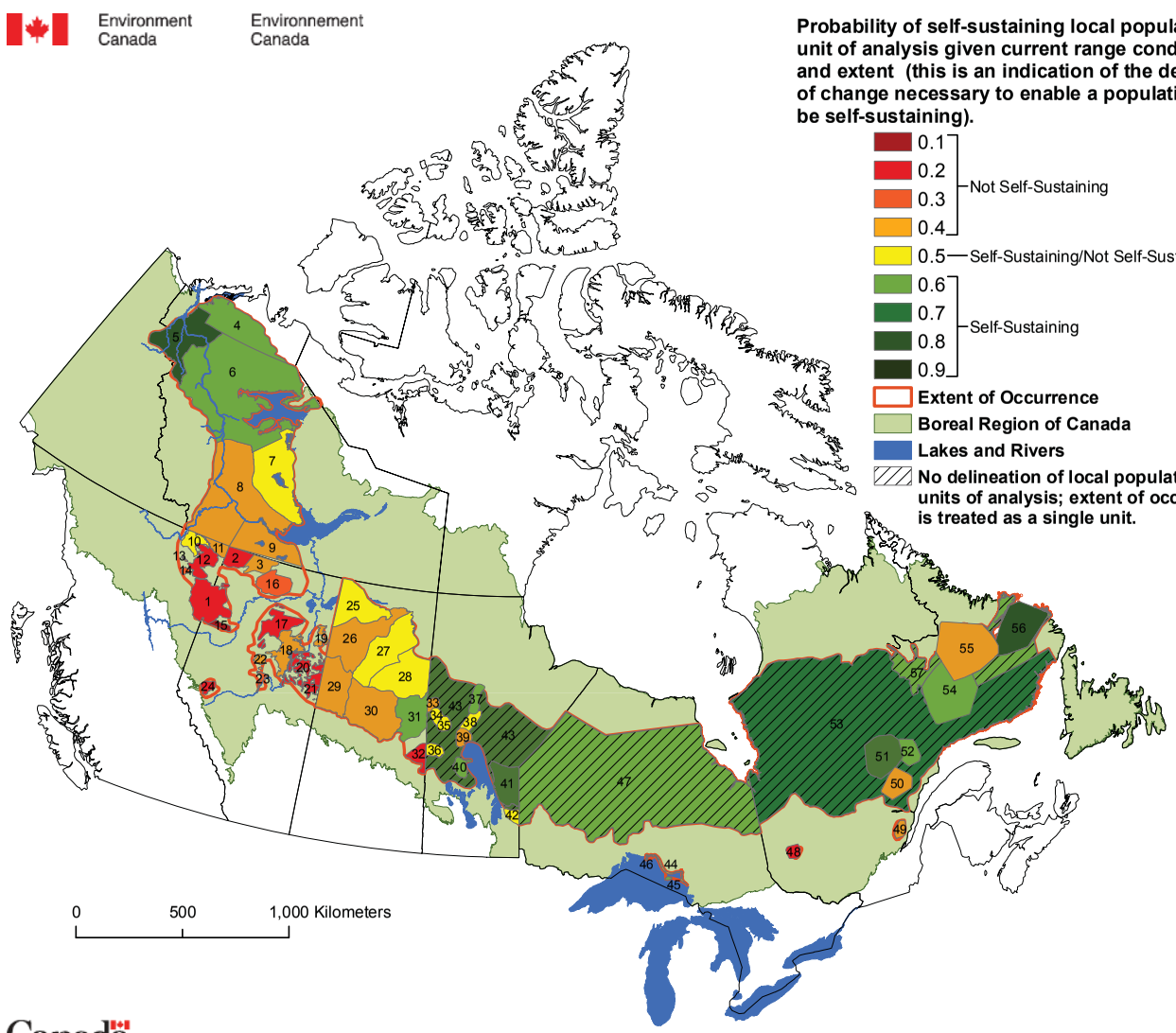
The first step in application of the Critical Habitat Framework was to determine the current distribution of boreal caribou across Canada, in order to define the national scope of Critical Habitat Identification. Information from the National Recovery Strategy for Boreal Caribou was used for the present delineation, but an environmental niche analysis was also undertaken to identify areas of uncertainty and guide future refinements of the distribution.

The second step of the Critical Habitat Framework was delineating units of analysis within the current distribution. The population and distribution objective of the draft National Recovery Strategy specify local populations as the appropriate unit of analysis with respect to the recovery goal. Local population ranges are the spatial delineation of this analysis unit. Information on local population ranges was compiled from jurisdictions across the current distribution. Where local populations were part of a continuous distribution, or had not been defined, units of analysis encompassing the extent of occurrence of caribou within the regions were delineated.

The third step in the Critical Habitat Framework determined the habitat required for persistence of boreal caribou local populations through assessment of measurable criteria of population and habitat condition for each local population range. Three measurable criteria related to persistence probability were assessed: 1) *population trend*, an indicator of whether a population is self-sustaining over a relatively short measurement period; 2) *population size*, an indicator of the ability of a population to withstand stochastic events and persist over the long-term; and 3) *range disturbance*, an indicator of the ability of a given range to support a self-sustaining local population.

These three criteria -- population trend, population size and range disturbance -- represent three lines of evidence used to evaluate local population ranges relative to their potential to support self-sustaining populations. Empirically based, categorical states were defined for each criteria: Population trend was either Declining, Stable, Increasing or Unknown; Population size categories were Very Small, Small, or Above Critical, based on a non-spatial population viability analysis; and Disturbance categories were Very Low, Low, Moderate, High or Very High, based on a national meta-analysis of boreal caribou demography and range disturbance. A probability of local population persistence was associated with each categorical state, for each criterion. Categorical states were then assigned to each local population based on available data, then combined in an integrated assessment to determine whether the weight of evidence supported a conclusion of the current range being sufficient or not sufficient to support a self-sustaining local population. Results of this evaluation are presented in Executive Summary Figure 2.

The fourth step in the Critical Habitat Framework was the proposed identification of Critical Habitat, based on the results of the assessment of the probability of the current range supporting a self-sustaining local population. The assessment was translated to proposed Critical Habitat Identification following a set of decision rules, and expressed as the range condition and/or extent required relative to current range condition and extent. Potential outcomes for each local population or unit of analysis included: Current Range - current range condition



Number	Local Population/Unit of Analysis	Integrated Probability
1	AB/BC Chinchaga	0.2
2	AB/NWT Bistcho	0.2
3	AB/NWT Steen River/Yates	0.4
4	NWT Inuvialuit	0.6
5	NWT/YK Gwich'in	0.8
6	NWT Sahtu	0.6
7	NWT North Slave	0.5
8	NWT Dehcho (N/SW)	0.4
9	NWT South Slave/SE Dehcho	0.4
10	BC Maxhamish	0.5
11	BC Calendar	0.4
12	BC Snake Sahtaneh	0.2
13	BC Parker Core	0.4
14	BC Prophet Core	0.3
15	AB Deadwood	0.1
16	AB Caribou Mountains	0.3
17	AB Red Earth	0.2
18	AB West Side Athabasca River	0.4
19	AB Richardson	0.4
20	AB East Side Athabasca River	0.2
21	AB Cold Lake Air Weapons Range	0.2
22	AB Nipisi	0.4
23	AB Slave Lake	0.3
24	AB Little Smoky	0.2
25	SK Daw-Athabasca	0.5
26	SK Clearwater	0.4
27	SK Highrock-Key	0.5
28	SK Steephill-Foster	0.5
29	SK Primrose-Cold Lake	0.4
30	SK Smoothstone-Wapawekka	0.4
31	SK Suggi-Amisk-Kississing	0.6
32	SK Pasquia-Bog	0.2
33	MB Kississing	0.4
34	MB Naosap	0.5
35	MB Reed	0.5
36	MB The Bog	0.5
37	MB Wapisu	0.6
38	MB Wabowden	0.5
39	MB William Lake	0.4
40	MB North Interlake	0.6
41	MB Atikaki-Berens	0.7
42	MB Owl-Flintstone	0.5
43	Manitoba	0.7
44	ON North East Superior	0.4
45	ON Michipicoten	0.6
46	ON Slate Islands	0.6
47	Ontario	0.6
48	QC Val d'Or	0.2
49	QC Charlevoix	0.4
50	QC Pipmuacan	0.4
51	QC Manouane	0.7
52	QC Manicouagan	0.6
53	Quebec	0.7
54	LAB Lac Joseph	0.6
55	LAB Red Wine Mountain	0.4
56	LAB Mealy Mountain	0.8
57	Labrador	0.6

Executive Summary Figure 2: Probability that current range will support a self-sustaining population of boreal caribou, based on integrated probability assignments that considered population trend and size, and level of disturbance associated with anthropogenic activities and fire (see Section 2.6.5). This Figure is not an illustration of whether a population is recoverable or not, rather, it is an indication of the degree of habitat change necessary to enable a population to be self-sustaining (e.g. to persist without the need for ongoing management intervention).

and extent are required to maintain potential for self-sustaining population; Current Range and Consider Resilience – current range condition and extent may be sufficient to absorb additional disturbance while maintaining capacity to support a self-sustaining population; Current Range and Improved Conditions – current range condition and/or extent would need to be improved to restore potential to support a self-sustaining population.

The resultant proposed Critical Habitat identification for the 57 recognized local populations or units of analysis considered was:

- Current Range for 25 local populations or units of analysis;
- Current Range and Improved Conditions for 21 local populations or units of analysis;
- Current Range and Consider Resilience for 11 local populations or units of analysis.

Further elaboration of Critical Habitat outcomes for local populations can be achieved through spatial population viability analysis linked with dynamic landscape modelling (see Section 2.6.6 and Appendix 6.7). Incorporation of landscape dynamics is necessary to understand the conditions and management options associated with recovery (Current Range and Improved Conditions) and resilience (Current Range and Consider Resilience), as well as additional risks associated with present conditions (Current Range). Such evaluations may be undertaken with varying levels of complexity and concomitant requirements for data. It is clear from the present review that minimum data requirements could be met for most areas within the current distribution of boreal caribou in Canada, particularly when viewed in the context of adaptive management.

Application of the Critical Habitat Framework provided an assessment of all local populations or units of analysis within the current distribution of boreal caribou in Canada. Like habitat selection by caribou, critical habitat identification is a hierarchical process that must consider needs across multiple spatial and temporal scales. The national evaluation focused on the scale most appropriate for considering the persistence of local populations – the local population range. Consideration of components of critical habitat at finer scales is possible where local population information can be augmented.

In summary, this review was based on a set of guiding principles and undertaken by Environment Canada with the support of an expert Science Advisory Group that provided continuous peer-review. Development of a Critical Habitat Framework provided a formal structure for assembling and analyzing data relevant to Critical Habitat identification, and the foundation for continuous improvement of knowledge through the process of adaptive management. A weight of evidence approach was used to identify the most plausible outcome of combinations of population and habitat conditions relative to the recovery goal of self-sustaining local populations.

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1.0 INTRODUCTION

1.1 Background

The Woodland Caribou (*Rangifer tarandus caribou*), Boreal Population (herein referred to as boreal caribou), was last assessed in May 2002 as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Boreal Caribou were added to Schedule 1 of *Species at Risk Act (SARA)* and in accordance with *SARA*, the Minister of the Environment must prepare a Recovery Strategy for this species that includes an identification of its Critical Habitat (CH) and/or if there is insufficient information available, a Schedule of Studies to determine that information. A National Recovery Strategy for boreal caribou was due for posting on the SARA Public Registry by June 5, 2007. The identification of CH is a key element of posted Recovery Strategies on the SARA Public Registry (SARA S. 41 (1) (c)).

In February 2002, a National Boreal Caribou Technical Steering Committee, represented by the 10 jurisdictions involved in the recovery of the boreal caribou, was established to develop a National Recovery Strategy for Boreal Caribou. A draft strategy was completed in June 2007 and tabled as advice to all 10 jurisdictions that are responsible for caribou. Earlier drafts of the National Recovery Strategy documented extensive deliberations on the concept of Critical Habitat for boreal caribou (see also Racey and Arsenault 2007). Critical Habitat was not identified in the final draft National Recovery Strategy.

In August 2007, Environment Canada (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 to support its identification. To complete this task, EC established an internal management team to conduct the review, and to compile and analyze all information relevant to this initiative. Environment Canada also engaged leading experts in landscape ecology, caribou biology, spatial habitat modeling, and population analysis to provide scientific advice in the identification of Critical Habitat for boreal caribou. Of these leading experts, 18 were part of a Science Advisory Group (SAG) mandated to provide ongoing peer review throughout the process (see Appendix 6.1 for list of SAG members). An additional group of experts participated in the science review during a 2-day workshop held in Toronto on November 19-20, 2007. This report is the product of the full scientific review.

2.0 METHODOLOGY

2.1 Framing the Critical Habitat Question for Boreal Caribou

2.1.1 SARA: Critical Habitat

SARA Section 2 defines Critical Habitat as "... 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 a recovery strategy or in an action plan for the species."
Note : SARA does not limit Critical Habitat identification to the habitat that is currently occupied by the species at risk.

2.1.2 National Recovery Strategy

To identify Critical Habitat, a recovery target must be established. This target is qualitatively expressed in the draft National Recovery Strategy for boreal caribou through the following Recovery Goal and Population and Distribution Objective:

Recovery Goal:
Boreal caribou are conserved and recovered to self-sustaining levels, throughout their current distribution (extent of occurrence) in Canada.

Population and Distribution Objective:
Maintain existing local populations of boreal caribou that are self-sustaining and achieve population growth of local populations that are not self-sustaining, to the extent possible, throughout the current distribution (extent of occurrence) of boreal caribou in Canada.
Note: "To the extent possible" appears in the population and distribution objective in recognition that technical and biological feasibility may affect the probability of conserving and/or recovering some individual local populations as described in the draft National Recovery Strategy for boreal caribou (Environment Canada 2007).

2.2 Definitions

The following definitions were established for the Boreal Caribou Critical Habitat Science Review. Development of these definitions was supported by the 2002 COSEWIC Status Assessment and 2007 draft National Recovery Strategy for boreal caribou (Environment Canada 2007), a review of relevant scientific work, and consultation with the Science Advisory Group for the review.

2.2.1 Current Distribution (Extent of Occurrence):

The area included in a polygon that encompasses the geographic distribution of all known local populations of boreal caribou (COSEWIC - Adapted from IUCN 2001), based on provincial and territorial distribution maps developed from observation and telemetry data, local knowledge (including in some cases Aboriginal and Traditional Knowledge), and biophysical analyses. The area may contain unsuitable or unoccupied habitats (see Appendix 6.2 for explanation of time frame for "Current").

2.2.2 Local Population:
A group of caribou occupying a defined area distinguished spatially from areas occupied by other groups of caribou. Local populations experience limited exchange of individuals with other groups, such that population dynamics are driven primarily by local factors affecting birth and death rates, rather than immigration or emigration among groups (see Appendix 6.2).

2.2.3 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).

2.2.4 Self-Sustaining:
A local population of boreal caribou that on average demonstrates stable or positive population growth ($\lambda \geq 1.0$) over the short term, and is large enough to withstand stochastic events and persist over the long-term, without the need for ongoing intensive management intervention (e.g. predator management or transplants from other populations).

2.2.5 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 extinction risk. The IUCN criterion for classifying species as Vulnerable (equivalent to COSEWIC's Threatened category) is a risk of extinction ≥10% over 100 years (SSC 2001).

2.2.6 Range:
A geographic area occupied by individuals of a local population that are subjected to the same influences affecting vital rates over a defined time frame (see Appendix 6.2: Delineating Units of Analysis for Boreal Caribou Critical Habitat Identification). Range is a function of both spatial extent and habitat conditions.

2.2.7 Critical Habitat:
The resources and environmental conditions (habitat as per Section 2.2.3) required for persistence of local populations of boreal caribou throughout their current distribution in Canada. The quantity, quality and spatial configuration of resources and conditions may be influenced by both natural and human-induced factors.

2.3 Critical Habitat Identification Framework for Boreal Caribou

A *Critical Habitat Identification Framework for Boreal Caribou* (here referred to as the Framework) was developed to support a consolidated, scientifically defensible identification of Critical Habitat for boreal caribou and a complementary Schedule of Studies. The Framework is not the sole product but rather a logic model to support the process. Development of the Framework was informed by Critical Habitat identification approaches applied in Canada and elsewhere. Its systematic and transparent structure enables decision-analysis within the context of adaptive management. The approach was anchored by analysis and synthesis of available quantitative data and published scientific information of population and habitat ecology as well as boreal caribou population distribution, trends, habitat use, and conditions for persistence. Knowledge gaps and uncertainty are identified throughout the process, and feed into a Schedule of Studies designed to improve knowledge and understanding of Critical Habitat over time. Aboriginal knowledge was not included in the present review, nor are needs specific to this body of knowledge included in the Schedule of Studies.

Development of the framework and the proposed Critical Habitat identification were guided by the following set of principles:

2.3.1 Guiding Principles

1) Consider available published scientific information and seek multiple lines of evidence to support conclusions.
2) Recognize the need to address the dynamic nature of boreal systems, and the resultant effects on boreal caribou habitat.
3) Acknowledge and consider that the habitat requirements of this species operate at multiple spatial and temporal scales, including both physical and functional properties.
4) Recognize that variation in population structure, population and landscape condition, and state of knowledge may warrant different approaches to identifying Critical Habitat across the national distribution of this species.
5) Apply a precautionary approach when evidence suggests serious or irreversible harm, recognizing that absence of full scientific certainty should not be used as a reason to postpone decisions.
6) Consider the precautionary approach a provisional measure that requires follow-up activities such as research and monitoring to reduce significant scientific uncertainty and improve decision-making.
7) Apply adaptive management to identify and reduce key uncertainties, and to achieve management objectives while gaining reliable knowledge.
8) Recognize that socio-economic considerations are not part of Critical Habitat identification, but are appropriately considered in other phases of the overall SARA recovery planning process.

2.3.2 The Critical Habitat Identification Framework

The Framework is used as a logic model to organize the acquisition and analysis of the best available knowledge to identify Critical Habitat, while recognizing uncertainty. Consistent with an adaptive management process, it is acknowledged that ongoing research and monitoring will provide new knowledge that can be used to refine the identification of Critical Habitat over time. The Framework (see Figure 1) flows from the following three major questions to be addressed in the identification of Critical Habitat:

- What is the current distribution of boreal caribou in Canada?
- Where are the local populations within the current distribution of boreal caribou in Canada?
- What conditions are required for long-term persistence of local populations of boreal caribou in Canada?

Identification of Critical Habitat is an outcome of these questions, such that:

Critical Habitat is comprised of the resources and environmental conditions required for persistence of local populations of boreal caribou throughout their current distribution in Canada. The quantity, quality and spatial configuration of resources and conditions may be influenced by both natural and human-induced conditions.

Each component of the Framework (Figure 1) was informed by available quantitative data and published scientific information acquired or assembled as part of the Boreal Caribou Critical Habitat Science Review.

Each step in the framework is described below:

i) What is the current distribution of boreal caribou in Canada?

The recovery goal specifies the geographic scope of boreal caribou recovery as the current distribution for the species. The current distribution of boreal caribou across Canada was described and mapped to define the national spatial scope of Critical Habitat Identification. Current distribution delineation was based on information provided by jurisdictions. Areas of uncertainty and needs for further assessment were identified and included in the Schedule of Studies.

ii) Where are the local populations (or units of analysis) within the current distribution of boreal caribou in Canada?

The population objective of the Draft National Recovery Strategy specifies local populations as the relevant unit of analysis for achieving the recovery goal. For the purposes of Critical Habitat identification, the range associated with each local population was considered to be the unit of analysis. Several population patterns were recognized, and methods for range delineation varied according to the population pattern and the amount of animal location and movement data available. Areas of uncertainty regarding units of analysis were highlighted and included in the Schedule of Studies.

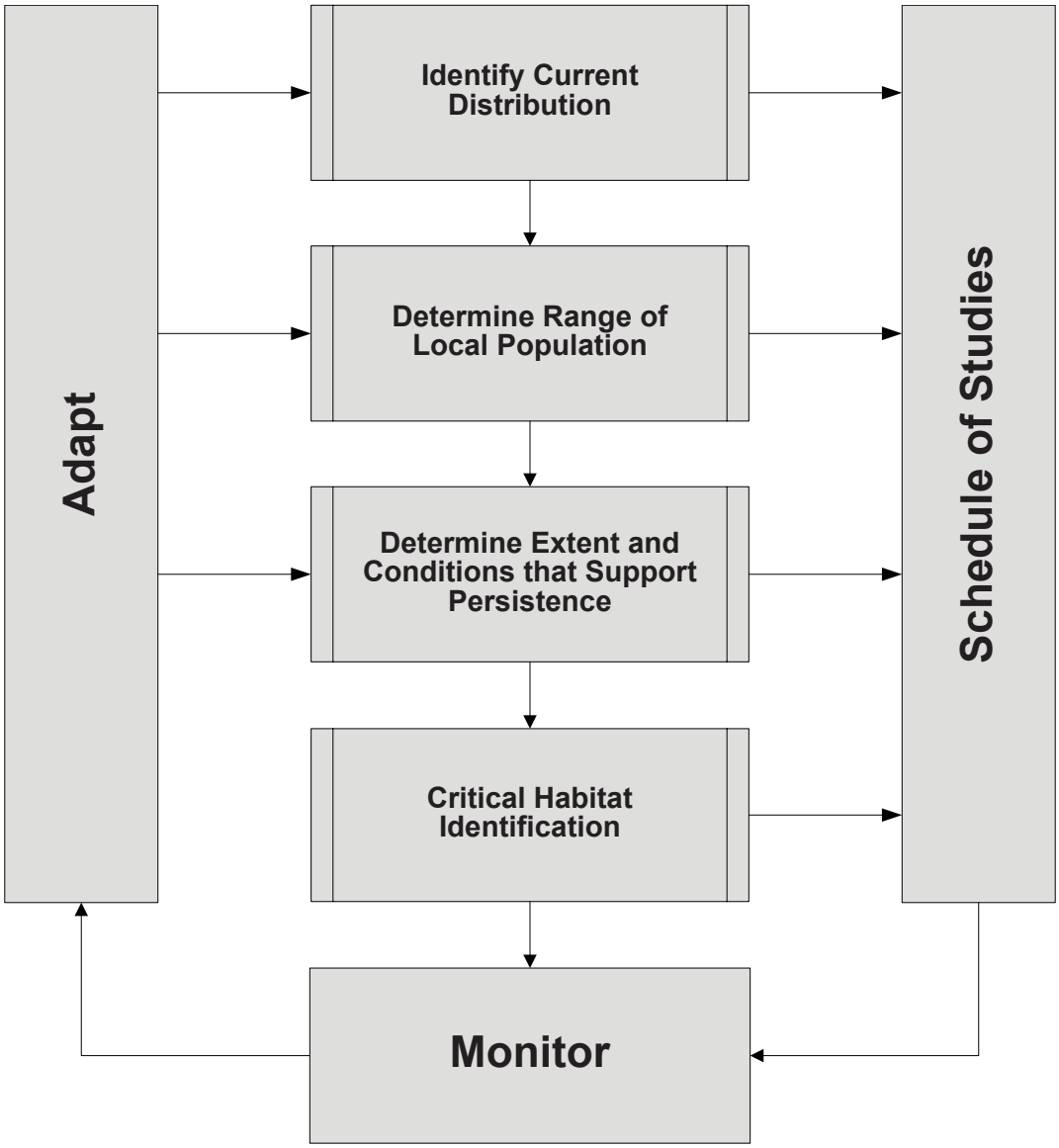


Figure 1: Critical Habitat Identification Framework for Boreal Caribou

iii) What habitat conditions are required for long-term persistence of boreal caribou populations?

The recovery objective of self-sustaining populations is expressed quantitatively as the probability of a given set of habitat conditions supporting self-sustaining (persistent) local populations. Lower probability or certainty is generally associated with greater risk. While it is not the role of science to determine "acceptable" levels of risk, a science-based approach can be applied to explore a range of persistence parameters, given available knowledge. In the absence of scientific certainty, the identification of Critical Habitat can thus be viewed **as reflecting both our current state of understanding, and an explicit expression of risk,** both of which should be evaluated and refined as new knowledge is generated.

iv) Critical Habitat Identification

A central premise of the Framework is a definition of habitat that encompasses physical and functional attributes at a scale that is aligned with the goal of self-sustaining local populations. In this context "habitat" includes physical attributes (e.g. forage plants or thermal cover) used by caribou to carry out their life functions, as well as conditions (such as degree of natural and human disturbance) within the landscape mosaic that comprises the range of a local population. This approach addressed the influence of landscape conditions on mechanisms such as predation that affect short-term population trends and long-term persistence.

The Draft National Recovery strategy (Environment Canada 2007; see also Racey and Arsenault 2007) recognized that critical habitat for boreal caribou is appropriately conceptualized as caribou ranges and their components. Consistent with this recognition, Critical Habitat identification within the framework focused on local population range as the scale at which habitat extent and conditions have the greatest influence on population persistence (see Section 2.5.2). The Critical Habitat Identification framework incorporates the need for further refinement of CH identification where necessary for local populations.

v) Monitor, Adapt and Schedule of Studies

Because Critical Habitat for boreal caribou is not a fixed entity, but an emergent property of dynamic landscapes, a robust research and monitoring program is an important component of Critical Habitat identification and management. New knowledge informs management actions that proceed with the best available information, gained through a structured process of adaptive management. Knowledge gaps and uncertainties are identified, compiled, evaluated, and reflected in a recommended Schedule of Studies. In the Schedule of Studies, emphasis is placed on the identification of key uncertainties that prevent choosing between different conceptual models representing our understanding of what comprises Critical Habitat for boreal caribou.

Over time, understanding of the necessary conditions for persistence is improved by ensuring that Critical Habitat identification is subject to evaluation and refinement. Thus the adaptive management loop is fundamental to the question of "What is Critical Habitat?" and an essential component of the framework as a decision-analysis tool to refining what Critical Habitat is in the face of uncertainty.

2.4 Habitat and Persistence

Understanding the relationship between habitat selection and scale, and how this hierarchical approach is linked to persistence, is fundamental to the identification of Critical Habitat for boreal caribou.

2.4.1 Habitat and Scale

In general, suitable boreal caribou habitat is characterized by large tracts of mature to old conifer forests with abundant lichens, or peatlands intermixed with uplands dominated by mature to old conifers (Darby and Pruitt 1984, Brown et al. 1986, Bradshaw et al. 1995, Stuart-Smith et al. 1997, Rettie and Messier 2000, Courtois 2003). However, there is variability among regions in vegetation types used.

Boreal caribou have habitat requirements at several spatial and temporal scales (Rettie and

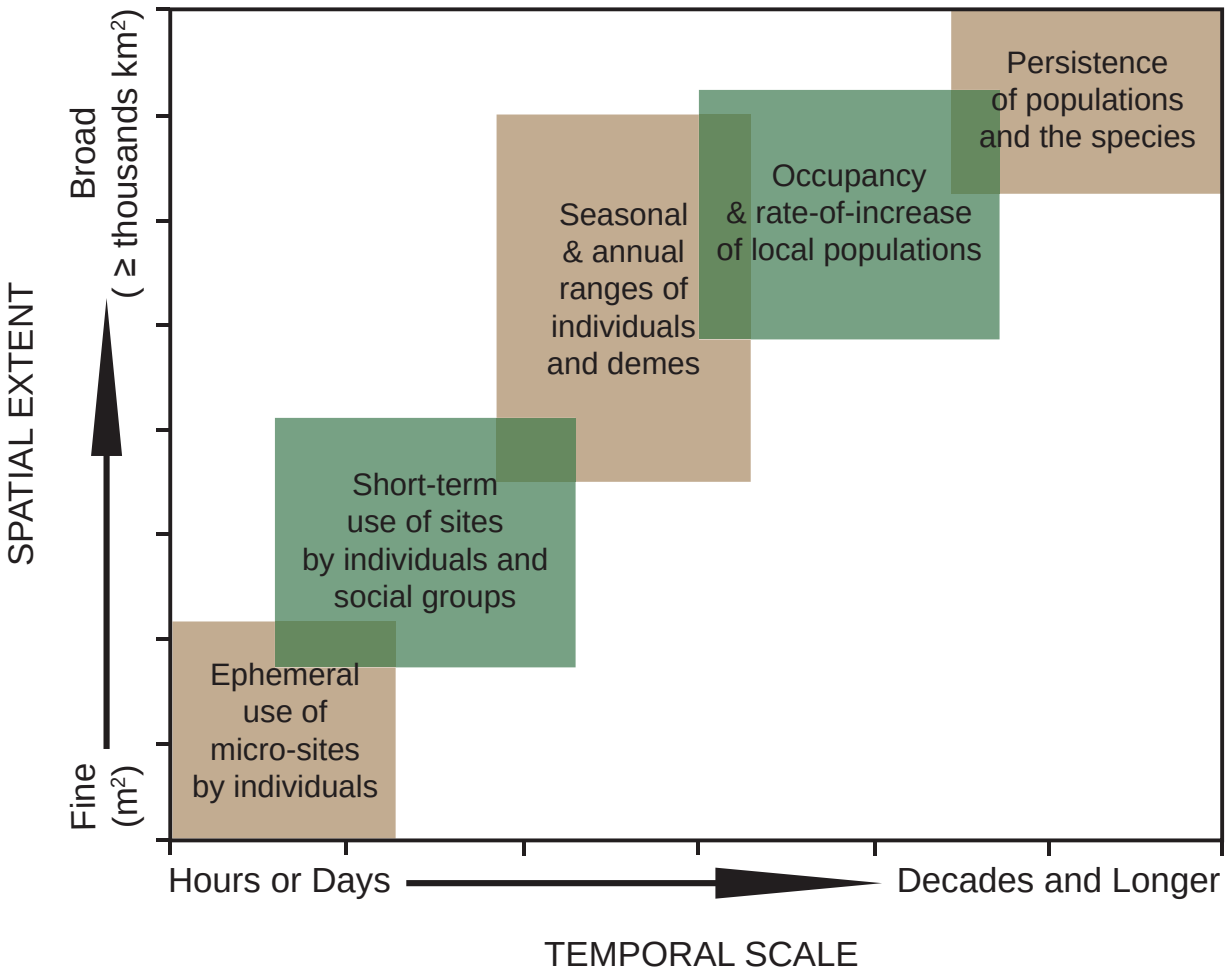


Figure 2: Boreal caribou habitat exists at multiple spatial and temporal scales, and includes both physical and functional properties. The absolute magnitude of spatial and temporal scales for habitat may vary across the national distribution of boreal caribou.

Messier 2000, Johnson et al. 2001, O'Brien and Manseau 2003) as illustrated in Figure 2. Coarser scales encompass large areas (e.g. ranges) and broad time frames (e.g., seasons, years and decades), whereas finer scales cover small areas (e.g., forest stands or habitat patches) and narrow time frames (e.g., hours and days). Boreal caribou select habitat to avoid predation at coarser scales (Bergerud 1988, Johnson et al. 2001) and then select habitat to meet forage requirements at finer scales (Schaefer and Pruitt 1991, Rettie and Messier 2000).

At coarser scales, boreal caribou local populations require large range areas that contain sufficient suitable habitat and reduce predation by allowing caribou to avoid areas of high predation risk (Rettie and Messier 2001, Brown et al. 2003). At finer scales, boreal caribou select individual habitat patches (within ranges) that provide food, particularly ground and tree lichens during late winter and early spring, and they avoid early seral-stage forests and recently disturbed areas (Schaefer and Pruitt 1991, Stuart-Smith et al. 1997, Rettie and Messier 2000). Although forest fire destroys lichens and other vegetation in the short term, it is an important factor in regenerating caribou forage over long time scales (Dunford 2003). During winters with deep or crusted snow, boreal caribou require habitats that have shallower and uncrusted snow (such as in mature coniferous stands with closed canopies) and tree lichens to enable access to forage (Vandal and Barrette 1985, Thomas and Armbruster 1996).

In general, boreal caribou require habitats that provide necessary functional attributes (the conditions and resources that provide for all of their life requirements), including physiological health, dispersion of cows during calving and post-calving periods, and refuge from predation.

2.4.2 Scale and Persistence

There is increasing recognition within scientific and management communities that factors influencing caribou populations must be considered at regional scales (see Vistnes and Nellemann 2008 for a recent review). Changes in conditions that affect the number and distribution of alternative prey species and their associated predators, resulting in reduced habitat effectiveness for caribou, impact the viability of boreal caribou populations at the scale of their range. These changes are related to disturbances that increase the amount of early seral-stage forest, promote higher densities of prey species such as moose (Alces alces) and white-tailed deer (Odocoileus virginianus), which in turn support higher predator densities, especially of wolves (Canis lupus) (Bergerud and Elliott 1986; Seip 1992; Stuart-Smith et al. 1997, Racey and Armstrong 2000; Wittmer et al. 2005, 2007). The range of a given local population of caribou may contain a variety of habitat components that are differentially used by caribou, as well as the landscape matrix between these areas. Whether habitat components within a range are selected or avoided by caribou, all affect the viability of the population in positive or negative ways, thus are important when considering the conditions necessary for persistence.

Therefore, **local population range is the relevant scale for the identification of Critical Habitat to support self-sustaining local populations of boreal caribou**, such that the range is a geographic area occupied by individuals of a local population that are subjected to the same influences affecting vital rates over a defined time frame. Range is a function of both spatial extent and habitat conditions. Extent refers to the physical area of the range and habitat conditions refer to the quantity, quality and spatial configuration of resources (including the presence of other species) within the range. A more detailed discussion of the concept of range and methods of delineation is included in Appendix 6.2.

2.5 Scientific Undertakings to Support Application of the Framework

The large amount of scientific information that exists on boreal caribou in Canada facilitated the scientific review of Critical Habitat and identification process. Relevant boreal caribou information was compiled, analyzed and synthesized to support the Framework (Figure 3).

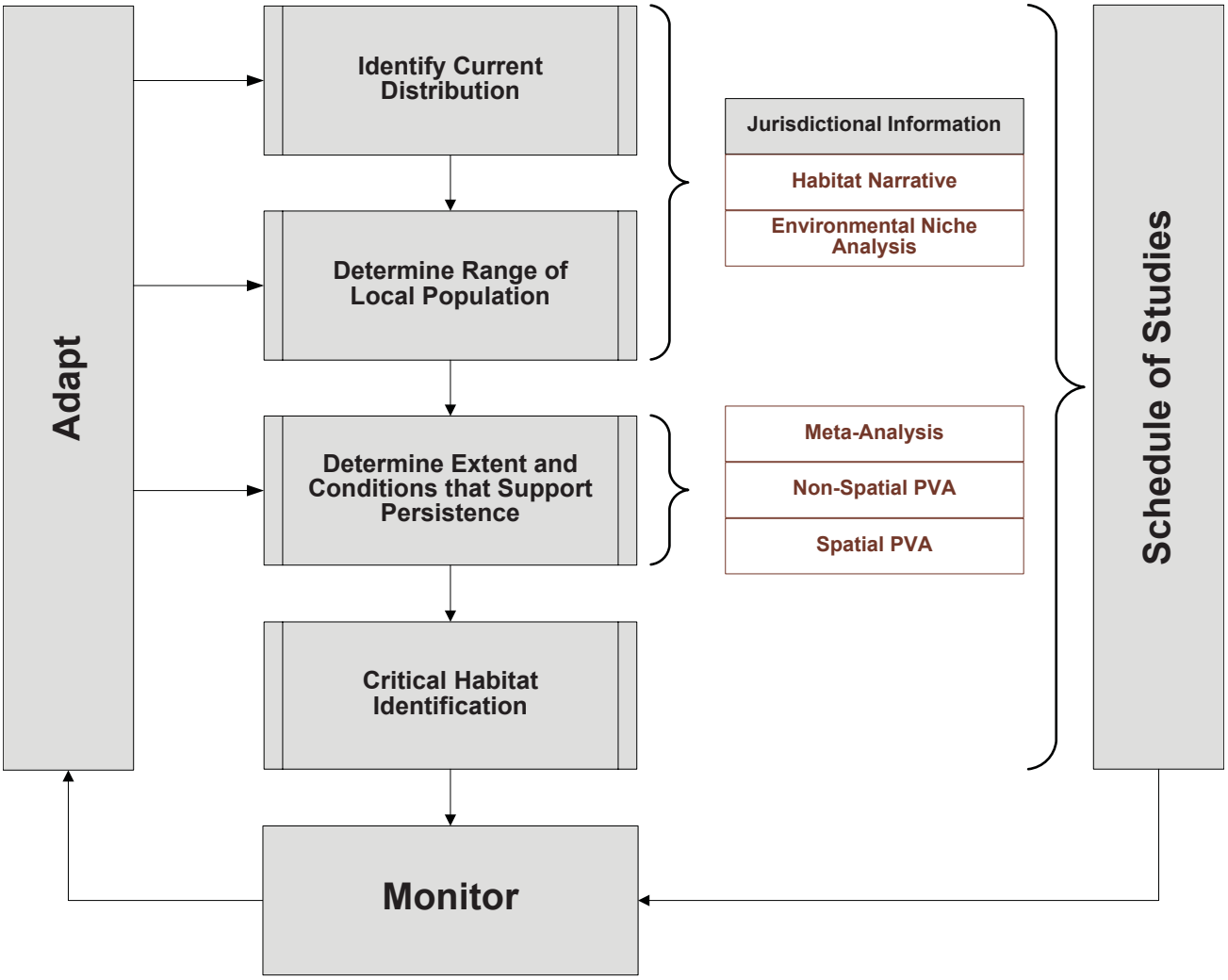


Figure 3: Science components supporting the Critical Habitat Identification Framework for Boreal Caribou

The science activities were comprised of five main components presented as Appendices to the report, and summarized here: a habitat narrative, an environmental niche analysis (ENA), a meta-analysis of population and range condition, a non-spatial population viability analysis (PVA), and spatially-explicit population viability analysis. The habitat narrative summarized existing knowledge of boreal caribou habitat use and requirements across a variety of spatial and temporal scales, throughout their distribution in Canada. The other four components represent a spatial and analytical hierarchy of methods of decreasing generality and increasing complexity. The environmental niche analysis and range-wide meta-analysis provided top-level information, followed by the non-spatial PVA, and finally the spatial PVA. Results from top-level analyses reveal overarching constraints on processes that can be

examined at lower levels; lower-level results suggest factors missing from the top-level analyses, and completing the learning cycle, top-level analyses suggest the extent to which conclusions from the lower-level results may lack generality. These components informed the Critical Habitat identification process by feeding into a Critical Habitat Decision Tree (introduced in Section 2.6).

2.5.1 Habitat Narrative (Appendix 6.3)

The habitat narrative provided a description of boreal caribou habitat, including spatial and temporal aspects of biophysical attributes used throughout the species' life cycle, and considered both physical and functional characteristics of the habitat. This work summarized the primary and grey literature pertaining to caribou habitat use across the current distribution. Boreal caribou habitat-use information was extensive in some regions and quite limited elsewhere. The narrative informed the environmental niche analysis through identification of variables influencing the extent of occurrence, and potential areas of occupancy, of boreal caribou throughout their distribution. The narrative also provided detailed information to augment understanding of components of Critical Habitat that vary among and within local population ranges. The information is organized by ecological regions.

2.5.2 Environmental Niche Analysis (Appendix 6.4)

The environmental niche analysis was a tool to enhance understanding of the historic and current geographic distribution of boreal caribou, and patterns of occupancy, relative to abiotic and biotic factors. The ENA used abiotic factors (climate and topography) to characterize the potential distribution of observed boreal caribou locations, and then incorporated broad-scale biotic variables (land cover and human impact levels) to predict the pattern of occupancy within the current extent of occurrence. The ENA supports the Framework and associated decision-analysis by identifying areas of uncertainty and generating hypotheses about limiting factors, which guide sampling and refinement efforts identified in the Schedule of Studies. The results also identify areas supporting potentially suitable conditions for habitat restoration adjacent to current ranges, or potential corridors of movement between ranges.

2.5.3 Meta-Analysis of Population and Range Condition (Appendix 6.5)

A key element of the Critical Habitat Framework is determining attributes of a caribou range that support or compromise population persistence (e.g. the ability of the range to support a self-sustaining population). The meta-analysis compiled demographic data from boreal caribou populations across Canada to evaluate the hypothesized relationship between caribou population parameters (index of population condition) and levels of anthropogenic and/or natural (fire) disturbance on caribou ranges (index of range condition). Natural disturbances could also include insect outbreaks and their stand-level effects associated with climate change projections that may in fact result in a fire disturbance, however insect disturbances were not directly considered in this analysis. Results from the meta-analysis provided quantitative guidelines for one of the three assessment criteria (e.g. range condition) used in the evaluation of local populations for Critical Habitat identification (see Section 2.6.3 and 2.6.4).

2.5.4 Non-Spatial Population Viability Analysis (Appendix 6.6)

The Critical Habitat Framework requires information on population persistence. The non-spatial PVA evaluated how population persistence is affected by aspects of boreal caribou life history and population age and sex structure, using the range of published population vital rates and their variance for boreal caribou across Canada. Results of this work provided quantitative guidelines for the population size required for persistence under various demographic conditions, the second of three criteria assessed in Critical Habitat identification (see Sections 2.6.3 and 2.6.4), and informed the spatially-explicit PVA by providing information on the vital rates that most influence population dynamics of boreal caribou.

2.5.5 Spatially-explicit Population Viability Analysis (Appendix 6.7)

Spatially explicit population models have many more parameters and computational demands than a non-spatial PVA, such as simulating a dynamic landscape over time, and thus can explore only a subset of the parameter space for local populations. Spatial PVA adds consideration of landscape structure and individual movement, and when results are compared with a non-spatial PVA, helps assess whether spatial effects produce different predictions of population persistence. Application of spatial PVA can also help interpret results of the meta-analysis by offering heuristic insights of the mechanisms by which the ability of an area to support caribou scales up spatially from the scale of patch to the scale of landscape (range), and allows simulation of longer-term trends and scenarios to extrapolate relationships to future landscapes. The work completed as part of this review was a proof of concept for applications of methods exploring how landscape condition affects boreal caribou population persistence for two case study populations. Further elaboration of Critical Habitat outcomes at spatial scales finer than range, over specified time frames, can be achieved through spatially explicit population viability analysis linked with dynamic landscape modelling.

2.6 Decision Analysis to Support Identification of Critical Habitat

As concluded in Section 2.4.2, local population range (including extent and habitat conditions) is the relevant scale for the identification of Critical Habitat to support self-sustaining local populations of boreal caribou. The identification of CH requires an understanding of the ability of existing habitat (with respect to extent and condition), to support self-sustaining local populations of boreal caribou. Expanding on the Critical Habitat Framework (Figures 1 and 3), the Critical Habitat Decision Tree (herein referred to as Decision Tree; Figure 4), is a more detailed decision analysis tool. The Decision Tree outlines the logical sequence of steps necessary for the identification of CH for boreal caribou, considering the variability and uncertainty associated with ecological processes operating at the scale of local population ranges. The Decision Tree represents the alternatives available, the associated uncertainty, and the evaluation measures applied to support identification. Where possible, uncertainties were represented through probabilities (see Sections 2.6.4 and 2.6.5) and knowledge gaps were directed to a Schedule of Studies. The process of CH identification was framed as an exercise in adaptive management, integrating research and monitoring in a cycle of evaluation that addresses knowledge gaps and key uncertainties, and incorporates new knowledge to refine the identification of Critical Habitat over time.

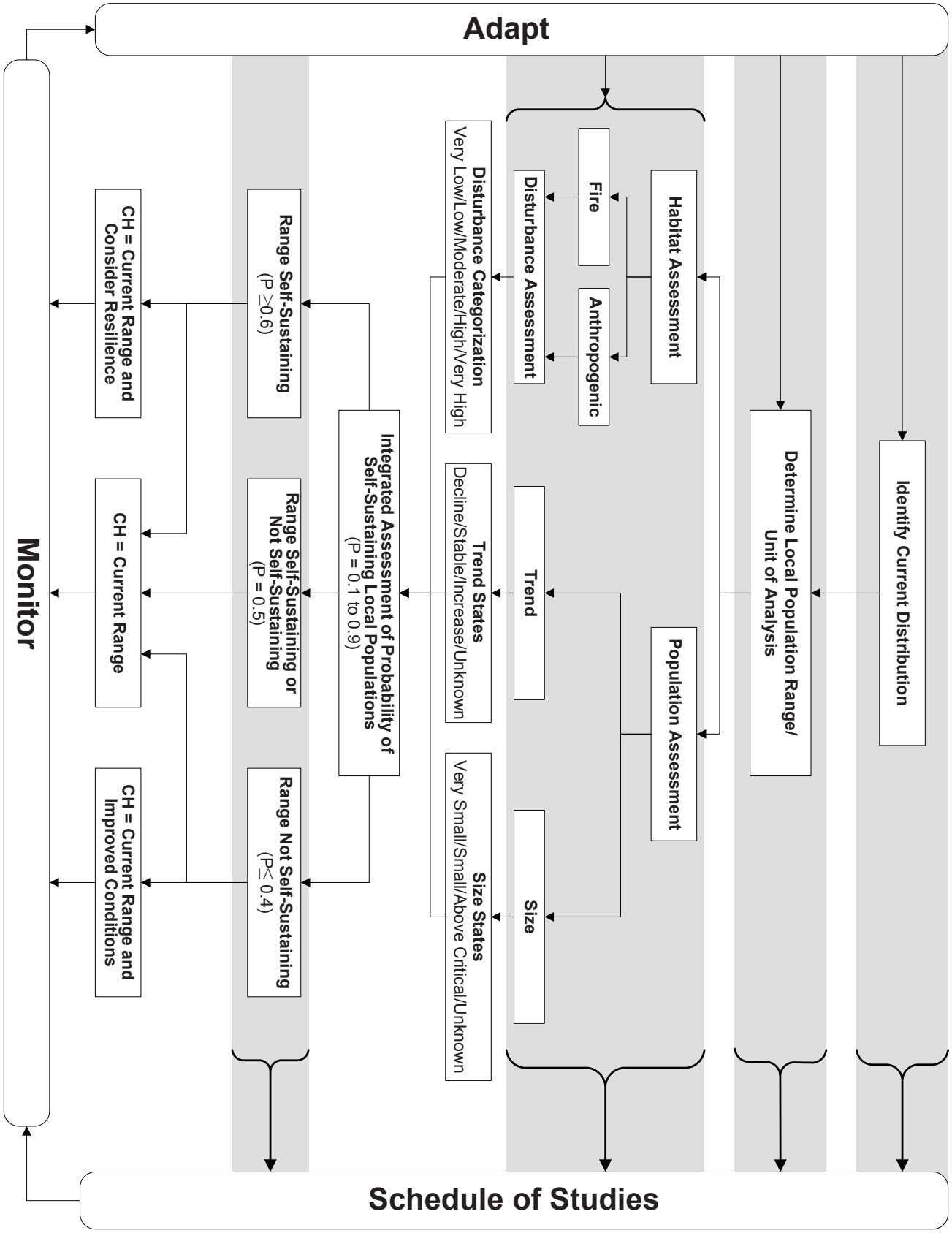


Figure 4: Boreal Caribou Critical Habitat Decision Tree

Steps in the Decision Tree are described below.

2.6.1 Identify Current Distribution

The recovery goal for boreal caribou specifies the geographic scope as the current distribution for the species. Boreal caribou are distributed in the boreal forest across seven ecozones, including nine provinces and territories, from the Yukon Territory in the west, to Labrador in the east, and extending as far south as Lake Superior[1]. Figure 5 illustrates the current distribution of boreal caribou as depicted in the Draft National Recovery Strategy, based on information provided by jurisdictions. This geographic extent was used in the present Boreal Caribou Critical Habitat Identification Framework and Decision Tree.

The current distribution (extent of occurrence) is subject to revision with new knowledge, and standard methods should be applied across the extent to ensure consistency in representation of understanding. The Environmental Niche Analysis (Appendix 6.4) can be used to identify areas of uncertainty based on available abiotic and biotic data, and therefore guide sampling efforts to refine understanding (model-based sampling), as part of the Schedule of Studies. Revisions are reflected in the Decision Tree as adjustments to future assessments, as part of the adaptive management loop.

2.6.2 Determine Local Population Range (Units of Analysis)

Application of the Decision Tree required delineation of local populations and their associated ranges. It was recognized that populations often function demographically at scales that are different from those suggested by genetic indicators (e.g. Esler et al. 2006; see Appendix 6.2 for further detail). Demographically defined local populations are the appropriate population unit for Critical Habitat identification to address the National Recovery strategy objective of self-sustaining local populations.

Local populations were defined as a group of caribou occupying an area distinguished spatially from areas occupied by other groups. Local populations experience limited exchange of individuals with other groups, such that population dynamics are driven by local factors affecting birth and death rates, rather than immigration or emigration among groups. Ecological conditions, as well as patterns and intensity of anthropogenic disturbance, vary tremendously across the national distribution for boreal caribou in Canada, resulting in variation in local population patterns. Some local populations may be spatially discrete and experience little or no exchange of individuals; other local populations may exist as part of a broader, continuous distribution where periodic exchange of individuals may be greater. Alternatively, a local population could occupy a large continuous distribution where regular exchange of individuals occurs.

[1] Boreal caribou on the island of Newfoundland are excluded from this Report and the National Recovery Strategy because the insular Newfoundland population has been designated Not at Risk by COSEWIC.

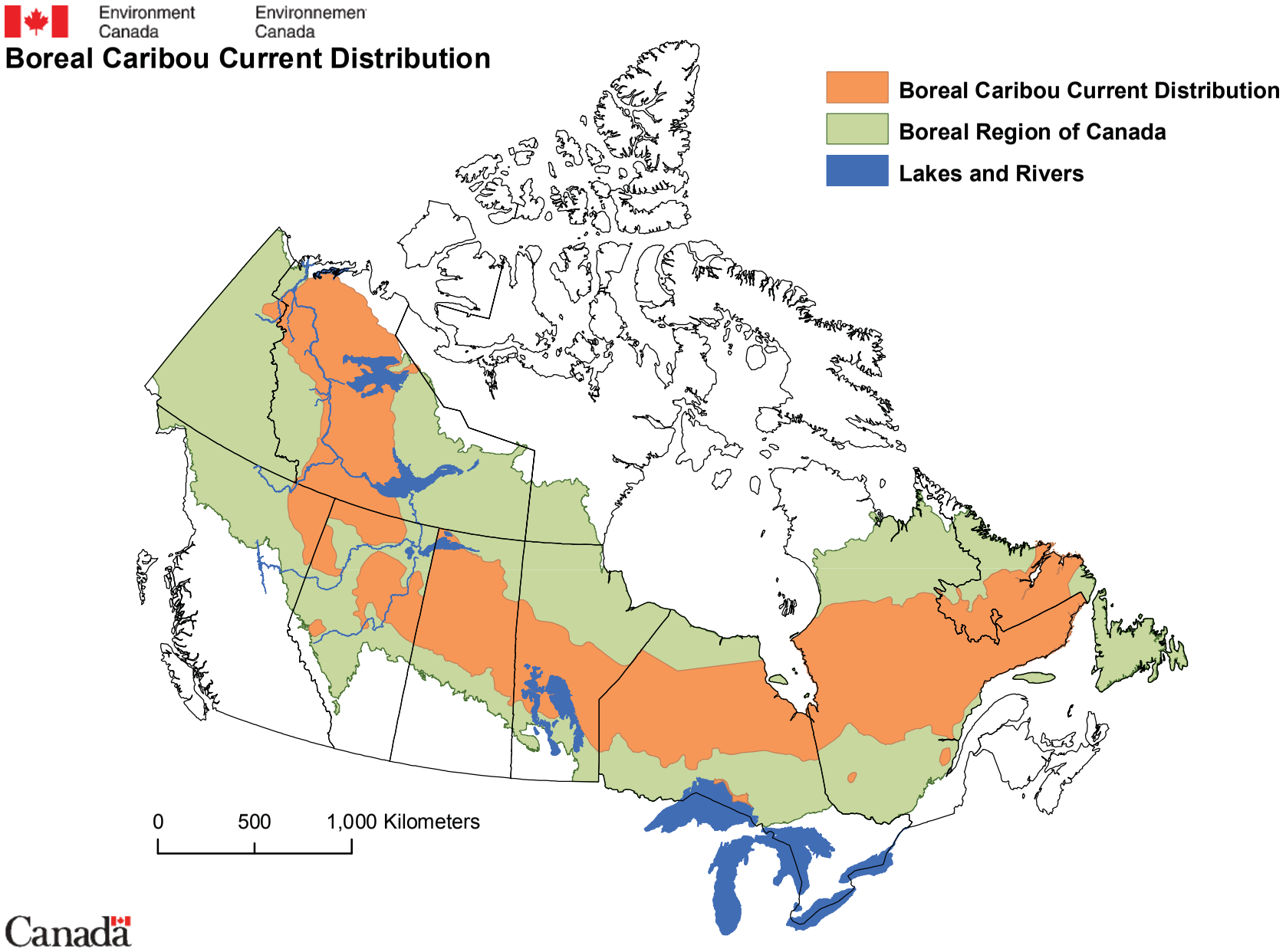


Figure 5: The current distribution of boreal caribou in Canada.

Three local population patterns for boreal caribou were recognized:

1) Discrete local population with spatially discrete ranges
2) Multiple local populations within a large area of relatively continuous habitat
3) Single large local population across a large area of relatively continuous habitat

Movement data can be used to determine immigration and emigration rates and assess population patterns of boreal caribou (Bethke et al. 1996, McLoughlin et al. 2002). However, many regions lack sufficient data covering an adequate time period to assess immigration/emigration rates for the purpose of determining spatial population structure. In the absence of sufficient immigration/emigration data, available animal movement/survey data and the degree of geographic separation of area of occupancy can be used to suggest the most plausible local population pattern for boreal caribou (see Schaefer et al. 2001, Courtois et al. 2007). Uncertainty should be addressed through a Schedule of Studies and resultant adjustments should be made to local population identification and associated unit of analysis over time.

Where natural geographic boundaries and/or habitat alteration have resulted in discrete local populations, and range boundaries were delineated based on animal movement data and forest dynamics data, resultant local population and associated range were identified as the unit of analysis for purposes of Critical Habitat identification.

Where caribou local populations are not restricted by natural geographic boundaries or habitat alteration and are distributed across large areas of relatively continuous habitat, and animal movement data are not available, the delineation of range for local populations is more difficult. The draft National Recovery Strategy (Environment Canada 2007) specifies a Population and Distribution Objective of self-sustaining boreal caribou populations throughout the current distribution (extent of occurrence) in Canada (see Section 2.1.2). Hence, for continuous distributions within which local populations were not identified, the extent of occurrence was considered the range for the present assessment. For future evaluations, Appendix 6.2 provides potential criteria for subdividing large areas of continuous habitat into local population ranges based on animal movement and/or survey data and ecological criteria. Where studies have shown that large areas of relatively continuous habitat are occupied by one local population (> than 10% emigration and immigration among groups of animals) the extent of occurrence can be divided into contiguous sub-sample units in order to ensure that the mean condition does not mask variation that may occur across the range.

Local population ranges identified by jurisdictions were used in the present application of the Decision Tree. Figure 6 depicts the resulting units of analysis. Several jurisdictions with extensive areas of continuous habitat have not yet completed the process of local population delineation and therefore only provided extent of occurrence of boreal caribou for the continuous distribution area within the jurisdictional boundaries. The identification of local populations and associated range within large continuous distribution areas is a high priority, as identified in the Schedule of Studies. When completed, the proposed Critical Habitat for these units should be re-evaluated.

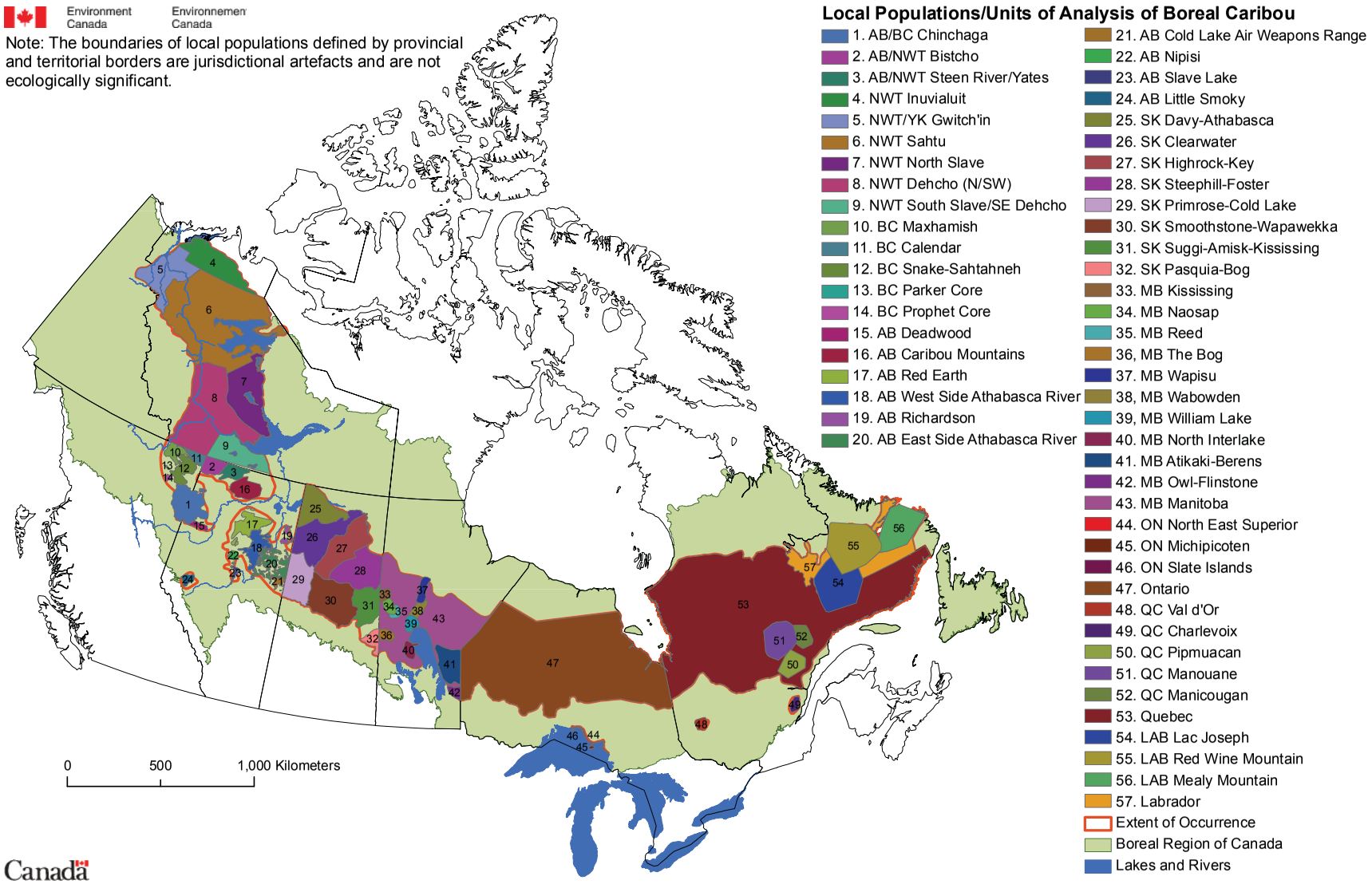


Figure 6: Boreal Caribou Local Populations and Units of Analysis for Critical Habitat Identification

Of the 57 recognized units of analysis assessed in this report, 39 represent discrete local populations and are referenced as "local populations" in the following figures and tables. Of the remaining units of analysis, 6 units in NWT resulted from subdivision of a large area of relatively continuous habitat considered to be occupied by one large population into recognized management units; 8 units in Saskatchewan represent multiple local populations and recognized management units within an area of relatively continuous habitat. The remaining 4 units of analysis found in parts of Manitoba, Ontario, Quebec and Labrador may include multiple local populations within a large area of relatively continuous habitat. In the absence of defined local populations or units of analysis for these areas, the extent of occurrence was used as the analysis unit.

2.6.3 Population and Habitat Assessment

Having identified local populations or units of analysis and associated ranges, the next step in the Decision Tree was the identification and assessment of measurable criteria of population and habitat status for each local population range. The recovery goal (and population objective) is self-sustaining local populations, here interpreted as the probability of persistence. Three measurable criteria related to persistence probability were assessed:

Population Trend: an indicator of whether a population is self-sustaining over a relatively short measurement period (approximately 3-5 years). Four qualitative states were recognized: stable, increasing, declining and unknown. Information on trend of local populations was provided by the jurisdictions in Appendix 1 of the Draft National Recovery Strategy. Updates were solicited as part of this review (see Appendix 6.8). Development of standards for measurement of this criterion is identified within the Schedule of Studies.

Population Size: an indicator of the ability of a population to withstand stochastic events and persist over the long-term. Results from the non-spatial population viability analysis (PVA) were used to derive empirical guidelines for size categories (states) related to probability of persistence (see Section 2.6.4.2 Population Size and Appendix 6.6). Three states were recognized in this review: very small (< 50), small (≥50 and ≤300), and above critical (>300). Information on size of local populations was provided by the jurisdictions in Appendix 1 of the Draft National Recovery Strategy. Updates were solicited as part of this review (see Appendix 6.8). Development of standards for measurement of this criterion is identified within the Schedule of Studies.

Range Disturbance: an indicator of the ability of a range to support a self-sustaining population. Results from a meta-analysis of demography and range disturbance (see Appendix 6.5) were used to derive empirical categories (states) for percent total range disturbance (anthropogenic and fire) related to demographic response (see Section 2.6.4.3 Range Disturbance). Five states were recognized in this review: very low, low, moderate, high and very high. Information on total range disturbance of local populations was measured from independent, national-scale data sources, consistent with methods applied in the meta-analysis.

Additional criteria were considered during the review, particularly measures of range condition in addition to disturbance. The amount, quality and spatial distribution of habitat components essential to caribou, such as winter and summer range, and calving and post-calving areas, also influence the ability of a range to support a self-sustaining population. Partitioning disturbance into natural and anthropogenic components, characterized by type, severity and distribution relative to habitat components could also help to refine evaluations. Other types of disturbances that cannot be readily extracted from maps can also influence range condition. However, access to readily available, standardized data on which to base a national assessment was a limiting factor in the current review. Development of a comprehensive Decision Tree and associated analyses are identified in the Schedule of Studies. Supplementary information (e.g. new knowledge) can also augment Critical Habitat identification through the adaptive management process.

2.6.4 Determination of States for Assessment Criteria

The population and habitat assessment criteria: population trend, population size and range disturbance, represent three lines of evidence used to evaluate local population ranges relative to their potential to support self-sustaining populations. This section describes the methods used to determine the states of assessment criteria.

2.6.4.1 Population Trend

The recognized states of population trend used in the Decision Tree and associated analyses were not rationalized beyond a literal interpretation of the trend state. For example, a population exhibiting a declining trend over a given measurement interval is, by definition, not self-sustaining, and thus has a low probability of persisting given continued decline. Alternatively, a stable or increasing population is, by definition, self-sustaining over the measurement interval, and has a moderate to high probability of persisting given continued stability or growth. Where trend was assigned a state of unknown, the population was considered to have an equal likelihood of being either self-sustaining or not, and thus may or may not persist (Table 1).

Table 1: Population trend states with corresponding values of population growth and assigned probability of persistence.

Trend State	Lamba (λ)	Prob. Persistence
Declining	≤ 0.98	0.1
Stable	0.99 to 1.01	0.7
Increasing	> 1.01	0.9
Unknown	--------	0.5

2.6.4.2 Population Size

Small populations face a high risk of extinction due to demographic stochasticity, Allee effects and emigration (Levins 1970, Shafer and Samson 1985). The situation is exacerbated when populations become isolated (Harris 1984, Belovsky et al. 1994), as is the case for most small caribou populations in Canada, due to human-caused range loss.

The non-spatial population viability analysis (PVA; Appendix 6.6) suggested that, under good demographic conditions (e.g. relatively high adult female and calf survival; Scenario 75th Percentile, Table 2), a population size of 50 had a ~10% chance of quasi extinction, within 100 years, defined as the probability of declining to a population size of 10 animals or fewer (Figure 7). This analysis further suggested that a population of 300 with moderate calf and adult female survival (MHMM, Table 2) had a 10% probability of quasi-extinction. Finally, large populations (≥ 300) had a high probability of persistence under favourable demographic conditions; however, no population size was sufficient to buffer against poor demographic conditions (low calf survival, moderate adult female survival; LHMM, Table 2; Figure 7).

Table 2. Scenario parameter values to assess population size thresholds of boreal caribou for population assessment and identification of Critical Habitat, based on calf and adult female survival (S) and variation (CV = coefficient of variation).

Scenario	Description of Scenario	Calf Survival (S_{calf})	CV[1] Calf Survival S_{calf} CV	Adult Female Survival (S_{ad})	CV Adult Female Survival (S_{ad} CV)
LHMM	Low S_{calf}; High CV of S_{calf}; Mean S_{ad}, Mean CV of S_{ad}	0.17	64%	0.85	8%
MHMM	Mean S_{calf}; High CV of S_{calf}; Mean S_{ad}, Mean CV of S_{ad}	0.38	64%	0.85	8%
75th Percentile	75thP_S_{calf}, 75thP_CV of S_{calf}; 75thP_S_{ad}, 75thP_CV of S_{ad}	0.44	51%	0.88	15%

[1] Coefficient of Variation

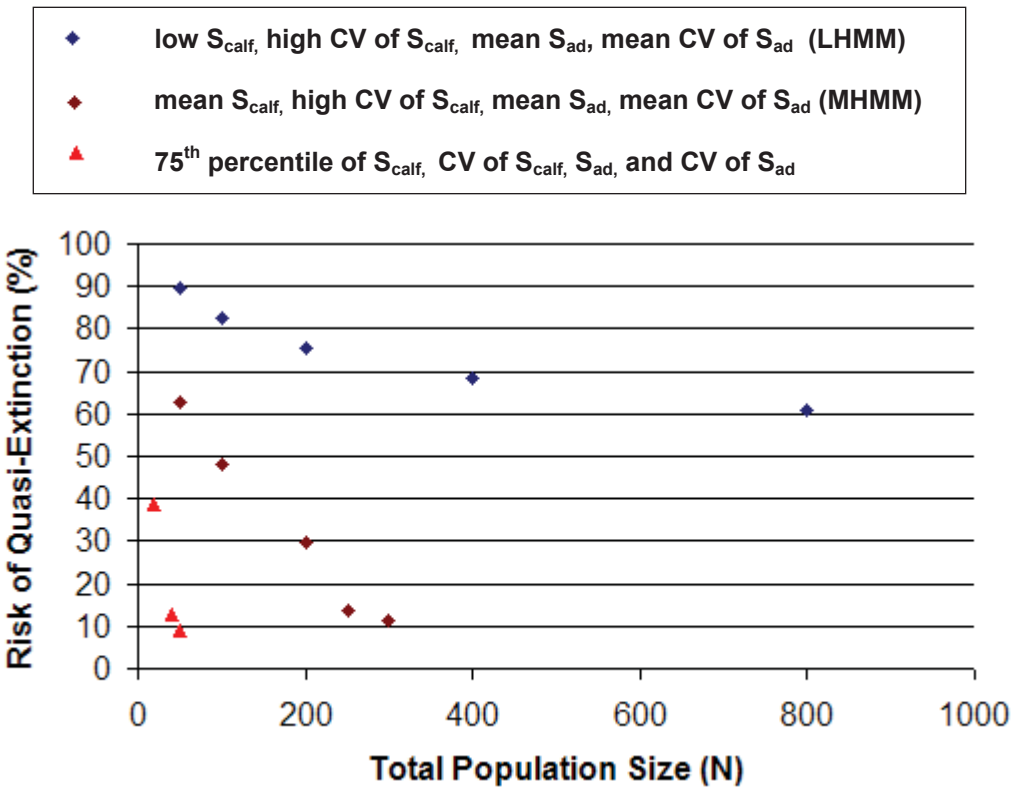


Figure 7. The effect of population size on risk of quasi-extinction under various survival rates for boreal caribou adult females and calves. Quasi-extinction is defined as the risk of the population declining to 10 animals or less over 100 yrs.

While some small populations may persist for long periods, and perhaps even expand depending on range conditions (e.g., Krausman et al. 1993, Wehausen 1999), there is general agreement that they usually require special management interventions to do so (Krausman and Leopold 1986, Krausman et al. 1993, Wehausen 1999). Further, there is usually a long lag period (two decades or more) between a population declining below a critical threshold and eventual extirpation (Tillman et al. 1994, Vors et al. 2007), and the period over which trend data for caribou populations are available is often less than the probability period associated with the most likely range perturbation under natural conditions (e.g., fire).

Therefore, the population assessment component of Critical Habitat identification recognized that very small populations (<50) are vulnerable to stochastic events and phenomena, resulting in an especially low probability of persistence, whereas local populations of >50 but <300 caribou are less vulnerable but are still at risk of quasi-extinction, and populations greater than 300 can persist indefinitely when range conditions support average adult female and calf survival. However, no population size was adequate to buffer against poor demographic conditions. Three states with corresponding population sizes and persistence probabilities were thus considered in this component of the population assessment (Table 3).

Table 3. Population size states derived from a non-spatial population viability analysis (Appendix 5.6), with corresponding population sizes and probability of persistence.

Population State	Population Size	Prob. Persistence
Very Small	< 50	0.1
Small	50 - 300	0.3
Above Critical	> 300	0.5 / 0.9*
Unknown	----------	0.5

* Declining or unknown, P=0.5; poor demographic or reference conditions
Stable or increasing, P=0.9

Given that the PVA did not include senescence (e.g. no constraints on maximum breeding age and maximum age), nor significant sources of environmental stochasticity, such as that caused by fire events, the population size thresholds could be considered liberal (e.g. conferring a greater probability of persistence than may be realized). However, the PVA also only modeled single, closed populations (e.g. no immigration or emigration). This is a reasonable assumption for very small populations and for discrete small populations. Nevertheless, where the potential for immigration exists, extinction risk may be moderated through rescue effects.

2.6.4.3 Range Disturbance

The national meta-analysis of caribou demography and range disturbance (Appendix 6.5) revealed a negative relationship between recruitment rate, as reflected in the ratio of calves to adult females in late winter population surveys, and the level of range disturbance. The percentage of the range disturbed by a non-overlapping measure of total area burned and disturbed by anthropogenic activities explained 61% of the variation in mean recruitment rates across 24 boreal caribou populations. For populations of caribou to be self-sustaining, population growth rates must be either stable or increasing. Population growth rate (λ) is a function of recruitment (R) and adult survival (S), such that $\lambda = S / (1 - R)$ (adapted from Hatter and Bergerud 1991). Thus for λ to be ≥ 1.0 (stable or increasing), R must be $\geq$ S.

The non-spatial PVA reported mean annual female survival as 85%, based on a review of boreal caribou studies from across Canada. With this adult female survival rate, a recruitment rate of 15% female calves into the total population is required for a stable population, or $\lambda = 1.0$, which is interpreted here as the condition necessary for a self-sustaining or persistent population. To achieve 15% female calves in a total population of 100 animals, assuming an equal sex ratio among calves, 14% yearlings in the population, an estimated 61% females in the adult population, and an average parturition rate of 0.76 (% yearlings, adult sex ratio and parturition rate from non-spatial PVA, see Appendix 6.6), a minimum recruitment rate of 28.9 calves/100 females is required. The non-spatial PVA suggested a positive probability of population persistence above this value, under a moderate female survival scenario, and given population size above critical (> 300 animals). Bergerud (1992) also reported that 27.7 calves/100 cows yielded a λ value of 1 based on 32 herd determinations (population survey years) of barren-ground and woodland caribou. Clearly, the appropriateness of a 15% target

and associated calf to cow ratio depends on the actual survival of adult females in a given population. However, the minimum recruitment rate or threshold of 28.9 calves/100 females provided a guideline for evaluating the probability of persistence (e.g. the ability of the range to support a self-sustaining population) of local populations associated with varying levels of range disturbance, for use in the habitat assessment component of the Decision Tree.

The results of the meta-analysis were extrapolated to predict persistence probability at varying levels of total range disturbance for individual local populations. To achieve this, it was necessary to account for the uncertainty of the measured response (the estimated empirical relationship based on sampled populations) and the predicted response (the expected value for a new observation). The uncertainty of the predicted response must be included if the interval used to summarize the prediction result is to contain the new observation with the specified confidence. As with conventional confidence intervals, which quantify the certainty around the estimated empirical relationship, a probabilistic interval is used when predicting a new observation. To distinguish the types of prediction, however, the later probabilities are termed prediction intervals. Prediction intervals around the threshold recruitment value of 28.9 calves/100 cows were used to derive the disturbance states used in habitat assessment (Figure 8).

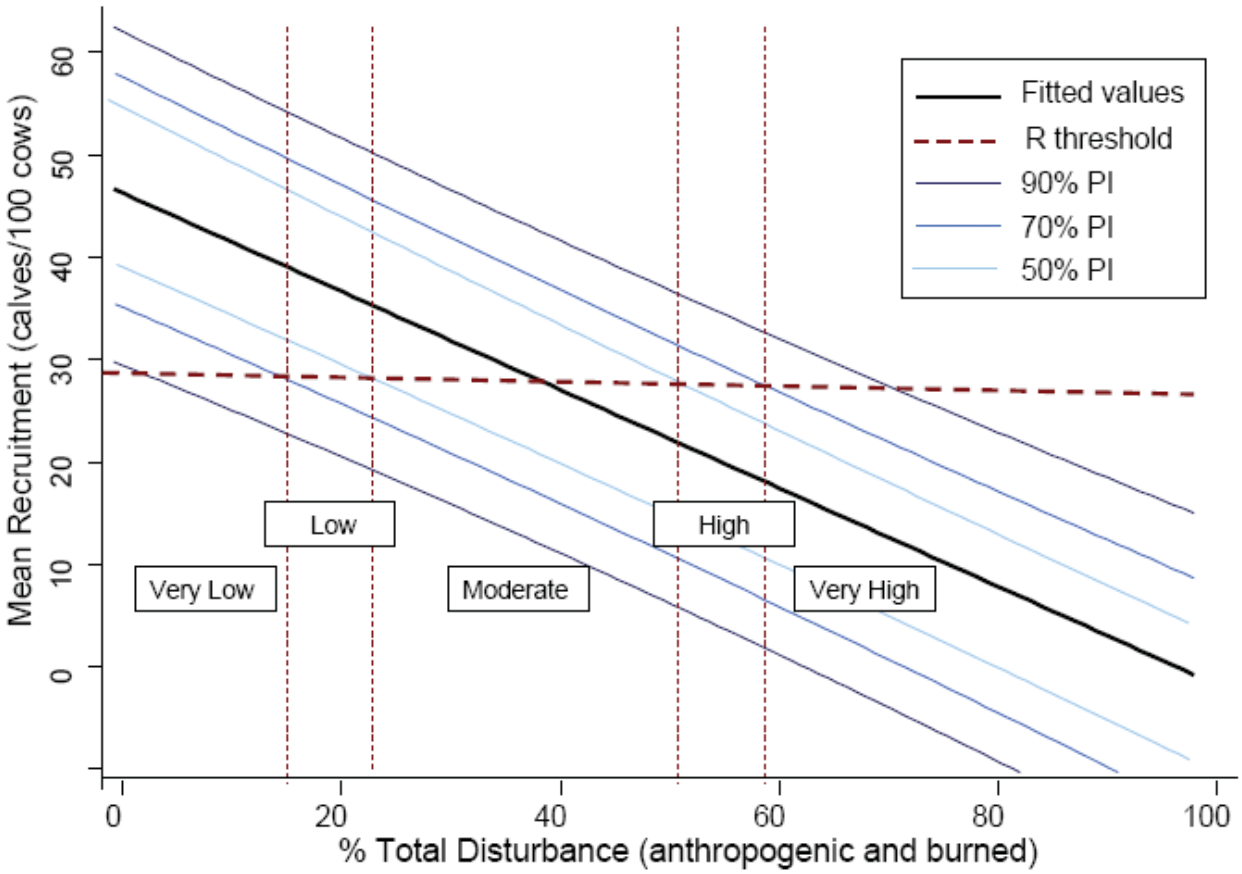


Figure 8. Disturbance states derived from the prediction intervals (PI) for the relationship between total range disturbance and boreal caribou recruitment, based on a recruitment threshold of 28.9 calves/100 cows (15% calves in total population).

The lower and upper bounds of the 50%, 70% and 90% prediction intervals defined 5 states of disturbance: very low, low, moderate, high, and very high, corresponding to values of total disturbance associated with varying levels of persistence probability (Table 4).

Table 4. Disturbance states derived from the meta-analysis of caribou demography and range disturbance (Appendix 5.5), with corresponding values of total disturbance (% anthropogenic and burned), and persistence probability, based on recruitment threshold of 28.9 calves/100 cows for a stable population.

Disturbance State	Total Disturbance	Prob. Persistence
Very Low	≤ 15%	0.9
Low	16 - 23%	0.7
Moderate	24 - 49%	0.5
High	50 - 58%	0.3
Very High	≥ 59%	0.1

While total disturbance was used to assess disturbance state for purposes of assigning persistence probability, results from the meta-analysis indicated that most of the explained variance in recruitment was attributed to the anthropogenic component of the total disturbance measure. Thus, when total disturbance was moderate or above, but the majority of the disturbance was attributed to fire, a local population range might be expected to support a higher probability of persistence than suggested by the composite measure.

2.6.5 Integrated Probability Assignments to Local Population Ranges

Once the states of individual assessment criteria were assigned to local populations of boreal caribou, the next step in the Decision Tree integrated these criteria to assign a relative probability of population persistence to each local population range. The alternative hypotheses or outcomes evaluated at the local population level were:

R_{NSS} (Range Not Self-Sustaining): current range conditions and/or extent are not adequate to support a self-sustaining population; probability of persistence is low.

R_{SS} (Range Self-Sustaining): current range conditions and extent are adequate to support a self-sustaining population; probability of persistence is moderate to high.

The Decision Tree provided a systematic means to evaluate the probability of persistence for a local population given its observed state of population trend, population size, and range disturbance. Whether states of the three criteria were known or unknown, a “prior probability” (prior) was assigned to each criterion as an expression of available quantitative data and published scientific information. A prior, which varies between 0 and 1, is an inferred probability that a hypothesis is correct, or the plausibility of an outcome given incomplete knowledge. When a state is unknown, a reference prior is assigned. This is functionally equivalent to the inferred probability of alternate hypotheses, or plausibility of different outcomes, being equal.

Assignment of prior probabilities to possible states of each criterion was based on inferred persistence probability (population trend), the statistical distribution of simulation results related directly to persistence probability (population size), and a combination of measurement and prediction uncertainty from the statistical properties of the recruitment-disturbance relationship (range disturbance). Determination of the states was described in the previous section (2.6.4). The assignment of prior probabilities reflects the probability of an observed state supporting a self-sustaining (SS) local population, given available information.

A conditional probability table for the joint distribution of criteria states was generated by averaging the individual, or marginal, priors to derive an integrated prior probability assignment for each combination set (Table 5). Integrated priors represent the prior probability distribution for the hypotheses R_{NSS} and R_{SS}. The variable SSƒR (probability of local population being self-sustaining given current range condition) is continuous from 0 to 1, with values ≤ 0.4 indicating the weight of evidence supports R_{NSS}, 0.5 placing equal weight on R_{NSS} and R_{SS} (specific conditions are evaluated to aid interpretation), and ≥ 0.6 supporting R_{SS}.

Table 5. Example portion of conditional probability table for the joint distribution of criteria states, with integrated prior probability assignments. SSƒR is the probability of a local population being self-sustaining, given present range and population conditions (See Appendix 6.8 for the complete table).

Trend		Size		Disturbance		SSƒR	Range Assessment
Declining	0.1	Very Small	0.1	Very High	0.1	0.1	R_{NSS}
				High	0.3	0.2	R_{NSS}
				Moderate	0.5	0.2	R_{NSS}
				Low	0.7	0.3	R_{NSS}
				Very Low	0.9	0.4	R_{NSS}
Stable	0.7	Small	0.3	Very High	0.1	0.4	R_{NSS}
				High	0.3	0.4	R_{NSS}
				Moderate	0.5	0.5	R_{SS}/R_{NSS}
				Low	0.7	0.6	R_{SS}
				Very Low	0.9	0.6	R_{SS}
Increasing	0.9	Above Critical	0.9	Very High	0.1	0.6	R_{SS}
				High	0.3	0.7	R_{SS}
				Moderate	0.5	0.8	R_{SS}
				Low	0.7	0.8	R_{SS}
				Very Low	0.9	0.9	R_{SS}

The result of the integrated assessment was assignment of a probabilistic outcome to each local population or unit of analysis, based on the weight of evidence supporting a conclusion of self-sustaining or not self-sustaining given current range conditions and extent.

2.6.6 Proposed Identification of Critical Habitat

The final step in the Decision Tree is the proposed identification of Critical Habitat, based on the probability of the current range supporting a self-sustaining local population (see Section 2.6.5). Critical Habitat Identification is expressed relative to the current range condition and extent for each local population or unit of analysis. Condition and extent determine the functional attributes of the range. Three Critical Habitat outcomes were considered, based on interpretation of the integrated and individual probability assignments and associated weight of evidence for range self-sustaining (R_{SS}) or not self-sustaining (R_{NSS}). The outcomes were:

- *Current Range* - current range condition and extent are required to maintain potential for self-sustaining population.

- *Current Range and Consider Resilience* – current range condition and extent may be sufficient to absorb additional disturbance while maintaining capacity to support a self-sustaining population.

- *Current Range and Improved Conditions* – current range condition and/or extent would need to be improved to restore potential to support a self-sustaining population.

The following decision rules were applied in the proposed identification of Critical Habitat for each local population or unit of analysis.

- **Where range assignment was self-sustaining (R_{SS}), based on weight of evidence from the integrated assessment (p≥0.6):**

  - If local populations or units of analysis were defined and all criteria had known states, **proposed Critical Habitat was identified as "Current Range and Consider Resilience".**

  - If local populations or units of analysis were not defined for large areas of continuous habitat or if both population criteria (trend and size) were unknown, **proposed Critical Habitat was identified as "Current Range"**, with a note that population delineation and/or data were necessary before potential resilience could be evaluated.

  - If population trend was unknown and population size was small or very small **proposed Critical Habitat was identified as "Current Range",** with a note to address data gap.

- If population trend was unknown and population size was above critical, **proposed Critical Habitat was identified as "Current Range and Consider Resilience"**, with a note to address data gap.

- **Where range assignment was not self-sustaining (R_{NSS}), based on weight of evidence from the integrated assessment (p≤0.4):**

  - If level of total disturbance was very low or low, **proposed Critical Habitat was identified as "Current Range"**, with a note to investigate other measures of habitat condition, non-habitat stressors and consider range extent, as appropriate.

  - If level of total disturbance was moderate, high or very high and trend was stable, **proposed Critical Habitat was identified as "Current Range"**, with a note to closely monitor trend.

  - If level of total disturbance was moderate, high or very high and population trend was declining, **proposed Critical Habitat was identified as "Current Range and Improved Conditions"**.

  - If population trend was unknown and total disturbance was moderate or total disturbance was high or very high with the anthropogenic component of disturbance low or very low, **proposed Critical Habitat was identified as "Current Range"**, with a note to address data gap.

  - If population trend was unknown and total disturbance was high or very high with anthropogenic component moderate or above, **proposed Critical Habitat was identified as "Current Range and Improved Conditions"**, with a note to address data gap.

- **Where range assignment was (R_{SS}/R_{NSS}), based on equal weight of evidence from the integrated assessment (p=0.5):**

  - **Proposed Critical Habitat was identified as "Current Range"**

  - If one or more of the criteria for the integrated assessment was unknown, addressing information gaps is indicated.

  - If all criteria states were known, situation was considered marginal; close monitoring of situation is recommended.

Where proposed Critical Habitat is identified as being “Current Range and Improved Conditions” or “Current Range and Consider Resilience”, this does not imply that Critical Habitat is unknown or un-identifiable. Rather, based on the current methodology, associated assumptions and data used, Critical Habitat is proposed as the Current Range, with direction on additional considerations necessary to refine the assessment. Ultimately, to meet the full requirement of “habitat that is necessary for the survival or recovery” (SARA S.2(1)), improved conditions and/or increased extent may be required (Current Range and Improved Conditions), or the Current Range could absorb additional disturbance without compromising persistence of the local population (Current Range and Consider Resilience).

3.0 RESULTS

3.1 Proposed Critical Habitat Identification for Local Populations of Boreal Caribou in Canada

The result of the application of the Decision Tree is described in Table 6. Based on this science review, proposed Critical Habitat designations are described for each local population as the Current Range, Current Range and Improved Conditions, or Current Range and Consider Resilience, based on the integrated probability assignment (Section 2.6.5) and application of decision rules (Section 2.6.6). The notes column provides explanations and considerations for each local population. These notes could be augmented by additional information available from jurisdictions. Limited, local population information was available at the time of this assessment, and for consistency, the results presented include only that information available across all populations, and considered in the present evaluation. A general description of the components of Critical Habitat to be considered within local population ranges is found in the Habitat Narrative (Appendix 6.3) and is referenced in Table 6 by ecozones and ecoregions relevant to each local population.

Application of the Critical Habitat Identification Framework to each local population or unit of analysis was based on the most current available information provided by jurisdictions for: delineation of local populations or units of analysis (where these have been defined); trend data; and population size data. Disturbance data was derived using a nationally consistent method as part of the science review. The science review did not include an assessment of data quality for data provided by jurisdictions, although Appendix 6.9 provides an indication of the level of confidence as provided by jurisdictions. National, standardized criteria and methods for boreal caribou population assessments do not exist and have been recommended as an activity in the Schedule of Studies (Section 4.4, Table 7) to improve comparability in reporting.

Table 6: Proposed Critical Habitat Identification, by local population or unit of analysis, for boreal caribou within their current distribution in Canada.

[1] Local populations refers to 57 recognized units of analysis assessed in this report; 39 represent discrete local populations; 6 units in NWT resulted from subdivision of a large area of relatively continuous habitat considered to be occupied by one large population into recognized management units; 8 units in Saskatchewan represent multiple local populations and recognized management units within an area of relatively continuous habitat. The remaining 4 units of analysis found in parts of Manitoba, Ontario, Quebec, and Labrador may include multiple local populations within a large area of relatively continuous habitat. In the absence of defined local populations or units of analysis for these areas, the extent of occurrence comprised the analysis unit.

[2] Data: see Appendix 6.9 for data source and quality used in population assessment; sources for disturbance data are described in Appendix 6.5.

[3] Range Assessment: RSS = Range self-sustaining; RNSS = Range not self-sustaining; RSS/RNSS = Range self-sustaining / Range not self-sustaining (See Section 2.6.5)

#	Local Population[1] Or Unit of Analysis	Assessment Criteria											Integrated Probability (P)	Range Assessment[3]	NOTES	Proposed Critical Habitat Identification	Ecozone	Ecoregion
		Population Trend			Population Size			Range Disturbance										
		Reported[2]	Category	Individual Probability	Reported[2]	Category	Individual Probability	Fire%	Anthro-pogenic %	Total %	Category	Individual Probability						
1	AB/BC Chinchaga	Rapidly Declining/ Suspected Declining	decline	0.1	250-300	Small	0.3	10.9	58.5	62.8	Very High	0.1	0.2	R_{NSS}	AB/BC transboundary population. High weight of evidence that current range is not self- sustaining given rapidly declining, small LP, and very high total disturbance. Anthropogenic disturbance at 58% suggests need for improved condition.	Current Range and Improved Conditions	4, 9	64, 66, 137, 138
2	AB/NWT Bistcho	Suspected Declining	decline	0.1	300	Small	0.3	24.3	40.1	57.5	High	0.3	0.2	R_{NSS}	AB/NWT transboundary population. High weight of evidence that current range is not self-sustaining given suspected decline, small population and high total disturbance. Anthropogenic disturbance at 40% suggests need for improved condition. Additional trend data required.	Current Range and Improved Conditions	4	64, 65
3	AB/NWT Steen River \ Yates	unknown	unknown	0.5	300	Small	0.3	29.6	32.2	57.0	High	0.3	0.4	R_{NSS}	AB/NWT transboundary unit of analysis. Weight of evidence suggests current range is not self -sustaining given population size below critical and high total disturbance. Trend data required.	Current Range and Improved Conditions	4	64, 65
4	NWT Inuvialuit	unknown	unknown	0.5	Unknown	Unknown	0.5	2.5	0.6	3.1	Very Low	0.9	0.6	R_{SS}	Weight of evidence suggests current range is self-sustaining given very low total disturbance. Trend data and population size data required before potential resilience can be assessed.	Current Range	3, 4	33, 34, 35, 37, 50, 52

#	Local Population[1] Or Unit of Analysis	Assessment Criteria											Integrated Probability (P)	Range Assessment[3]	NOTES	Proposed Critical Habitat Identification	Ecozone	Ecoregion
		Population Trend			Population Size			Range Disturbance										
		Reported[2]	Category	Individual Probability	Reported[2]	Category	Individual Probability	Fire%	Anthro-pogenic %	Total %	Category	Individual Probability						
5	NWT/YK Gwich'in	increasing	increase	0.9	500	Above Critical	0.9	30.1	7.5	36.0	Mod	0.5	0.8	R_{SS}	NWT/YT transboundary population. High weight of evidence that current range is self- sustaining with potential resilience given increasing trend, population size above critical, and moderate total disturbance comprised primarily of fire.	Current Range and Consider Resilience	3, 4, 11	33, 35, 50, 51, 52, 53, 165, 170
6	NWT Sahtu	unknown	unknown	0.5	2000	Above Critical	0.5	20.4	4.6	23.4	Low	0.7	0.6	R_{SS}	Weight of evidence suggests current range is self-sustaining with potential resilience, given large population and low total disturbance. Trend data required.	Current Range and Consider Resilience	3, 4, 5, 11	35, 36, 37, 51, 52, 53, 54, 55, 56, 57, 58, 59, 68, 170
7	NWT North Slave	unknown	unknown	0.5	700	Above Critical	0.5	36.0	1.2	36.9	Mod	0.5	0.5	R_{SS}/R_{NSS}	Equal weight of evidence that current range may or may not be self-sustaining, given large population size with moderate total disturbance, but unknown trend. Very low anthropogenic disturbance. Trend data required.	Current Range	4, 5	52, 59, 60, 63, 68, 69
8	NWT Dehcho (N/SW)	likely declining	decline	0.1	2000	Above Critical	0.5	28.2	17.7	43.3	Mod	0.5	0.4	R_{NSS}	Weight of evidence suggests current range is not self-sustaining given suspected decline and moderate total disturbance. Anthropogenic disturbance is low. Additional trend data required.	Current Range and Improved Conditions	4, 12	51, 55, 56, 58, 59, 60, 62, 63, 64, 65, 66, 182

#	Local Population[1] Or Unit of Analysis	Assessment Criteria											Integrated Probability (P)	Range Assessment[3]	NOTES	Proposed Critical Habitat Identification	Ecozone	Ecoregion
		Population Trend			Population Size			Range Disturbance										
		Reported[2]	Category	Individual Probability	Reported[2]	Category	Individual Probability	Fire%	Anthro-pogenic %	Total %	Category	Individual Probability						
9	NWT South Slave/SE Dehcho	likely declining	decline	0.1	600	Above Critical	0.5	34.6	16.0	46.7	Mod	0.5	0.4	R_{NSS}	Weight of evidence suggests current range is not self-sustaining given suspected decline and moderate total disturbance. Anthropogenic disturbance is low. Additional trend data required.	Current Range and Improved Conditions	4, 9	64, 65, 136
10	BC Maxhamish	unknown	unknown	0.5	306	Above Critical	0.5	1.0	45.9	46.4	Mod	0.5	0.5	R_{SS}/R_{NSS}	Equal weight of evidence that current range may or may not be self-sustaining given unknown trend, large population and moderate total disturbance. Total disturbance is at the high-end of moderate class, with 46% anthropogenic disturbance. Trend data required.	Current Range	4	64, 65
11	BC Calendar	unknown	unknown	0.5	291	Small	0.3	9.4	47.4	52.2	High	0.3	0.4	R_{NSS}	Weight of evidence suggests current range is not self-sustaining given small population and high total disturbance. Anthropogenic disturbance at 47% suggests need for improved condition. Trend data required.	Current Range and Improved Conditions	4	64, 65
12	BC Snake Sahtaneh	declining	decline	0.1	365	Above Critical	0.5	14.2	56.3	63.1	Very High	0.1	0.2	R_{NSS}	High weight of evidence that current range is not self-sustaining given declining trend and very high total disturbance. Anthropogenic disturbance at 56% suggests need for improved condition.	Current Range and Improved Conditions	4	64, 65

#	Local Population[1] Or Unit of Analysis	Assessment Criteria											Integrated Probability (P)	Range Assessment[3]	NOTES	Proposed Critical Habitat Identification	Ecozone	Ecoregion
		Population Trend			Population Size			Range Disturbance										
		Reported[2]	Category	Individual Probability	Reported[2]	Category	Individual Probability	Fire%	Anthro-pogenic %	Total %	Category	Individual Probability						
13	BC Parker Core	unknown	unknown	0.5	24	Very Small	0.1	0.5	31.1	34.6	Mod	0.5	0.4	R_{NSS}	Weight of evidence suggests current range is not self-sustaining given very small population and moderate total disturbance, with 31% anthropogenic. Trend data required.	Current Range	4	64
14	BC Prophet Core	unknown	unknown	0.5	54	Small	0.3	0.2	71.8	71.9	Very High	0.1	0.3	R_{NSS}	Weight of evidence suggests current range is not self-sustaining given small population and very high total disturbance. Anthropogenic disturbance at 71% indicates need for improved condition. Trend data required.	Current Range and Improved Conditions	4	64
15	AB Deadwood	suspect declining	decline	0.1	40	Very Small	0.1	10.3	63.1	66.5	Very High	0.1	0.1	R_{NSS}	High weight of evidence that current range is not self-sustaining given suspected decline, very small population and very high total disturbance. Anthropogenic disturbance at 63% suggests need for improved condition. Additional trend data required.	Current Range and Improved Conditions	9	137, 138
16	AB Caribou Mountains	rapidly declining (λ = 0.92)	decline	0.1	400-500	Above Critical	0.5	43.8	24.0	54.7	High	0.3	0.3	R_{NSS}	Weight of evidence suggests current range is not self-sustaining given rapid decline and high total disturbance.	Current Range and Improved Conditions	4, 9	64, 65, 138

#	Local Population[1] Or Unit of Analysis	Assessment Criteria											Integrated Probability (P)	Range Assessment[3]	NOTES	Proposed Critical Habitat Identification	Ecozone	Ecoregion
		Population Trend			Population Size			Range Disturbance										
		Reported[2]	Category	Individual Probability	Reported[2]	Category	Individual Probability	Fire%	Anthro-pogenic %	Total %	Category	Individual Probability						
17	AB Red Earth	rapidly declining (λ = 0.94)	decline	0.1	250-350	Small	0.3	28.8	39.0	58.6	High	0.3	0.2	R_{NSS}	Weight of evidence suggests current range is not self-sustaining given declining LP and high disturbance. anthropogenic disturbance at 39% suggests potential need for improved conditions.	Current Range and Improved Conditions	9	136, 139, 142
18	AB West Side Athabasca River	declining (λ = 0.99)	decline	0.1	300-400	Above Critical	0.5	4.1	42.7	44.8	Mod	0.5	0.4	R_{NSS}	Weight of evidence suggests current range is not self-sustaining given declining trend and moderate total disturbance. Anthropogenic disturbance at 43% suggests need for improved conditions.	Current Range and Improved Conditions	9	139, 142
19	AB Richardson	unknown	unknown	0.5	<100	Small	0.3	19.7	19.9	37.1	Mod	0.5	0.4	R_{NSS}	Weight of evidence suggests current range is not self-sustaining given small population and moderate total disturbance. Anthropogenic disturbance is low. Trend data required.	Current Range	9	136, 139
20	AB East Side Athabasca River	declining (λ = 0.95)	decline	0.1	150-250	Small	0.3	26.5	49.5	61.9	Very High	0.1	0.2	R_{NSS}	High weight of evidence that current range is not self-sustaining given small, declining population and very high total disturbance. Anthropogenic disturbance at 49% suggests need for improved conditions.	Current Range and Improved Conditions	9	139, 142, 149

#	Local Population[1] Or Unit of Analysis	Assessment Criteria											Integrated Probability (P)	Range Assessment[3]	NOTES	Proposed Critical Habitat Identification	Ecozone	Ecoregion
		Population Trend			Population Size			Range Disturbance										
		Reported[2]	Category	Individual Probability	Reported[2]	Category	Individual Probability	Fire%	Anthro-pogenic %	Total %	Category	Individual Probability						
21	AB Cold Lake Air Weapons Range	rapidly declining (λ = 0.93)	decline	0.1	100-150	Small	0.3	35.0	45.7	65.9	Very High	0.1	0.2	R_{NSS}	High weight of evidence that current range is not self-sustaining given small, declining population and very high total disturbance. Anthropogenic disturbance at 46% suggests need for improved conditions.	Current Range and Improved Conditions	9	139
22	AB Nipisi	unknown	unknown	0.5	60-70	Small	0.3	6.0	46.1	49.9	High	0.3	0.4	R_{NSS}	Weight of evidence suggests current range is not self-sustaining given small population and high total disturbance. Anthropogenic disturbance at 46% suggests need for improved condition. Trend data required.	Current Range and Improved Conditions	9	139, 142
23	AB Slave Lake	unknown	unknown	0.5	75	Small	0.3	46.8	67.7	81.9	Very High	0.1	0.3	R_{NSS}	Weight of evidence suggests current range is not self-sustaining given small population and very high total disturbance. Anthropogenic disturbance at 68% suggests need for improved condition. Trend data required.	Current Range and Improved Conditions	9	138, 139, 145
24	AB Little Smoky	Rapidly declining (λ = 0.89)	decline	0.1	80	Small	0.3	0.2	81.5	81.5	Very High	0.1	0.2	R_{NSS}	High weight of evidence that current range is not self-sustaining given small, rapidly declining population and very high total disturbance. Anthropogenic disturbance at 82% strongly suggests need for improved conditions.	Current Range and Improved Conditions	9, 14	145, 207

#	Local Population[1] Or Unit of Analysis	Assessment Criteria											Integrated Probability (P)	Range Assessment[3]	NOTES	Proposed Critical Habitat Identification	Ecozone	Ecoregion
		Population Trend			Population Size			Range Disturbance										
		Reported[2]	Category	Individual Probability	Reported[2]	Category	Individual Probability	Fire%	Anthro-pogenic %	Total %	Category	Individual Probability						
25	SK Davy-Athabasca	unknown	unknown	0.5	310	Above Critical	0.5	34.6	1.1	35.4	Mod	0.5	0.5	R_{SS}/R_{NSS}	Equal weight of evidence that current range may or may not be self-sustaining given unknown trend with large population size and moderate total disturbance. Anthropogenic disturbance is extremely low; disturbance is by fire. Trend data required.	Current Range	5, 6	69, 87
26	SK Clearwater	unknown	unknown	0.5	425	Above Critical	0.5	53.6	1.2	54.0	High	0.3	0.4	R_{NSS}	Weight of evidence suggests current range is not self-sustaining given high total disturbance, with unknown trend. Large population size and extremely low anthropogenic disturbance (1.2%) suggests population may be self-sustaining. Trend data required.	Current Range	5, 6, 9	69, 71, 87, 88, 139
27	SK Highrock-Key	unknown	unknown	0.5	1060	Above Critical	0.5	45.6	3.0	47.3	Mod	0.5	0.5	R_{SS}/R_{NSS}	Equal probability that current range may or may not be self-sustaining given large population size and moderate disturbance. Total disturbance is at the high-end of the moderate class, but anthropogenic disturbance is very low (4%), suggesting a self-sustaining designation. Trend data required.	Current Range	5, 6, 9	71, 87, 88, 139

#	Local Population[1] Or Unit of Analysis	Assessment Criteria											Integrated Probability (P)	Range Assessment[3]	NOTES	Proposed Critical Habitat Identification	Ecozone	Ecoregion
		Population Trend			Population Size			Range Disturbance										
		Reported[2]	Category	Individual Probability	Reported[2]	Category	Individual Probability	Fire%	Anthro-pogenic %	Total %	Category	Individual Probability						
28	SK Steephill-Foster	unknown	unknown	0.5	1075	Above Critical	0.5	38.6	1.9	39.9	Mod	0.5	0.5	R_{SS}/R_{NSS}	Equal weight of evidence that current range may or may not be self-sustaining given large population size and moderate total disturbance, with unknown trend. Total disturbance is at the high-end of the moderate class, but anthropogenic disturbance is extremely low (2%), suggestion a self-sustaining designation. Trend data required.	Current Range	6	88
29	SK Primrose-Cold Lake	unknown	unknown	0.5	350	Above Critical	0.5	38.6	19.5	52.0	High	0.3	0.4	R_{NSS}	Weight of evidence suggests current range is not self-sustaining given high total disturbance. Disturbance is at the high-end of the moderate class; anthropogenic component is relatively low (14%). Trend data required.	Current Range	6, 9	88, 139, 149
30	SK Smoothstone-Wapawekka	declining w/ hab change	decline	0.1	700	Above Critical	0.5	14.7	18.2	29.5	Mod	0.5	0.4	R_{NSS}	Weight of evidence suggests current range is not self-sustaining given declining trend and moderate total disturbance. Conditions require improvement.	Current Range and Improved Conditions	6, 9	88, 139, 148, 149
31	SK Suggi-Amisk-Kississing	unknown	unknown	0.5	430	Above Critical	0.5	12.6	7.9	19.8	Low	0.7	0.6	R_{SS}	Weight of evidence suggests that current range is self -sustaining and potentially resilient given population size above critical and very low total disturbance. Trend data required.	Current Range and Consider Resilience	6, 9	88, 148

#	Local Population[1] Or Unit of Analysis	Assessment Criteria											Integrated Probability (P)	Range Assessment[3]	NOTES	Proposed Critical Habitat Identification	Ecozone	Ecoregion
		Population Trend			Population Size			Range Disturbance										
		Reported[2]	Category	Individual Probability	Reported[2]	Category	Individual Probability	Fire%	Anthro-pogenic %	Total %	Category	Individual Probability						
32	SK Pasquia-Bog	Threat of decline	decline	0.1	30	Very Small	0.1	12.1	25.5	35.6	Mod	0.5	0.2	R_{NSS}	High weight of evidence that current range is not self-sustaining given a very small population, suspected decline and moderate total disturbance. Additional trend data required.	Current Range and Improved Conditions	9	139, 148, 149, 155
33	MB Kississing	stable	stable	0.7	50-75	Small	0.3	39.2	12.5	50.8	High	0.3	0.4	R_{NSS}	Weight of evidence suggests that current range is not self-sustaining given small population with high total disturbance. Anthropogenic component of disturbance is low (13%). Additional trend data required.	Current Range	6	88
34	MB Naosap	stable	stable	0.7	100-200	Small	0.3	15.0	28.1	41.2	Mod	0.5	0.5	R_{SS}/R_{NSS}	Equal weight of evidence suggests current range is marginal given small, stable population and moderate total disturbance. Anthropogenic component of disturbance is moderate (28%). Additional trend data required.	Current Range	6, 9	88, 148
35	MB Reed	stable	stable	0.7	100-150	Small	0.3	6.9	22.0	28.0	Mod	0.5	0.5	R_{SS}/R_{NSS}	Equal weight of evidence suggests current range is marginal given small, stable population and moderate total disturbance. Additional trend data required.	Current Range	6, 9	88, 148

#	Local Population[1] Or Unit of Analysis	Assessment Criteria											Integrated Probability (P)	Range Assessment[3]	NOTES	Proposed Critical Habitat Identification	Ecozone	Ecoregion
		Population Trend			Population Size			Range Disturbance										
		Reported[2]	Category	Individual Probability	Reported[2]	Category	Individual Probability	Fire%	Anthro-pogenic %	Total %	Category	Individual Probability						
39	MB William Lake	stable	stable	0.7	25-40	Very Small	0.1	4.1	24.2	27.6	Mod	0.5	0.4	R_{NSS}	Weight of evidence suggests current range is not self-sustaining given very small population and moderate total disturbance. Disturbance is primarily anthropogenic (24%). Additional trend data required.	Current Range	9	148
37	MB Wapisu	stable	stable	0.7	100-125	Small	0.3	10.6	12.9	23.3	Low	0.7	0.6	R_{SS}	Weight of evidence suggests current range is self-sustaining and potentially resilient given stable trend and low disturbance. Small population presents risk. Additional trend data required.	Current Range and Consider Resilience	6	88, 89
36	MB The Bog	stable	stable	0.7	50-75	Small	0.3	10.0	19.6	28.1	Mod	0.5	0.5	R_{SS}/R_{NSS}	Equal weight of evidence suggests current range is marginal given small, stable population and moderate total disturbance. Additional trend data required.	Current Range	6, 9	88, 89, 148
38	MB Wabowden	stable	stable	0.7	200-225	Small	0.3	16.9	15.2	29.3	Mod	0.5	0.5	R_{SS}/R_{NSS}	Equal weight of evidence suggests current range is marginal given small, stable population and moderate total disturbance. Additional trend data required.	Current Range	6, 9	89, 148
40	MB North Interlake	stable	stable	0.7	50-75	Small	0.3	3.2	14.7	16.6	Low	0.7	0.6	R_{SS}	Weight of evidence suggests current range is self-sustaining given stable trend and low disturbance. Potential resilience is indicated however risk associated with small population (50-75) should be considered. Additional trend data required.	Current Range and Consider Resilience	9	148, 155

#	Local Population[1] Or Unit of Analysis	Assessment Criteria											Integrated Probability (P)	Range Assessment[3]	NOTES	Proposed Critical Habitat Identification	Ecozone	Ecoregion
		Population Trend			Population Size			Range Disturbance										
		Reported[2]	Category	Individual Probability	Reported[2]	Category	Individual Probability	Fire%	Anthro-pogenic %	Total %	Category	Individual Probability						
41	MB Atikaki-Berens	stable	stable	0.7	300-500	Above Critical	0.9	25.9	5.4	28.2	Mod	0.5	0.7	R_{SS}	Weight of evidence suggests current range is self-sustaining with potential resilience given large, stable population and moderate total disturbance. Anthropogenic disturbance is very low (5%). Additional trend data required.	Current Range and Consider Resilience	6, 9	90, 148
42	MB Owl Flintstone	stable	stable	0.7	71-85	Small	0.3	23.9	23.8	43.8	Mod	0.5	0.5	R_{SS}/R_{NSS}	Equal weight of evidence suggests current range is marginal given small, stable LP and moderate total disturbance. Current conditions should be maintained.	Current Range	6	90
43	Manitoba (Remainder of boreal caribou in MB)	stable	stable	0.7	775-1585	Above Critical	0.9	20.5	9.9	29.3	Mod	0.5	0.7	R_{SS}	Delineation of local populations or units of analysis has not yet occurred. Weight of evidence suggests the extent of occurrence is self-sustaining given large, stable population and moderate total disturbance. Resilience can not be considered until units of analysis are defined and reassessed.	Current Range	6, 9, 15	88, 89, 90, 139, 148, 155, 216

#	Local Population[1] Or Unit of Analysis	Assessment Criteria											Integrated Probability (P)	Range Assessment[3]	NOTES	Proposed Critical Habitat Identification	Ecozone	Ecoregion
		Population Trend			Population Size			Range Disturbance										
		Reported[2]	Category	Individual Probability	Reported[2]	Category	Individual Probability	Fire%	Anthro-pogenic %	Total %	Category	Individual Probability						
44	ON North East Superior	decreasing	decline	0.1	42	Very Small	0.1	0.0	0.0	0.0	Very Low	0.9	0.4	R_{NSS}	Weight of evidence suggests current range is not self-sustaining given a very small and declining population. Very low disturbance suggests other factors are contributing to decline. Range extent, other measures of habitat condition, and non-habitat factors should be assessed.	Current Range and Improved Conditions (Extent)	6	94, 96, 97
45	ON Michipicoten	increasing	increase	0.9	200	Small	0.3	0.0	20.8	20.8	Low	0.7	0.6	R_{SS}	Island Population. Weight of evidence suggests current range is self-sustaining given a small, increasing population and low total disturbance. Potential resilience is indicated however risk associated with small population should be considered.	Current Range and Consider Resilience	6	96
46	ON Slate Islands	unknown	unknown	0.5	250	Small	0.3	0.0	0.0	0.0	Very Low	0.9	0.6	R_{SS}	Island Population. Weight of evidence suggests current range is self-sustaining given small population and very low total disturbance. Trend data required before resilience can be assessed.	Current Range	6	94

#	Local Population[1] Or Unit of Analysis	Assessment Criteria											Integrated Probability (P)	Range Assessment[3]	NOTES	Proposed Critical Habitat Identification	Ecozone	Ecoregion
		Population Trend			Population Size			Range Disturbance										
		Reported[2]	Category	Individual Probability	Reported[2]	Category	Individual Probability	Fire%	Anthro-pogenic %	Total %	Category	Individual Probability						
47	Ontario (Estimate of total number of forest-dwelling ecotype)	unknown	unknown	0.5	~5000	Above Critical	0.5	12.6	6.3	18.5	Low	0.7	0.6	R_{SS}	Delineation of local populations or units of analysis has not yet occurred; extent of occurrence was evaluated. Weight of evidence suggests the extent of occurrence is self-sustaining given large population and low disturbance. Population units must be identified and evaluated before resilience can be assessed. Pattern of disturbance exhibits north/south gradient, with higher anthropogenic disturbance in southern portion of extent. Trend data required.	Current Range	6, 15	89, 90, 91, 94, 95, 96, 216, 217
48	QC Val d'Or	declining	decline	0.1	30	Very Small	0.1	0.2	50.3	50.3	High	0.3	0.2	R_{NA}	High weight of evidence that current range is not self-sustaining given very small, declining population and high total disturbance. Anthropogenic disturbance at 50% suggests need for improved condition.	Current Range and Improved Conditions	6	96

#	Local Population[1] Or Unit of Analysis	Assessment Criteria											Integrated Probability (P)	Range Assessment[3]	NOTES	Proposed Critical Habitat Identification	Ecozone	Ecoregion
		Population Trend			Population Size			Range Disturbance										
		Reported[2]	Category	Individual Probability	Reported[2]	Category	Individual Probability	Fire%	Anthro-pogenic %	Total %	Category	Individual Probability						
49	QC Charlevoix	stable	stable	0.7	75	Small	0.3	3.6	68.4	70.3	Very High	0.1	0.4	R_{NSS}	Weight of evidence suggests current range is not self-sustaining given small population and very high total disturbance. Stable trend with very high anthropogenic disturbance (68%) indicates need to better understand the nature of disturbance in this area. Trend should be closely monitored.	Current Range	6	99
50	QC Pipmuacan	stable	stable	0.7	134	Small	0.3	10.5	45.7	53.1	High	0.3	0.4	R_{NSS}	Weight of evidence suggests current range is not self-sustaining given small population and high total disturbance. Stable trend indicates a need to better understand the nature of disturbance in this area. Trend should be closely monitored.	Current Range	6	101
51	QC Manouane	stable	stable	0.7	358	Above Critical	0.9	17.9	10.2	25.4	Mod	0.5	0.7	R_{SS}	Weight of evidence suggests current range is self-sustaining with potential resilience given large, stable population and moderate total disturbance. Anthropogenic component of disturbance is very low (10%).	Current Range and Consider Resilience	6	101
52	QC Manicouagan	increasing	increase	0.9	181	Small	0.3	3.0	28.8	30.5	Mod	0.5	0.6	R_{SS}	Weight of evidence suggests current range is self-sustaining given increasing trend and moderate total disturbance. Potential resilience is indicated; risk associated with small population should be considered.	Current Range and Consider Resilience	6	101

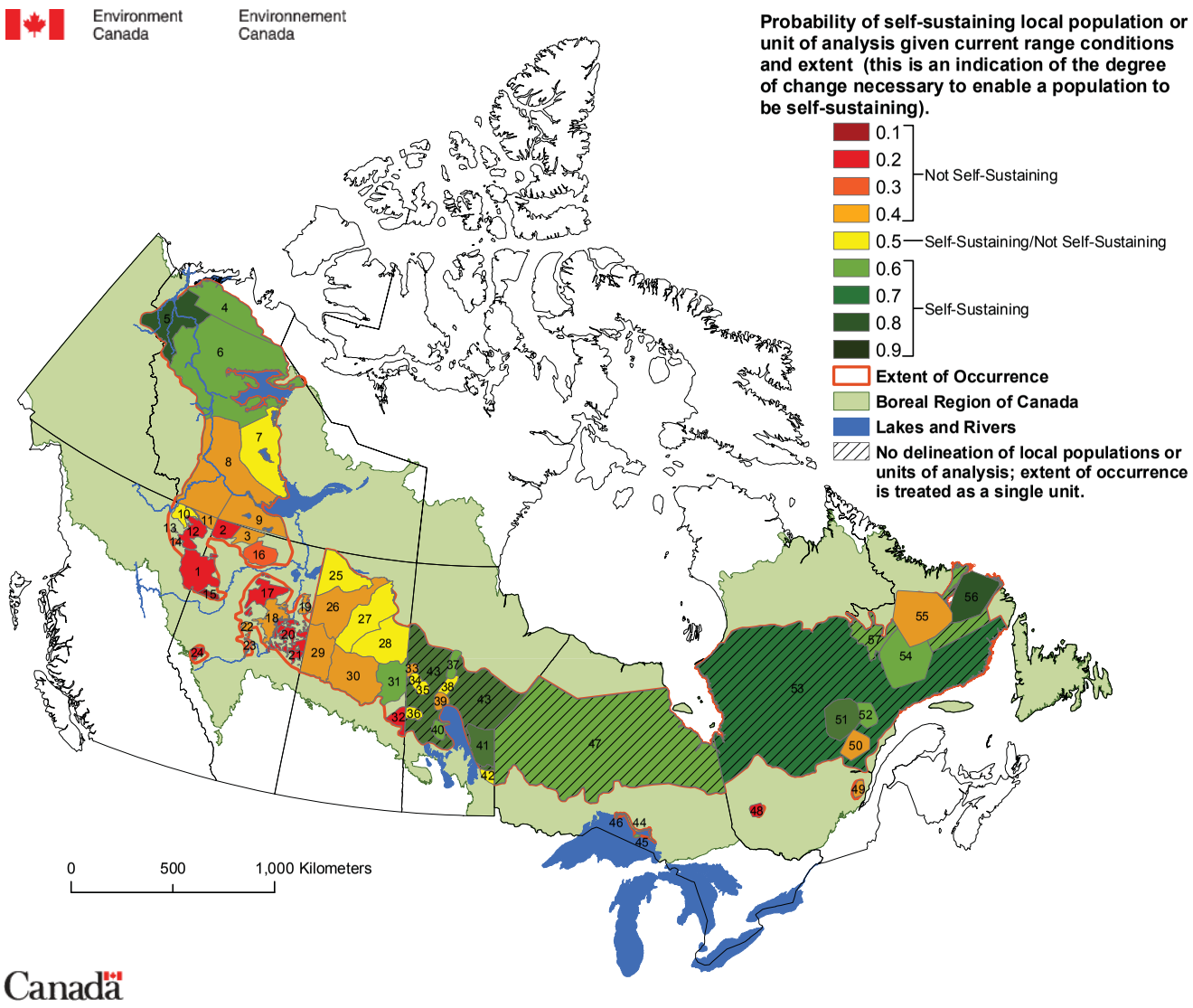
#	Local Population[1] Or Unit of Analysis	Assessment Criteria											Integrated Probability (P)	Range Assessment[3]	NOTES	Proposed Critical Habitat Identification	Ecozone	Ecoregion
		Population Trend			Population Size			Range Disturbance										
		Reported[2]	Category	Individual Probability	Reported[2]	Category	Individual Probability	Fire%	Anthro-pogenic %	Total %	Category	Individual Probability						
53	Quebec (Remainder of boreal caribou in QC)	suspected stable	stable	0.7	6000-12000	Above Critical	0.9	16.7	12.9	25.9	Mod	0.5	0.7	R_{SS}	Delineation of population units has not yet occurred; extent of occurrence was evaluated. Weight of evidence suggests the current extent of occurrence is self-sustaining given a very large, stable population and moderate total disturbance. Units of analysis must be defined and evaluated before resilience can be assessed. Additional trend data required.	Current Range	5, 6, 15	72, 73, 74, 78, 80, 96, 99, 100, 101, 103, 217
54	LAB Lac Joseph	unknown	unknown	0.5	1101	Above Critical	0.5	4.1	1.9	5.9	Very Low	0.9	0.6	R_{SS}	Weight of evidence suggests current range is self-sustaining and potentially resilient given large population and very low total disturbance. Trend data required.	Current Range and Consider Resilience	5, 6	78, 80, 84, 101, 103, 105
55	LAB Red Wine Mountain	Declining	decline	0.1	97	Small	0.3	2.4	8.5	10.8	Very Low	0.9	0.4	R_{NSS}	Weight of evidence suggests current range is not self-sustaining given small, declining population. Very low disturbance indicates that other measures of habitat condition and non-habitat factors should be assessed and addressed. Human-caused mortality and other forms of anthropogenic disturbance may be significant.	Current Range	5, 6	78, 80, 84, 85, 105

#	Local Population[1] Or Unit of Analysis	Assessment Criteria											Integrated Probability (P)	Range Assessment[3]	NOTES	Proposed Critical Habitat Identification	Ecozone	Ecoregion
		Population Trend			Population Size			Range Disturbance										
		Reported[2]	Category	Individual Probability	Reported[2]	Category	Individual Probability	Fire%	Anthro-pogenic %	Total %	Category	Individual Probability						
56	LAB Mealy Mountain	stable	stable	0.7	2106	Above Critical	0.9	0.2	0.4	0.6	Very Low	0.9	0.8	R_{SS}	Weight of evidence suggests current range is self-sustaining with potential resilience given very large, stable population and very low total disturbance.	Current Range and Consider Resilience	5, 6	77, 79, 80, 82, 104, 105
57	Labrador (Remainder of boreal caribou in LAB)	unknown	unknown	0.5	unknown	Unknown	0.5	5.0	5.3	10.0	Very Low	0.9	0.6	R_{SS}	Weight of evidence suggests that current range is self-sustaining given very low total disturbance. Population trend and size data required before resilience can be assessed.	Current Range	5, 6	74, 75, 78, 79, 80, 82, 101, 103, 104, 105

To support Results interpretation, Figure 9 illustrates the integrated probability assignments to each local population, and the assessment of the most plausible outcome relative to the likelihood that the current range is self-sustaining. It is important to note that the integrated probability assignment should not be interpreted as an absolute probability of persistence, due both to variation in the generation of probabilities for each criterion, and the method by which the criteria were integrated. However, it is a weight of evidence measure relative to the question of whether a given range (the spatial delineation of a local population or unit of analysis) is likely to support a self-sustaining population as a function of the current range and population conditions. Further, it is not an indication of whether a population is recoverable or not; rather, it is an expression of the degree of habitat recovery or management intervention necessary to restore the population's ability to be self-sustaining (e.g., to persist without the need for ongoing management intervention; Section 2.2.4).

The resultant proposed Critical Habitat Identification for the 57 recognized local populations or units of analysis considered in the decision analysis was:

- Current Range for 25 local populations or units of analysis;
- Current Range and Improved Conditions for 21 local populations or units of analysis;
- Current Range and Consider Resilience for 11 local populations or units of analysis.



Number	Local Population/Unit of Analysis	Integrated Probability
1	AB/BC Chinchaga	0.2
2	AB/NWT Bistcho	0.2
3	AB/NWT Steen River/Yates	0.4
4	NWT Inuvialuit	0.6
5	NWT/YK Gwich'in	0.8
6	NWT Sahtu	0.6
7	NWT North Slave	0.5
8	NWT Dehcho (N/SW)	0.4
9	NWT South Slave/SE Dehcho	0.4
10	BC Maxhamish	0.5
11	BC Calendar	0.4
12	BC Snake Sahtaneh	0.2
13	BC Parker Core	0.4
14	BC Prophet Core	0.3
15	AB Deadwood	0.1
16	AB Caribou Mountains	0.3
17	AB Red Earth	0.2
18	AB West Side Athabasca River	0.4
19	AB Richardson	0.4
20	AB East Side Athabasca River	0.2
21	AB Cold Lake Air Weapons Range	0.2
22	AB Nipisi	0.4
23	AB Slave Lake	0.3
24	AB Little Smoky	0.2
25	SK Daw-Athabasca	0.5
26	SK Clearwater	0.4
27	SK Highrock-Key	0.5
28	SK Steephill-Foster	0.5
29	SK Primrose-Cold Lake	0.4
30	SK Smoothstone-Wapawekka	0.4
31	SK Suggi-Amisk-Kississing	0.6
32	SK Pasquia-Bog	0.2
33	MB Kississing	0.4
34	MB Naosap	0.5
35	MB Reed	0.5
36	MB The Bog	0.5
37	MB Wapisu	0.6
38	MB Wabowden	0.5
39	MB William Lake	0.4
40	MB North Interlake	0.6
41	MB Atikaki-Berens	0.7
42	MB Owl-Flintstone	0.5
43	Manitoba	0.7
44	ON North East Superior	0.4
45	ON Michipicoten	0.6
46	ON Slate Islands	0.6
47	Ontario	0.6
48	QC Val d'Or	0.2
49	QC Charlevoix	0.4
50	QC Pipmuacan	0.4
51	QC Manouane	0.7
52	QC Manicouagan	0.6
53	Quebec	0.7
54	LAB Lac Joseph	0.6
55	LAB Red Wine Mountain	0.4
56	LAB Mealy Mountain	0.8
57	Labrador	0.6

Figure 9: Probability that current range will support a self-sustaining population of boreal caribou, based on integrated probability assignments that considered population trend and size, and level of disturbance associated with anthropogenic activities and fire (see Section 2.6.5). This Figure is not an illustration of whether a population is recoverable or not, rather, it is an indication of the degree of habitat change necessary to enable a population to be self-sustaining (e.g. to persist without the need for ongoing management intervention).

4.0 DISCUSSION

4.1 Interpretation of Proposed Critical Habitat Outcomes

The application of the Critical Habitat Framework and associated Decision Analysis provided an assessment of all local populations or units of analysis within the current distribution of boreal caribou in Canada. Like habitat selection by caribou, Critical Habitat identification is a hierarchical process that must consider needs across multiple spatial and temporal scales. The national analysis focused on the scale most appropriate for considering the persistence of local populations – the local population range. Factors operating at this scale act as constraints on population dynamics, and determine whether or not a population is likely to be sustained. It has been previously demonstrated, and is implicit in this evaluation, that predation acts as a limiting factor for boreal caribou populations. Conditions present in the range of a local population determine the type, amount and distribution of habitat for caribou and other prey species with shared predators on caribou, and hence the abundance and distribution of these predators within the range. As a result, the premise of this evaluation – that Critical Habitat is most appropriately identified at the scale of the local population range – is not equivalent to saying that every element within the range is critical to support a self-sustaining boreal caribou population, in all instances. However, it does provide a spatial delineation of the area of consideration when assessing the current conditions and quantifying risk relative to the recovery goal of maintaining or restoring self-sustaining local populations, for assigning potential Critical Habitat outcomes, and for planning for the management of the habitat conditions necessary to support population persistence (e.g. maintaining the functional attributes of the range). Refinement of needs at finer spatial scales over specific timeframes is possible within the constraints of the range level designation. Guidance on important considerations is provided in the Habitat Narrative (Appendix 6.3). General parameters associated with Critical Habitat outcomes are described below.

For each local population or unit of analysis, proposed Critical Habitat was expressed as one of three outcomes, based on weight of evidence from the integrated assessment (Range Self-Sustaining or Range Not Self-Sustaining; Section 2.6.5), and application of decision rules (Section 2.6.6). These outcomes included: Current Range, Current Range and Improved Conditions, or Current Range and Consider Resilience. An interpretation of each is provided below.

Current Range: Current range condition and extent are required to maintain potential for self-sustaining population. Further degradation of the current range may compromise the ability to meet the recovery goal. Five scenarios occurred under this outcome.

1) Local populations or units of analysis for several large and relatively continuous areas within the current distribution of boreal caribou have yet to be been delineated. The present assessment considered the extent of occurrence within the relevant jurisdiction as a single unit of analysis. In some cases, this indicated a moderate to high probability of

the area supporting a self-sustaining population (P≥0.6). However, caribou in the area may consist of more than one local population. As a result, the mean condition among these populations could be masking important variation across the extent of the area considered, with implications for population sustainability and critical habitat evaluation. Population units should be identified and assessed, which could lead to alternative outcomes.

2) The uncertainty around population condition (trend unknown) in combination with moderate disturbance did not provide a clear indication of whether the current range is adequate to support a self–sustaining population (P=0.5). The first priority is to address the information gaps, then to re-assess the local population.

3) An integrated probability of P=0.5 when all parameters were known was interpreted as a marginal situation. The criteria assigned the greatest risk (lowest individual probability) should be examined, and additional local information considered.

4) Weight of evidence supported Range Not Self-Sustaining (P≤0.4) for a number of local populations, but improvements to range condition were not clearly indicated, because either (a) disturbance was very low or low, or (b) population trend was stable. Maintenance of current range in conjunction with (a) investigation of other factors negatively affecting the population, or (b) close monitoring of trend for possible lag effects is recommended. Situations falling under (b) should also be examined to better understand potential resilience to different forms of disturbance.

5) In several cases, weight of evidence supported Range Not Self-Sustaining (P≤0.4), but the total disturbance was comprised primarily of fire (e.g., the amount of anthropogenic disturbance was low or very low), and population trend was unknown. Improvements to range condition were not clearly indicated given that percent range burned explained little variation in the relationship underlying the disturbance categories, at least up to upper end of the moderate disturbance level. A better understanding of the differential effects of fire and anthropogenic disturbances on caribou demography was identified as an area for further study.

Current Range and Improved Conditions: Current range conditions and/or extent would need to be improved to restore the potential to support a self-sustaining population. Further degradation of the range may have serious consequences for local population persistence. Three scenarios occurred under this outcome.

1) For most local populations or units of analysis with weight of evidence supporting Range Not Self-Sustaining (P≤0.4), levels of anthropogenic disturbance in conjunction with population trend suggest that recovery efforts are required to restore conditions that support persistence (e.g., a reduction in anthropogenic disturbance and recovery of disturbed habitat is necessary). The nature and magnitude of restoration could be determined through spatial population modeling combined with dynamic landscape simulation.

2) For several local populations or units of analysis, a high level of total disturbance was comprised primarily of fire, with low levels of anthropogenic disturbance, but was associated with a declining population trend. The percent area burned fell outside the range of values included in the meta-analysis (Appendix 6.5), thus inference based on the documented relationship was weak. Natural recovery may be sufficient to improve range condition, but additional stressors on the population should be considered, including potential interactions between fire and anthropogenic disturbance at high levels of fire, and non-habitat factors (e.g., mortality sources).

3) In two cases, the total measured disturbance levels were low or very low, but a negative population trend indicated the need for improved range conditions and/or extent. Therefore, aspects of habitat condition other than disturbance may be affecting the local population. Non-habitat factors such as poaching, reduction in habitat quality for example low flying aircraft or other forms of disturbance not included here, and population health (disease and parasites) should also be considered. It is also possible that the current range has been reduced in extent such that it is insufficient to support a self-sustaining local population, and restoration of adjacent habitat is required to enable the population to persist. Population isolation and the need to restore connectivity should be examined.

Current Range and Consider Resilience: Current range condition and extent may be sufficient to absorb additional disturbance while maintaining capacity to support a self-sustaining population. Two scenarios occurred under this outcome.

1) Local populations or units of analysis with large or very large population size (e.g., above critical based on the non-spatial population viability analysis), stable or increasing population trend, and levels of total disturbance that were moderate, low or very low. This situation presents the least risk with respect to meeting the population objective of the recovery goal, and represents the greatest potential to apply active adaptive management to evaluate resilience (e.g., experimental management to test alternate hypotheses regarding population responses to different types and levels of disturbance).

2) Local populations or units of analysis with small population size, stable or increasing trends, and low or very low levels of total disturbance. This situation also represents a relatively high probability of achieving the recovery goal. However, the inherent risks associated with a small population size warrant a cautious approach when considering potential resilience to any additional disturbance. Nevertheless, this situation may also present an opportunity for active adaptive management.

One of the guiding principles of the science review was to recognize and address the dynamic nature of boreal systems and resultant effects on boreal caribou habitat in time and over space. Boreal landscapes are naturally dynamic, driven by processes such as fire and other disturbances and resultant forest succession. Similar landscape dynamics may be associated with certain types of anthropogenic disturbances. Recognition of such dynamics is commensurate with the scale of consideration for Critical Habitat identification – the

local population range – which reflects multi-decadal dynamics of the system and species response. However, neither the spatial nor temporal dynamics within a local population range were directly addressed by this evaluation.

The non-spatial population viability analysis considered temporal components of persistence associated with demographic, and to some extent, environmental stochasticity. As well, the 50-year window for area burned considered by the meta-analysis recognized in a limited way the dynamic properties of disturbance by fire, relative to habitat recovery and response by caribou. Nonetheless, the present evaluation represents a point-in-time assessment of the current range relative to the recovery goal of self-sustaining local populations.

Further elaboration of Critical Habitat outcomes for local populations can be achieved through spatial population viability analysis linked with dynamic landscape modelling (see Section 2.6.6 and Appendix 6.7). Incorporation of landscape dynamics is necessary to understand the conditions and management options associated with recovery (Current Range and Improved Conditions) and resilience (Current Range and Consider Resilience), as well as additional risks associated with present conditions (Current Range). Such evaluations may be undertaken with varying levels of complexity and concomitant requirements for data. It is clear from the present review that minimum data requirements could be met for most areas within the current distribution of boreal caribou in Canada, particularly when viewed in the context of adaptive management.

4.2 Decision Analysis and Adaptive Management

The Decision Tree provided a structured and transparent method to evaluate individual local populations and determine prior probabilities of alternative hypotheses regarding definition of Critical Habitat, through consideration of measurable criteria assigned to categorical states based on available quantitative data and published scientific information. The prior probabilities indicated the most plausible outcome, relative to probability of persistence, for each local population or unit of analysis. At each step in the Decision Tree, any assumptions made were explicitly described, and uncertainties were identified that could be addressed through a Schedule of Studies to improve understanding.

The approach to Critical Habitat identification applied here follows established methodologies for decision-analysis in operations research and management science. In this case, the objective function is population persistence, expressed as the set of conditions necessary to support self-sustaining local populations. Syntheses of existing information, evaluation of likely outcomes, and refinement of understanding are also fundamental components of the adaptive management framework. While a more detailed Decision Tree could be developed to elucidate the relationships among criteria (variables) and identify underlying mechanisms, the simple model considered here is a “white box” that can be easily applied, evaluated, and communicated with available information, and supports a science based component of the process leading to the potential final identification of proposed Critical Habitat across a spectrum of local population conditions.

The assignment of prior probabilities and their use in the identification of Critical Habitat represents a starting point in an adaptive management cycle (Figure 4). As uncertainties are addressed through the Schedule of Studies, and new information becomes available, local population assignments can be updated. The Decision Tree can also be interpreted as a Bayesian Decision Network (BDN). The assessment criteria are equivalent to nodes in a BDN, representing variables that can assume multiple states. Associated with each node is a probability table that expresses the likelihood of each state, conditional on the state of nodes that feed into it. Weightings could be assigned to nodes to represent the relative importance of the variable on the outcome. The current process does not address interactions among the criteria or their relative influence on outcomes, so no weightings were applied to the assessment criteria (population trend, population size, and range disturbance), nor were conditional probabilities assigned to individual criteria. However, estimation methods for generating these probabilities exist, and can be incorporated over time through the adaptive management process. Development of a more comprehensive BDN is recommended as part of the Schedule of Studies, to enhance understanding and provide a formal process for updating the prior probability distribution for the recovery goal of self-sustaining local populations.

4.3 Transition to Action Planning/Recovery Implementation

As previously noted, this national analysis and proposed identification of critical habitat was conducted at a spatial scale appropriate to addressing persistence of local populations, as per the recovery goal and objectives for this species. However, habitat selection by boreal caribou is hierarchical, and where/if deemed necessary, assessments may be further refined within local population ranges to identify the habitat necessary for the recovery of the species at finer temporal and spatial scales.

A variety of approaches could be applied at the local population level to define the degree of change required in range condition and/or extent to support persistence, the appropriate management strategies for maintaining conditions where range is currently self-sufficient, and the amount of additional disturbance that might be absorbed by local populations with potential resilience. For example, the probability of persistence over specified time frames can be further quantified using spatially explicit population viability analysis to model the fate of populations relative to changing habitat conditions, and to identify probable outcomes under a range of habitat scenarios. By linking spatially explicit population and landscape simulation models, dynamic elements of the system can be incorporated (see Appendix 6.7 – spatial PVA). Further meta-analyses could be applied across multiple populations to link current conditions (e.g., vegetation composition and structure), created by natural and anthropogenic factors, to population status, and predict future trends. Similarly, a retrospective approach could be used to explore conditions for persistence, by quantifying historic variation in natural systems and examining circumstances that have contributed to persistence, recognizing the uncertainty among persistence, historical disturbances, and habitat change. Such investigations could also yield insights into the differential effects of fire and anthropogenic disturbance on caribou demography; an important distinction when considering the application of such approaches to caribou management.

4.4 Conclusions

The Boreal Caribou Critical Habitat Science Review performed by EC was undertaken with the support of an independent Science Advisory Group that provided continuous peer-review throughout the process. Development of a Critical Habitat Framework and Decision Tree provided a formal structure for assembling and analyzing data relevant to Critical Habitat identification, and the foundation for continuous improvement of knowledge through the process of adaptive management. A weight of evidence approach was used to identify the most plausible outcome of combinations of population and habitat conditions relative to the recovery goal of self-sustaining local populations.

This report contains a proposed Critical Habitat identification, based on empirical science and inherent assumptions associated with the methodology used, for each of the spatial analytical units associated with each local population. Other factors such as the incorporation of Aboriginal and traditional knowledge (ATK), and the extent to which the assumptions taken in this report align with Critical Habitat policy directives, may influence any potential final identification of Critical Habitat in the Recovery Strategy.

General conclusions from the review include:

1) Critical Habitat for boreal caribou is most appropriately identified at the scale of local population range, and expressed relative to the probability of the range supporting 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) Application of the Critical Habitat Identification Framework, for the 57 recognized local populations or units of analysis for Boreal caribou in Canada, yielded 3 proposed outcomes: Current Range, Current Range and Improved Conditions, or Current Range and Consider Resilience;

4) Like habitat selection by caribou, 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 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, present findings should be monitored and assessed for the purposes of refinement and adjustment over time, as new knowledge becomes available (e.g., a Schedule of Studies as part of Adaptive Management).

This science based review was framed as one of transparent decision-analysis and adaptive management. Thus, the Schedule of Studies produced is a key requirement of the process that is designed to produce continuously improving results over time. Aboriginal and Traditional Knowledge was not included in the present review, nor are needs specific to this body of knowledge identified in the Schedule of Studies.

4.5 Addressing Uncertainty – A Schedule of Studies

All readily available information, including peer-reviewed and grey literature, caribou population and location data, and biophysical and land-use data was reviewed to support the Critical Habitat Decision Analysis. A Schedule of Studies is required by SARA (S. 41(1) (c.1)) if sufficient information is not available to complete the identification of Critical Habitat. Thus, a Schedule of Studies remains a requirement of the process, as described throughout this document. The Schedule of Studies is an outline of activities (e.g., survey work, mapping, population viability analysis) designed to address knowledge gaps and uncertainties to improve the Critical Habitat identification process. These activities include new studies, improvement or continuation of existing studies, and collection of standardized data through monitoring and assessment. Aboriginal traditional knowledge was not considered in the present Science Review, except where accessible in published documents, nor are needs specific to this body of knowledge addressed in the Schedule of Studies. Aboriginal and traditional knowledge provides important information that could augment this review and improve understanding of critical habitat for boreal caribou.

The following Schedule of Studies is designed to address uncertainties identified at each step in the Decision Tree (see Figure 4).

Table 7: Schedule of Studies

Activity	Description
Identify Current Distribution: The current distribution of boreal caribou across Canada is described and mapped in order to define the national scope of Critical Habitat Identification.	
Environmental Nich Analysis	The Environmental Niche Analysis (Appendix 6.4) should be further developed and applied to identify areas of uncertainty based on available abiotic and biotic data, and therefore guide sampling efforts to refine understanding (model-based sampling) of the drivers of current distribution, as well as patterns of occupancy within the distribution. This method could also be used to identify areas with high restoration potential, and areas for enhancing population connectivity, where necessary.
Identify Unit of Analysis: The ranges of local populations are the unit of analysis for Critical Habitat Identification	
Develop a Local Population Range Mapping Standard	Develop a standardized approach to delineating local population ranges (units of analysis) that can be applied across Canada by jurisdictions responsible for the management of Boreal Caribou.
Determine Local Populations	Determine and/or update local population ranges using standardized criteria and methodology. Note: Delineation of local populations is a high priority for large continuous distribution areas currently lacking this information.

Table 7: Schedule of Studies

Activity	Description
Population and Habitat Assessment : Application of a systematic process for evaluating the probability of persistence of a local population given observed states of population and range condition.	
Develop a comprehensive Bayesian Decision Network (BDN)	Identify and incorporate measurable parameters (variables) that influence population persistence into a comprehensive BDN that specifies the conditional probabilities among variables, and provides a formal method for updating Critical Habitat assignments with new knowledge. This activity will be informed by results from additional meta-analyses and non-spatial and spatial population viability analyses.
Conduct additional meta-analyses of caribou demography and range condition	Extend analyses of national data to incorporate additional measures of population and range condition (e.g., adult survival, habitat fragmentation, forest composition), understand variation in relationships attributable to different disturbance types, other habitat measures, or regional contexts, and augment or refine criteria used to assess range condition for identification of Critical Habitat.
Refine population size thresholds in relation to probability of persistence	Further develop the Non-Spatial PVA by: ■ Incorporating maximum age and senescence ■ Evaluating interactions between selected demographic parameters, and the influence of population size on these relationships, relative to risk of extinction and expected time to extinction
Develop survey standards	Develop standardized criteria and methods for boreal caribou population assessments, including local population size and trend information.
Determine local population trends	Population demographic data are required to calculate lambda and evaluate trends of local populations, including more detailed demographic data (from survival analyses, population composition and recruitment surveys).
Determine local population sizes	Population census data are required to determine current population size.

Table 7: Schedule of Studies

Activity	Description
Critical Habitat Identification: Determining the quantity, quality and spatial configuration of habitat required for persistence of boreal caribou populations throughout their current distribution in Canada.	
Refine Quantity, Quality and Spatial Configuration of Critical Habitat for local populations	Identification and completion of case studies using spatially-explicit population modeling to explore a range of population and habitat conditions, and management scenarios, to improve understanding of habitat-based constraints on population persistence (quantity, quality and spatial configuration) and inform development of the Bayesian Decision Network. A variety of modeling approaches should be explored, to inform Critical Habitat identification and recovery planning (e.g. effective protection and recovery implementation). Alternative analytical approaches, such as additional meta-analyses, can also support this activity.
Develop and/or apply methods for determining needs and conditions to support population connectivity	Critical Habitat has been identified at the scale of the range of local populations, with the assumption that local populations experience limited exchange of individuals with other groups. Enhanced population connectivity may be necessary to support persistence of small populations, and maintenance of existing connectivity an important element of Critical Habitat for large populations. Development and/or application of methods to evaluate population connectivity and its relationship to habitat or landscape attributes is necessary. This work could be undertaken in conjunction with spatially-explicit population modeling.
Identify opportunities for active adaptive management	Uncertainties regarding the potential resilience of local populations to different levels and types of disturbance may be most effectively addressed through active adaptive management designed to test alternate hypotheses regarding population response. Parameters to support this could be identified through spatially-explicit population modelling.

5.0 ACKNOWLEDGEMENTS

This scientific assessment was made possible thanks to the contributions of the following individuals and organizations:

Members of the Science Advisory Group:
Dr. Fiona Schmiegelow (Chair), Dr. Stan Boutin, Dr. Carlos Carroll, Dr. Réhaume Courtois, Dr. Vince Crichton, Dr. Marie-Josée Fortin, Dr. Mark Hebblewhite, Mr. Dave Hervieux, Mr. John Nagy, Dr. Tom Nudds, Dr. Richard Pither, Mr. Gerry Racey, Dr. Justina Ray, Dr. Jim Schaefer, Dr. Isabelle Schmelzer, Dr. Dale Seip, Dr. Don Thomas, Mr. Tim Trottier.

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Data Sharing:
Data provided and published with the permission of Global Forest Watch Canada; Government of the Northwest Territories, Environment and Natural Resources; Government of British Columbia; Alberta Sustainable Resource Development; Alberta Caribou Committee; Saskatchewan Environment; Manitoba Conservation (MC) and Eastern Manitoba Woodland Caribou Advisory Committee (EMWCAC) (© 2008 MC and EMWCAC); Ontario Ministry of Natural Resources (© 2008 Queen's Printer Ontario); Le Ministère des Ressources naturelles et de la Faune du Québec, L'Université du Québec à Montréal; L'Université du Québec à Rimouski; L'Université Laval; Government of Newfoundland and Labrador, Wildlife Division, Department of Environment and Conservation; Department of National Defence, Goose Bay; National Boreal Caribou Technical Steering Committee; Natural Resources Canada; Parks Canada; and University of Alberta.