Environment and Climate Change Canada
Environnement et Changement climatique Canada

Scientific Assessment of Federal and Provincial Frameworks for the Conservation of Boreal Caribou in Ontario

Science Assessment Report

Canada

Cat. No.: CW66-1523/2024E-PDF
ISBN: 978-0-660-71258-1
EC24119

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Context

Caribou (*Rangifer tarandus*), boreal population (boreal caribou), are endemic to Canada's boreal forest region. The species requires large tracts of undisturbed, mature forest with a high abundance of lichens and low predator densities. Boreal caribou was listed as threatened under the federal *Species at Risk Act* in 2003. The federal Recovery Strategy (2012, amended 2020) identified the species' critical habitat, which includes the need to maintain sufficient undisturbed habitat to allow for adequate habitat amount and access to key biophysical attributes. In Ontario, the species has been listed as threatened under Ontario's *Endangered Species Act* since 2007. The Government of Ontario's caribou conservation framework includes a suite of policies and processes that collectively aim to sustain local populations through strategic land management and adherence to forest sustainability regulations.

The governments of Canada and Ontario signed a conservation agreement under sections 10 and 11 of the *Species at Risk Act* in April 2022 to sustain or improve the environmental conditions necessary for the recovery of boreal caribou in the province. Conservation Measure 4.1 of the agreement commits both governments to review, refine, and validate existing and alternative evidence-based approaches to maintain or move towards self-sustaining local populations within ranges. The governments of Canada and Ontario requested a scientific review of the evidence underpinning the federal and provincial boreal caribou conservation frameworks in partial fulfillment of Conservation Measure 4.1.

This Science Assessment Report is the result of collaboratively run Canada and Ontario scientific review workshops held on November 8-9th, 2023 and December 5-7th, 2023. A Directors' Steering Committee – composed of directors from the governments of Ontario and Canada – provided oversight and direction to the Expert Group, as well as a Terms of Reference to guide their work. The Expert Group itself consisted of experts from the governments, academia, industry and environmental non-government organizations. Secretariat support was provided by Canada's Expert Scientific Advice Section, who also produced the initial draft of this report. Experts were given an opportunity to review and contribute to the report.

Summary

- In April 2022, the governments of Canada and Ontario signed the *Agreement for the Conservation of Caribou, Boreal Population in Ontario* (‘the Agreement’). Conservation Measure 4.1 of the Agreement commits both governments to review, refine, and validate existing and alternative evidence-based approaches to maintain or move towards self-sustaining local populations within ranges.
- This Science Assessment Report captures a discussion related to scientific information presented by the governments of Ontario and Canada in support of their respective frameworks for caribou conservation. Production of this report was intended as a partial fulfillment of Conservation Measure 4.1
- Experts recognized that the federal and provincial caribou conservation frameworks differ in scope. While the federal framework focuses on caribou persistence and recovery, the provincial framework also considers other aspects of biodiversity, as well as social and economic considerations. Nonetheless, the Agreement specifies that both approaches ‘seek equivalent outcomes for the species (i.e., self-sustaining local populations)’.
- Experts agreed that it was challenging to fit the Scientific Review Process into the objectives of the supplied Terms of Reference. It would have been beneficial for Expert Group members to have had an opportunity to contribute to development of the Terms of Reference, as well as allowing more time to review the provincial and federal scientific information packages.
- There have been considerable advancements in scientific knowledge relevant to caribou conservation and management in Ontario over the last 15 years. Such advances have not necessarily resulted in updates to existing models and tools used in planning and decision-making.
- Experts agreed that higher levels of cumulative disturbance lead to a reduced probability of population persistence for caribou in Ontario, similar to that demonstrated in the federal framework. There is also strong evidence of the mechanisms linking disturbance to caribou vital rates in Ontario, which acts through habitat-mediated impacts of predation and food availability on population persistence.
- Managing cumulative effects of habitat disturbance at a large scale (i.e., thousands of square kilometers) is required for successful caribou management over the long term (i.e., decadal scale). This will require spatially explicit approaches to evaluate all relevant drivers of caribou habitat condition at the landscape scale and link to the probability of persistence for caribou populations in Ontario, which are not currently being used. Management decisions at smaller scales (e.g., biophysical features) must be consistent with objectives at the large scale.
- It is uncertain how caribou populations differentially respond to the direct (e.g., lack of food) and indirect (e.g., predation risk) effects of different types and ages of disturbance. Assessing caribou responses to different disturbances is challenging because of high correlations among anthropogenic disturbance types (e.g., cut blocks and logging roads).
- Identifying the most effective, short-term management actions to improve probabilities of caribou persistence will require management interventions to act as experiments, with appropriate controls.

- Understanding caribou populations in Ontario requires appropriate monitoring, which could include assessment of habitat conditions, genetic information, habitat occupancy, population size, and survival and recruitment. Formalized Value of Information Analyses could support development of a more coherent monitoring approach that targets key data gaps and considers efficient use of the resources available. The Expert Group was limited in their ability to understand the effectiveness of caribou conservation frameworks due to an absence of current data related to most of these parameters.
- A variety of limitations and improvements were identified for specific models or tools related to caribou habitat and caribou population dynamics in Ontario (see Table 1). This included a general need to test model predictions using (i) comparisons to other model outputs, (ii) evaluation against new data not used in model development, or (iii) through landscape scale experiments with appropriate controls.
- There are challenges associated with accurate and consistent habitat classification across Ontario (e.g., detailed vegetation mapping is not available outside of the Managed Crown Forest).
- This Scientific Review Process was unable to evaluate how the federal framework could be implemented in Ontario because it was not intended or designed as a comprehensive management framework.
- The federal model of disturbance and caribou vital rates should be further refined for the Ontario context using new and/or higher resolution data available in the province, and/or mechanistic based approaches to understanding differences in disturbance types. This refinement could also consider additional predictor variables and using model averaging approaches to account for uncertainty in model structure.
- Experts were not provided clarity as to how the various provincial policies and regulations work together to inform caribou management and recovery and how it is intended to be implemented. This, combined with the complexity of the regulatory framework, hampered the ability to assess how likely the provincial framework is to achieve self-sustaining caribou populations.
- Increased transparency in the intent of policies, the evidence used in decision-making, as well as the evidence that would have led to a different decision, would better support public confidence and feedbacks between science and policy, for decisions related to caribou management in Ontario.
- There is a need and opportunity for managers and scientists to engage more effectively with stakeholders and rights holders in sharing knowledge about caribou in Ontario. These techniques should be leveraged to provide feedback on research, model development and implementation to improve outcomes for caribou.

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INTRODUCTION

Boreal caribou ecology

Caribou (*Rangifer tarandus*), boreal population ("boreal caribou") are endemic to Canada's boreal forest and are distributed across nine provinces and territories. Boreal caribou require large areas composed of continuous tracts of undisturbed habitat. In general, boreal caribou prefer habitat consisting of mature to old-growth forest with abundant lichens, or muskegs and peat lands intermixed with upland or hilly areas. Large range areas reduce the risk of predation by allowing caribou to maintain low population densities and spatial separation from predators (e.g., wolf and bear) and alternate prey species (e.g., moose and deer).

The species has experienced distribution-wide declines over the past century. Habitat disturbance, which facilitates penetration of predators into caribou habitat and the conversion of mature forest to younger seral stages (thereby benefitting alternate prey species), is widely recognized as the primary driver of declines.

Boreal caribou (also called 'forest-dwelling woodland caribou', *Rangifer tarandus caribou*) were formerly found throughout most of northern Ontario. Their range has now receded, and the species is generally found north of Sioux Lookout, Geraldton and Cochrane, with an isolated population along the coast of Lake Superior. Historic data suggest that the species previously ranged further south but has experienced a northward range recession of around 34 km per decade between 1880 and 1990 (Schaefer 2003).

Overview of federal framework for boreal caribou conservation

Boreal caribou have been listed as threatened on Schedule 1 of the federal *Species at Risk Act (2002)* since 2003, and was reassessed as threatened by the Committee on the Status of Endangered Wildlife in Canada in 2014. Environment and Climate Change Canada (ECCC), in collaboration with the provinces and territories, published the federal *Recovery Strategy for the Woodland Caribou (*Rangifer tarandus caribou*), Boreal population, in Canada* (hereafter, the *federal Recovery Strategy*) in October 2012, and amended it in 2020. The *federal Recovery Strategy* sets a goal of achieving a self-sustaining population status[1] in all of Canada's 51 federal local population ranges[2] and identified the critical habitat required to support the species' recovery.

As part of the federal framework, the probability of caribou population persistence at different levels of habitat disturbance was estimated based on a statistical relationship between the observed levels of disturbance within local population ranges and boreal caribou vital rates across Canada (Environment

[1] Defined by ECCC as a local population that demonstrates stable or increasing population growth over ≤20 years and is large enough to withstand stochastic events and persist over ≥50 years in the absence of active management intervention (Environment Canada 2011).

[2] ECCC defines a range as the area inhabited by a group of caribou that experience similar impacts to their demography and is used to meet life-history requirements over a defined time frame (Environment Canada 2012; Environment and Climate Change Canada 2020).

Canada 2011; Johnson et al. 2020). This relationship was then used to estimate the percentage of undisturbed habitat required to achieve a given likelihood of population persistence in local population ranges.

Informed by this statistical relationship, and other information, the *federal Recovery Strategy* identifies critical habitat[3] as the area within each range that allows for an ongoing recruitment and retirement cycle of habitat, and which maintains a perpetual state of a minimum of 65% of the area as undisturbed habitat and biophysical attributes required by boreal caribou to carry out life processes. The 65% undisturbed habitat management threshold provides an estimated 60% probability (Environment Canada 2011) that a given local population will be self-sustaining; the choice of this threshold was a policy decision. The *federal Recovery Strategy* calls on provinces and territories to develop range plans or other landscape-level plans to demonstrate how they will manage cumulative disturbance and protect critical habitat within each range to reach or maintain a minimum 65% undisturbed habitat.

Overview of Ontario provincial framework for boreal caribou conservation

The Government of Ontario implements its own boreal caribou conservation framework that includes laws, policies, and processes to manage boreal caribou and their habitat. This framework is informed by the:

- *Endangered Species Act (2007)*, as the primary piece of provincial legislation for the protection of species at risk and their habitat in Ontario. Boreal caribou were already assessed as Threatened when the *Endangered Species Act (2007)* took effect in 2008.
- *Crown Forest Sustainability Act (1994)*, which intends to provide for the social, economic and environmental sustainability of Crown forests, including by using forest practices that emulate natural disturbance and landscape patterns; and,
- *Fish and Wildlife Conservation Act (1997),* which restricts hunting of boreal caribou and provides authority to manage other wildlife species that influence boreal caribou (e.g., predators and alternate prey).

Ontario's *Woodland Caribou Recovery Strategy* (Ontario Woodland Caribou Recovery Team, 2008) sets a goal to maintain self-sustaining and genetically connected local populations where they currently exist, strengthen security and connections among isolated mainland local populations, and facilitate the return of boreal caribou to strategic areas near their current extent. Ontario's *Woodland Caribou Conservation Plan* (MNR 2009) summarizes the actions the Government of Ontario intends to take in response to recommendations in their recovery strategy. The *Woodland Caribou Conservation Plan* also directs the adoption of a Range Management Approach to caribou recovery, which is outlined by the *Range Management Policy in Support of Woodland Caribou Conservation and Recovery* (MNRF 2014a).

The *General Habitat Description for the Forest-dwelling Woodland Caribou* (MNR 2013) is the technical document that clarifies the area of habitat protected for the species under the *Endangered Species Act (2007)*. This document distinguishes between Category 1 (high use areas, which includes nursery areas, winter use areas, travel corridors), Category 2 (seasonal ranges), and Category 3 (remaining

[3] The definition applies to all ranges excepting northern Saskatchewan's Boreal Shield range (SK1).

areas within the range) habitat for caribou. The delineation of Category 1 habitat is based on caribou observations (e.g., visual observations of animals, tracks, pellets, GPS collar locations), habitat information and expert opinion, whereas the delineation of Category 2 and 3 habitat is based on a resource selection function described in Hornseth and Rempel (2015) and Rempel and Hornseth (2018).

Forestry operations in Crown forests conducted in accordance with an approved forest management plan are excluded from application of the *Endangered Species Act (2007)* prohibitions through provisions in the *Crown Forest Sustainability Act (1994)*. Instead, the *Forest Management Guide for Boreal Landscapes* (MNRF 2014b, hereafter the '*Boreal Landscape Guide*') includes direction, through the application of standards, guidelines and best management practices, for forest management planning intended to maintain or enhance the quality, quantity, and arrangement of habitat for the persistence of boreal caribou in managed Crown forests. The direction includes measuring indicators of caribou habitat derived from landscape characteristics, comparing the current status of those habitat indicators to the natural range of forest conditions (i.e., the Simulated Ranges of Natural Variation, SRNV) using the Boreal Forest Landscape Dynamic Simulator (BFOLDS) model (Elkie et al. 2019), directional statements to maintain or move towards milestones which are applied over the short (10 years), medium (20 years) and long (100 years) terms, and developing a Dynamic Caribou Habitat Schedule (DCHS) for maintaining large, interconnected caribou habitat tracts during forestry activities.

Reason for Scientific Assessment

The governments of Canada and Ontario signed the *Agreement for the Conservation of Caribou, Boreal Population in Ontario* under sections 10 and 11 of the *Species at Risk Act (2002)* on April 21, 2022. The overarching goal and purpose of this Agreement is:

"…for Ontario, with support from Canada, to work collaboratively with Indigenous and non-Indigenous partners to sustain or improve the environmental conditions necessary for recovery of the boreal caribou at the range-scale, informed by best available science", and,

"…to support the implementation of Conservation Measures, building on the base of existing management under boreal caribou conservation frameworks, that create the environmental conditions necessary to maintain and recover self-sustaining local populations of boreal caribou[4]"

Conservation Measure 4.1 stipulates that in years 1-2 of the five year Agreement, Canada and Ontario will "collaborate to review and refine existing and alternative evidence-based approaches to maintain or move towards self-sustaining local populations within ranges" and "validate, including through review by recognized experts, and integrate accepted evidence-based approaches, into provincial and federal boreal caribou conservation frameworks, that achieve equivalent outcomes (i.e., self-sustaining local populations) where appropriate". As a partial fulfillment of this requirement, the governments of Ontario and Canada coordinated an expert review of scientific evidence supporting the federal and provincial boreal caribou conservation frameworks.

[4] A "self-sustaining local population" is defined within the Agreement as: "a boreal caribou population that demonstrates stable or positive population growth over the short term, and is large enough (number of boreal caribou) to withstand stochastic events and persist over the long term without external intervention or support."

Overview of the Assessment

The Canada-Ontario Boreal Caribou Conservation Measure 4.1 Directors' Steering Committee was responsible for oversight of this scientific assessment and was composed of Directors from ECCC, the Ontario Ministry of Natural Resources and Forestry (MNRF), and the Ontario Ministry of the Environment, Conservation and Parks (MECP). To conduct the assessment, the Directors' Steering Committee formed an Expert Group composed of individuals with scientific expertise related to caribou and caribou management in Ontario, including individuals employed by the provincial and federal governments, academia, non-governmental organizations, and industry. This group was tasked with addressing specific objectives outlined in a Terms of Reference supplied by the Directors' Steering Committee, which were:

To review, refine, and validate the scientific underpinnings of the federal and provincial boreal caribou conservation frameworks, participants of the Expert Group will aim to answer the following questions:

a) Is the federal boreal caribou conservation framework scientifically sound and supported by evidence? Are there any information/knowledge gaps?

> i. What is the likelihood that the federal framework will achieve self-sustaining local populations of boreal caribou in Ontario?

b) Is the provincial boreal caribou conservation framework scientifically sound and supported by evidence? Are there any information/knowledge gaps?

> i. What is the likelihood that the provincial framework will achieve self-sustaining local populations of boreal caribou in Ontario?

An overview of the federal and provincial caribou conservation frameworks, as well as scientific evidence related to the frameworks, was provided to the Expert Group in a series of presentations delivered in a virtual workshop on November 8-9th, 2023. On November 14th, the Expert Group received copies of these presentations and a large volume of supporting documentation (>45 primary and >150 background reference documents) which provided further detail on the federal and provincial caribou conservation frameworks. On December 5-7th, the Expert Group participated in an in-person workshop with the intent to discuss the scientific evidence provided. During this workshop, the Expert Group agreed on the main conclusions presented in this report, and collaboratively developed the summary bullets.

The workshops described above were coordinated and facilitated by ECCC's Expert Scientific Advice Section, with logistical support from MECP. Following the workshops, the Expert Scientific Advice Section produced an initial draft of this report. Expert Group members were given an opportunity to review and contribute to the report.

ASSESSMENT

Caribou space use

The management of boreal caribou in Ontario requires understanding of the patterns and processes driving how caribou use space (i.e., habitat) across landscapes. The Expert Group discussed a variety

of models and approaches used to investigate and predict caribou space use in Ontario, including (i) the identification of caribou habitat indicators under the *Boreal Landscape Guide*, (ii) the categorization of habitat using the *General Habitat Description for the Forest-dwelling Woodland Caribou*, and (iii) a spatially explicit caribou movement model described in Avgar et al. (2015). Not all models discussed are applied in policy. These discussions are described below and summarized in Table 1.

Ontario's *Boreal Landscape Guide* identifies caribou habitat indicators to be included as part of forest management planning (Elkie et al. 2018). These indicators are informed by habitat suitability tables describing the relationship between forest stand type and age, and the function of habitat for caribou (e.g., whether stands are suitable as refuge or winter habitat).

Experts noted that caribou habitat indicators under the *Boreal Landscape Guide* are based on forest stand type and age, and do not consider other habitat characteristics that can impact caribou habitat use such as linear features. Furthermore, the habitat suitability tables were developed using informal, expert-based approaches that have not been subject to empirical validation and have not been updated in *circa* 20 years. As a result, the habitat suitability tables and caribou habitat indicators do not reflect the current scientific understanding of caribou habitat preferences in Ontario. Moreover, the Expert Group noted that caribou habitat indicators do not have a clear link to caribou population dynamics, and therefore it is unclear whether achieving caribou habitat management targets under the *Boreal Landscape Guide* are sufficient to achieve self-sustaining populations. While Expert Group members noted that components of the *Boreal Landscape Guide* are being reviewed and updated under Conservation Measure 3.1 of the *Agreement for the Conservation of Caribou, Boreal Population in Ontario*, the proposed updates were not available to the Expert Group.

Experts suggested that the caribou habitat indicators could be improved by incorporating new information and knowledge, integrating additional habitat characteristics known to influence caribou habitat use (e.g., linear features), and linking habitat indicators to caribou demography. In addition, Expert Group members suggested that habitat suitability indicators should be validated using out-of-model data sets. In other words, the capacity of the model to predict habitat use should be assessed using new data that were not used to develop the model.

Ontario's *General Habitat Description for the Forest-dwelling Woodland Caribou* provides technical guidance on categorizing sub-range caribou habitat. Under this guidance, Category 1 habitat (high-use areas) is assumed to have the lowest tolerance to alteration before its function in supporting caribou is compromised, while Category 2 (seasonal ranges) and Category 3 (remaining areas within the range) habitat are intended to represent progressively increased tolerance for alteration because of decreased use and/or importance for caribou.

Category 1 habitat are sub-range habitat features that currently exhibit repeated, intensive use by individuals or multiple caribou, and include nursery areas, winter use areas, and travel corridors. Expert Group members noted that the identification of Category 1 habitat was based on direct observations of caribou habitat use (e.g., via telemetry or aerial surveys) and expert-based extrapolations related to apparent habitat features (e.g., lakes, peatlands) with which caribou are associated. As a result, the identification and delineation of Category 1 habitat is highly sensitive to survey effort and opportunistic observations, and fails to identify high-use habitat features when there is a lack of caribou location information in a given range. Furthermore, the Expert Group noted that the approach used to assign Category 1 has not been made public, nor has it been subject to formal validation through comparison with other datasets of caribou space use. The Expert Group suggested that publishing the specific methodology used to identify Category 1 habitat would allow for greater understanding and the identification of specific improvements to the process, where appropriate. Furthermore, validating the

method by comparison with out-of-model datasets or with other approaches to modelling caribou space use, would help clarify whether the approach accurately identifies high-use areas for caribou throughout each range.

Category 2 habitat describes large habitat features that encompass the majority of current caribou distribution across all seasons within the range, while Category 3 habitat represents remaining areas in a range which generally have the biophysical features and forest composition consistent with seasonal ranges, yet are currently young or disturbed (e.g., <40 years old). Category 2 habitat is identified using a resource selection function described in Hornseth and Rempel (2018), with areas identified as having a high probability of occupancy in any season being considered Category 2. Expert Group members noted that predictions may be impacted by correlations among, and errors in, the underlying GIS layers upon which the resource selection function is built and that inter-individual variation in habitat use is not considered. Expert Group members noted that the approach to identifying Category 2 and 3 habitat relies on the assumption that the resource selection function will continue to predict caribou habitat use even as landscape characteristics change over space and time. However, the method used to define used and available habitat is not well suited for prediction as landscape conditions change. The model also assumes that the various spatial scales at which landscape variables are summarized are appropriate for caribou habitat selection. Again, validating the method by comparison with out-of-model datasets or with other approaches to modelling caribou space use would help clarify whether the approach accurately distinguishes areas that are currently used by caribou (Category 2) from those that are not (Category 3).

Avgar et al. (2015) describe a mechanistic movement model that incorporates animal sensory and memory capabilities, parameterized with GPS telemetry data from 30 boreal caribou from two landscapes with a range of disturbance in Ontario. While not currently used in either the federal or provincial caribou conservation frameworks, this model is a component of the spatial population viability analysis presented in Fryxell et al. (2020) and provides an alternative approach to understanding patterns of caribou space use in Ontario. Strengths of the approach are that estimates of forage availability were informed by field-level sampling (as opposed to reliance on satellite information), that only areas near to each animal are considered available, and that variation in habitat selection among individuals is considered. Validation with 41 annual trajectories from the same two study areas and time-period showed simulated habitat selection patterns mimic observed patterns in some respects but not others. The model demonstrates that forage abundance is an important driver of caribou movement patterns, and that there is strong variation in movement parameters among individuals.

In the model, movement of caribou is related to an individual animal's perception of wolf predation risk, forage availability, snow depth and moose habitat. These intermediate variables were estimated at a landscape scale from various remotely sensed covariates. Expert Group members noted that while the use of such intermediate variables is valuable for exploring conceptual links among factors driving caribou movement, caribou movement may be more accurately predicted by directly linking behaviour (i.e., movement) to the underlying covariates. Because habitat availability is defined locally, and movement behaviour is modelled explicitly, the model may provide more accurate predictions under future environmental conditions in comparison to some other models. However, Expert Group members also noted that prediction of some of the underlying landscape variables (such as the normalized difference vegetation index, NDVI) is challenging, and that the model is informed by data from only 30 animals in two study areas, which may limit the overall predictive capabilities of the model. Furthermore, it was noted that the model is highly complex and computationally expensive, which may limit its usefulness in some contexts.

Predicting and emulating disturbance

Ontario's forest management guides direct forestry operations within Crown forests on the emulation of natural disturbance and landscape patterns, in alignment with the principles of the *Crown Forest Sustainability Act (1994)*. Emulation of natural landscape processes and patterns is predicated on the hypothesis that, having evolved under natural disturbance regimes (e.g., certain sizes and frequencies of forest fires), ecosystem functions will be maintained by employing resource-extraction methods that replicate the characteristics of such disturbances. The resulting landscape patterns are assumed to act as a "coarse filter" for conserving biodiversity, including boreal caribou.

Habitat considerations for boreal caribou under the emulated disturbance paradigm are generally applied through Ontario's *Boreal Landscape Guide*. This policy supports and builds upon the priorities outlined in Ontario's *Woodland Caribou Conservation Plan*. The coarse filter, dictating the composition, distribution, and abundance of mature and old forest through the emulation of natural disturbances, is intended to provide sufficient amount and distribution of caribou habitat. "Fine filter" directions, which modify the results of the coarse filter, further specify the management of the quality, quantity, and arrangement of physical attributes available to caribou within ranges, as defined by the *Woodland Caribou Conservation Plan*. The Expert Group discussed the coarse and fine filter approaches to managing caribou habitat in the *Boreal Landscape Guide*, specifically the Simulated Ranges of Natural Variation (SRNVs) (providing coarse filter direction) and the Dynamic Caribou Habitat Schedules (fine filter direction).

SRNVs are intended to characterize the dynamics of landscapes in the absence of human influence and are based on the quantification of a set of metrics (including metrics intended to characterize caribou habitat) calculated from landscape-scale simulations. SRNVs are calculated at the level of forest management units (for those forest management units that intersect caribou ranges), as well as at the level of full caribou ranges (Elkie et al. 2018). Forest management plans intersecting caribou ranges must include targets for caribou habitat indicators at years 10, 20, and 100, and additional targets at years 40, 60, and 80 are recommended. SRNVs calculated for full-range extent are used in determining integrated range assessments under the *Integrated Assessment Protocol for Woodland Caribou Ranges in Ontario* (MNRF 2014c).

BFOLDS is a spatially explicit landscape model for simulating crown-fire regimes, succession, and post-fire transitions. In Ontario, BFOLDS is used to produce SRNVs, which inform forest management plans and assessments of caribou habitat condition at the range scale. BFOLDS combines a process-based fire simulation module (using ignition, spread, and extinguishment information) with an expert-opinion based succession module to stochastically simulate the dynamics of landscapes in the absence of human influence. Primary model outputs include incidents of fire, forest type and forest age, which can then be used to calculate landscape-level metrics for the SRNV approach outlined above.

Experts noted several untested assumptions in the SRNV approach as implemented through the *Boreal Landscape Guide*. This included that the approach assumes BFOLDS accurately describes landscape dynamics in the absence of human influence, that the selected caribou habitat metrics sufficiently characterize important habitat attributes relevant to caribou, and that achieving the targets for caribou habitat metrics (i.e., managing such that area-based metrics are within the interquartile range of the SRNV, and that pattern-based metrics are at the mean SRNV values) is sufficient to conserve caribou populations. Experts noted that BFOLDS does not consider other types of natural disturbance beyond wildfire (e.g., insect outbreaks, wind, drought) which could impact habitat suitability for caribou. Further, some Experts expressed concern that BFOLDS underestimates fire return intervals, although the

Expert Group did not have a detailed discussion or reach consensus on this point. Experts also questioned the general premise of whether managing forests to emulate natural disturbance patterns is effective for supporting self-sustaining caribou populations in Ontario.

The DCHS is a landscape management approach which prescribes the identification of large landscape patches (usually > 10000 ha) and outlines a harvest schedule intended to maintain sufficient caribou habitat over space and time within the forest management unit. The large landscape patches are based on a caribou habitat tract map, which incorporates information on current caribou habitat use, as well as potential future habitat use based on forest age and composition.

Experts noted that the DCHS approach includes assumptions about the efficiency and efficacy of harvest schedules, road decommission and road remediation. Management practices outlined in the *Boreal Landscape Guide* for stand and site level harvesting call for operations in caribou habitat to take no more than 20 years and ideally be completed within 10 years (MNRF 2014b), but this is not a mandatory requirement. Further, this policy calls for operational roads to be decommissioned as quickly as possible following the completion of harvesting activities, as these linear features can provide travel corridors for caribou predators. However, Experts noted that these directions may be challenging to implement in practice; difficulties in accessing and harvesting tracts can result in cut blocks being open well beyond recommended timelines. Moreover, the Expert Group noted that it is unclear how effective road decommissioning and remediation is at restricting predator access, as well how timely decommissioning and remediation activities are completed. Protracted timelines associated with harvesting, road decommissioning, and road remediation represent a disconnect between the DCHS's design and implementation, that may limit its potential to effectively maintain a supply of caribou habitat that is consistent with a natural landscape.

Overall, the Experts noted the importance of validating assumptions underlying the DCHS and SRNV approaches against the realities observed on the landscape and through scientific study, which is consistent with the adaptive management approach recommended in the *Boreal Landscape Guide*. Existing data and models that reflect best available knowledge of landscape dynamics, caribou habitat selection, and demography could be used to assess whether the SRNV and DCHS approaches are likely to maintain an adequate supply of habitat within caribou ranges over the long term. In the absence of recent caribou population information, which was not available to the Expert Group, it was difficult to assess the overall effectiveness of the approaches.

Caribou demography

Understanding caribou population trends and probability of persistence in Ontario, like elsewhere, requires appropriate monitoring. Experts recognized that monitoring caribou in Ontario is challenging because the species is distributed across a large area, has low population densities, and given the high costs associated with carrying out surveys. While new monitoring activities are currently being pursued through Conservation Measure 1.1 of the *Agreement for the Conservation of Caribou, Boreal Population in Ontario*, monitoring data available to the Expert Group were primarily collected between 2008 and 2012. These data included aerial survey-based minimum animal counts, population trends calculated from aerial-based calf recruitment estimates and collaring-based adult survival estimates, habitat occupancy, and GIS-based analyses of habitat conditions. However, the Expert Group noted that their ability to understand the effectiveness of caribou conservation frameworks was limited by a dearth of population data from within the last decade. Furthermore, the Expert Group noted that even

with the addition of new data (e.g., data collected under Conservation Measure 1.1), there would only be a few years of data for most ranges. This presents challenges for understanding the impacts of policies and management actions implemented over long time periods and informing any commitments to adaptive management.

Expert Group members suggested that formalized Value of Information Analyses, which quantify the importance that different types of monitoring data would provide for management decisions, could support development of a more coherent monitoring approach that targets key data gaps and considers efficient use of the resources available. Selecting the elements of effective monitoring program should also consider the genetic analysis of fecal samples (which can provide information on individual identify, demographic rates and demographic composition), which is a less invasive approach compared to animal collaring.

Some models and management tools for boreal caribou in Ontario have used vital rate (i.e., survival and per-capita recruitment) data from monitoring activities to estimate population growth rates (λ). These include Ontario's *Integrated Range Assessment* approach under the *Range Management Policy in Support of Woodland Caribou Conservation and Recovery*, the federal disturbance-recruitment model, and Fryxell et al.'s (2020) spatial population viability analysis (the latter two models are further described below). Such approaches are valuable for understanding the expected trajectories and viability of populations, which is an important component of effective conservation and management. Experts noted that it is important to assess and communicate the uncertainty around estimates of λ and population viability, which requires statistical approaches that consider variation and uncertainty in the underlying vital rates and propagates those uncertainties through to the estimate of λ. This is especially important because λ estimates for boreal caribou in Ontario are based on limited data.

Caribou demographic rates are often measured at the range scale. In Ontario, the federal government recognizes nine boreal caribou ranges, while the provincial government recognizes 14 ranges (Figure 1), with the additional ranges resulting from a subdivision of the federal ON9 (Far North Range). The delineation of ranges impacts a variety of caribou demographic metrics and range-level population assessments by defining the total amount of habitat area, the amount of cumulative disturbance, and the group of caribou considered in analyses.

Expert Group members noted that boreal caribou ranges in Ontario are not strictly related to biological populations as individuals and genes flow between ranges. Further, some large areas are not currently used by caribou, but are included within ranges because they are areas where caribou existed previously or that have potential to support caribou in the future. As such, both federal and provincial boreal caribou ranges in Ontario should be interpreted as management units or recovery planning areas, rather than population-specific distribution ranges. However, experts expressed caution related to efforts underway to review and refine range boundaries (e.g., via Conservation Measure 1.2 of *Agreement for the Conservation of Caribou, Boreal Population in Ontario*) given that much of the historical monitoring and management efforts have been conducted using the current range boundaries. As such, initiatives to update range boundaries need to balance the advantages of better alignment with biological populations and the risks associated with a decreased understanding of changes in populations and disturbance over time.

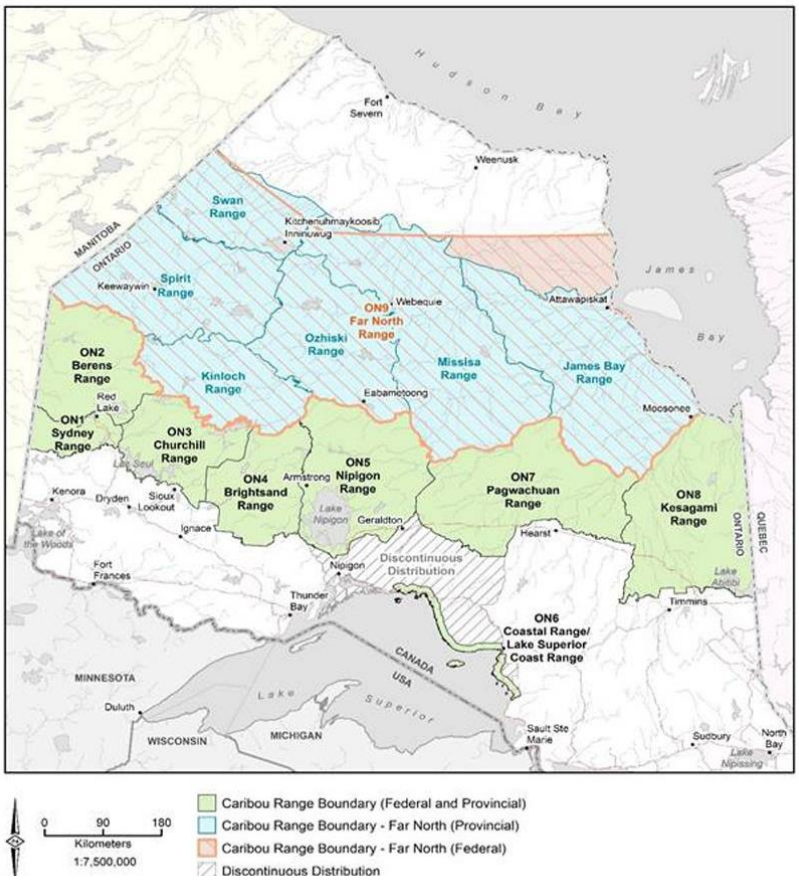

Figure 1. Locations of federal and provincial range designations for Boreal Caribou in Ontario. Areas designated in the Federal Amended Recovery Strategy are labeled ON1-ON9. In Ontario six ranges have been delineated within the federal Far North (ON9) Range. Figure reproduced from the *Agreement for the Conservation of Caribou, Boreal Population in Ontario.*

A spatial population viability analysis presented in Fryxell et al. (2020) combined the Avgar et al. (2015) caribou movement model (discussed above) with a demographic model to explore mechanistic relationships between environmental conditions, caribou movement, survival, and reproduction. Because the modelled population dynamics incorporate the impacts of predation risk and forage availability on vital rates, the model allows for a variety of 'scenario analyses' whereby the impacts of management interventions (e.g., predator control, or reductions in apparent competition via enhanced moose harvest) can be explored. Furthermore, the model's predictions of adult survival in the two study areas were consistent with field estimates, and the simulated population growth rates (λ) across 14 Ontario boreal caribou ranges were broadly consistent with available data and predictions from a different modelling approach (Rempel et al. 2021). The model is not currently being used for caribou management in Ontario.

Experts noted that the model assumes the impact of landscape condition on calf recruitment is indirect, and driven by the relationship between landscape condition and the survival and energetics of adult caribou. This is despite evidence that the impacts of landscape condition (e.g., disturbance) on per-capita recruitment are stronger than impacts on adult survival (Johnson et al. 2020). Experts suggested analyzing the sensitivity of model results to recruitment assumptions. Experts also noted the complexity and computational costs associated with the movement model (discussed above) also apply to the population viability model, which may limit its utility in some contexts.

Relationship between landscape conditions and disturbance

Central to the Government of Canada's boreal caribou framework is an analysis of the relationship between range-level cumulative disturbance (i.e., fire, anthropogenic disturbance) and per-capita recruitment, which resulted in a modelled decreasing probability of self-sustaining population status over a 20-year period under increasing levels of cumulative disturbance (Environment Canada 2011). This analysis was based on the ratio of cows to calves identified through monitoring efforts and non-overlapping cumulative disturbance measures (fires ≤ 40 years and anthropogenic disturbance buffered by 500 m) for 24 caribou ranges across Canada, including two in Ontario. Disturbance effects tended to be greater for anthropogenic disturbances than fire, and linear disturbances were more deleterious than polygonal features, though explanatory power was greater when disturbance types and arrangement were considered holistically. The application of the 500 m buffer on anthropogenic disturbance (which represents an estimated zone of influence imparted by human-caused disturbance) was chosen as it was the most conservative buffer distance that produced stable predictive power in the disturbance-recruitment model. Subsequent analysis of data from 58 study areas across Canada, including all of the Ontario ranges, has reaffirmed this relationship and suggested that anthropogenic disturbance has a 3 to 4 times greater effect on per-capita recruitment than fire (Johnson et al. 2020).

Experts discussed concerns about the classification of disturbance under the federal approach and the application of the 500 m buffer. Classification of anthropogenic disturbance was accomplished manually by individuals reviewing Landsat imagery with a spatial resolution of 30 m at a viewing scale of 1:50,000 (Pasher et al. 2013). Experts questioned the assumption that disturbances visible in Landsat imagery are all equally important to caribou, and the assumption that areas that are not visibly disturbed can be considered suitable or recovered. There is also no clear method for assessing the age of disturbances or projecting how long it will take for areas that are visibly disturbed to recover. Validation of classifications with on-the-ground observations was suggested as a potential solution. Some experts were also interested in using information about causal mechanisms to select buffer distances, and applying different buffers to different types of disturbance, as an alternative to the current empirical approach.

Additional discussion centered on potential improvements and tests of the disturbance-recruitment model. A key limitation noted for the federal model is that high-resolution disturbance mapping producing by Ontario was not used in order to maintain consistency across the country (i.e., because high-resolution disturbance mapping was not available from other jurisdictions included in the analysis). Concerns were also raised about regional variation in demographic-disturbance relationships, and the ability of a national model to accurately characterize the relationship between disturbance and caribou vital rates within individual regions. To address these concerns, the Experts agreed that demographic-disturbance models could be refined for Ontario, using higher resolution provincial disturbance mapping. While the ease-of-interpretation was a noted benefit of the federal, single-predictor (total disturbance) model, some experts suggested that a model-averaging approach could improve predictive power. Experts also suggested validating the model with new demographic data.

Broader discussion centered on the impacts of disturbance on caribou persistence. The Experts unanimously agreed that high levels of cumulative disturbance have a negative effect on caribou vital rates (i.e., per-capita recruitment and adult female survival), both nationally and in Ontario, due to habitat-mediated impacts on predation risk and food availability. However, the Experts also discussed uncertainties about the effectiveness of habitat restoration and the degree to which reducing cumulative disturbance within ranges will improve the likelihood of achieving self-sustaining status for local populations. Experts also discussed the impacts of different disturbance types on caribou and agreed

that teasing apart impacts of different types of disturbance is challenging because there are high correlations among some disturbance types (e.g., roads almost always co-occur with other anthropogenic disturbances). However, treating disturbance as a compound variable within models limits the decision-space available to policymakers and wildlife managers.

Table 1. Summary of discussion by Expert Group members of models related to boreal caribou conservation in Ontario.

	Component of	Limitations	Potential improvements
Caribou habitat indicators under the Boreal Landscape Guide	Provincial caribou conservation framework	Does not consider some habitat features that are highly relevant to caribou (e.g., linear features); Habitat suitability tables developed via informal, expert opinion; Have not been updated in ~20 years.	Update to reflect current understanding of caribou habitat use in Ontario; Incorporate other habitat features known to impact caribou habitat use; Assess relationship between habitat indicators and caribou demography; Formally evaluate approach in comparison to out-of-model information on caribou habitat use.
General Habitat Description – Process for delineating Category 1 habitat	Provincial caribou conservation framework	Highly sensitive to search/survey effort; Relies upon informal criteria and expert opinion; Methodology not available for external scrutiny and review.	Report the methodology and results in a transparent manner, and subject it to peer review; Formally evaluate approach by comparison to out-of-model information on caribou habitat use.
General Habitat Description – Resource selection function for delineating Category 2 and 3 habitat	Provincial caribou conservation framework	Does not provide information on amount of habitat needed; No accounting for individual differences in habitat use within a given range; Limited capability for predicting habitat use for new combinations of environmental conditions.	Consider alternative resource selection modelling methods that could improve predictions as environmental conditions change; Formally evaluate approach by comparison to out-of-model information on caribou habitat use.
Avgar et al. (2015) caribou movement model	Not used for caribou management in Ontario	Complex to fit and run; Parameterized with data from just 30 individuals.	Consider linking movement directly to landscape covariates (e.g., NDVI), rather than through intermediate variables related to predation risk and forage availability.
BFOLDS	Provincial caribou conservation framework	Does not consider other types of natural disturbance beyond wildfire; Forest succession trajectories are based largely on expert opinion.	Update forest succession trajectories with empirical information.

Methods for calculating population growth rate (λ)	Federal and provincial caribou conservation frameworks	Uncertainty in *λ* and projected population viability not always assessed or communicated	Use statistical methods to estimate uncertainty with *λ* and projected population viability.
Demographic submodel in Frxyell et al. (2020)	Not used for caribou management in Ontario	Assumes per-capita recruitment not directly impacted by landscape condition; Complex to fit and run.	Assess sensitivity of results to recruitment and adult survival assumptions.
Federal disturbance – recruitment model	Federal caribou conservation framework	Classification of disturbance relies on whether or not they appear on Landsat imagery, and does not make use of finer-resolution products available at the provincial scale; No clear methods for assessing age of disturbances or projecting habitat recovery; National model may not accurately describe regional variability; Single predictor variable may limit predictive potential.	Incorporate higher resolution spatial data specific to Ontario; Consider mechanistic information for defining buffer sizes, and use of model averaging approach; Validate model using new demographic data.

**This table summarizes material presented in the Scientific Assessment of Federal and Provincial Frameworks for the Conservation of Boreal Caribou in Ontario, and should not be presented independent of the additional context provided in this document*

Other sources of uncertainty

Expert Group members identified several areas of uncertainty that pose general challenges for boreal caribou conservation in Ontario. For example, there is a general limitation in the availability of historical data on boreal caribou populations, habitat occupancy, and trends over time. While patterns of range contraction since 1880 are described in Schaefer (2003), the Expert Group noted that this analysis relies primarily on anecdotal information. High quality scientific data on caribou populations in Ontario is generally limited to the last 15 years, and almost all relevant demographic and movement data was collected between 2008 and 2012.

Many models and approaches used to inform caribou management in Ontario rely on remote sensing data products. However, some relevant data products are not available across the full extent of boreal caribou occurrence in Ontario (e.g., detailed vegetation mapping is not available outside of the Managed Crown Forest) which makes it difficult to develop models and management tools that are both adequately detailed and consistent across the province. Furthermore, some remote sensing products are associated with a high degree of error, which introduces additional uncertainty into the models that are dependent on them.

The Expert Group also noted the impacts of sensory disturbances and their effects on caribou behaviour in Ontario have received minimal research attention and are not well understood. A variety of

human activities create noise, lights, scents, and other sensory disturbance which may have effects on caribou habitat use and population persistence in addition to the direct effects of habitat disturbance generally discussed above.

A better understanding of predator-prey relationships within caribou ranges would also help inform management approaches. This includes the impacts of black bear (*Ursus americanus*) predation on caribou, and the role of North American beaver (*Castor canadensis*) as alternate prey for predators. Further, the significant role and impact beavers can have on the landscape should be examined and considered in landscape-management approaches.

Effectiveness of policy for boreal caribou conservation in Ontario

The Expert Group was unable to determine the likelihood that applying the federal framework in Ontario would lead to self-sustaining caribou populations, as the federal framework has not been applied in Ontario to date. Furthermore, the federal framework is not a comprehensive management framework; the disturbance-recruitment model was developed to support the identification of critical habitat and provide a probabilistic assessment of the likelihood of population persistence under different landscape conditions. It, alone, is not prescriptive of which actions need to be taken to achieve recovery outcomes. It is also caribou-centric, national in scope, and does not provide guidance on the multitude of considerations that are required for land management at the provincial scale.

The Expert Group did not have sufficient time and information to understand how the individual policies that constitute Ontario's caribou conservation framework work together to support conservation and recovery of the species. The information provided to the Expert Group was not sufficient to clarify which policies factor into decision-making, how consequential individual policies are, and what evidence supports individual policies. For example, there was a lack of clarity provided on the number and extent of activities managed through the *Range Management Policy in Support of Woodland Caribou Conservation and Recovery,* which is intended to support the implementation of the protection provisions under the *Endangered Species Act (2007).* This was of interest given that forestry operations in Crown forests (that are conducted in accordance with an approved forest management plan) are exempt from the *Endangered Species Act (2007)* because of provisions in the *Crown Forest Sustainability Act (1994).* As such, the relative importance of the *Range Management Policy in Support of Woodland Caribou Conservation and Recovery* was uncertain. The overall lack of clarity, in combination with the complexity of the framework, limited the Expert Group's ability to assess the likelihood of achieving self-sustaining caribou populations and address questions posed in the Terms of Reference.

The Expert Group agreed that managing the cumulative effects of habitat disturbance at a large scale (i.e., thousands of square kilometers) is required for successful caribou conservation over the long term (i.e., decadal scale) in Ontario. This will require spatially explicit approaches that evaluate all relevant drivers of caribou habitat condition at the landscape scale, and that link habitat condition to the probability of persistence for caribou populations in Ontario. Spatially explicit methods are not currently used to assess or project the cumulative effects of relevant management decisions at large spatial scales relevant for caribou, and many of the models that inform habitat decisions do not include caribou population dynamics. Additionally, Experts noted that many management decisions are made at scales smaller than the range-scale, but the Expert Group did not have sufficient information to assess if decisions at smaller scales, when taken together, are consistent with caribou needs at the larger scale.

Experts commented that there is a need and opportunity for managers and scientists to engage more effectively with stakeholders and rights holders in sharing knowledge about caribou in Ontario. This could include improving the communication of scientific information to land users, as well as ensuring that land user observations and values are incorporated into scientific initiatives, objectives which can be addressed by techniques in participatory research and collaborative conservation planning and decision-making. These techniques could be leveraged to provide feedback on past, ongoing and planned research, on the development of models and tools, and on the implementation of management activities, to improve outcomes for caribou.

Finally, the Experts highlighted concerns regarding the length of time required to determine the effectiveness of habitat restoration and recovery in Ontario. While the overarching cause of boreal caribou decline (cumulative disturbance and resulting changes to predator-prey dynamics) is well-understood, restoring disturbed areas so that they recover their function for caribou takes decades. There are a range of management options, such as reducing densities of predators and alternate prey and/or decommissioning and remediating roads, that could be undertaken in the short-term. However, to comprehensively understand the most effective combination of management actions, experts suggested an experimental policy approach (applying combinations of short-term management options within some ranges, and treating others as controls) to assess the efficacy of short-term interventions. In order to be effective, landscape-scale experiments will need to be monitored with meaningful and sensitive indicators, include criteria for stopping an experimental activity when there is sufficient evidence of benefits or impacts for caribou, and with careful consideration of the ethics of experimentation with a threatened species.

Recommendations

As a result of the discussions and assessment described above, the Expert Group developed the following key recommendations:

Understanding caribou populations in Ontario requires appropriate monitoring, which could include assessment of habitat conditions, genetic information, habitat occupancy, population size, and survival and recruitment. Formalized Value of Information Analyses could support development of a more coherent monitoring approach that targets key data gaps and considers efficient use of the resources available. The Expert Group was limited in their ability to understand the effectiveness of caribou conservation frameworks due to an absence of current data related to most of these parameters.

Accessing caribou and caribou habitat knowledge and data, as well as understanding what research is currently being conducted, is an ongoing challenge. New models and incentives are needed to encourage data and knowledge sharing among governments, academics, proponents, and other stakeholders and rights holders to ensure that up-to-date information is available for research and decision-making.

Ensure there is a commitment to a transparent process for evaluating and incorporating new information in existing regulatory frameworks, in a timely manner.

The federal model of disturbance and caribou recruitment should be further refined for the Ontario context using new and/or higher resolution data available in the province, and/or mechanistic-based approaches to understanding differences in disturbance types. This refinement could also consider additional predictor variables and using model averaging approaches to account for uncertainty in model structure.

Identifying the most effective, short-term management actions to improve probabilities of caribou persistence will require management interventions to act as experiments, with appropriate controls.

Other considerations

Ontario's forest management policies identify a variety of management objectives beyond boreal caribou, including other aspects of biodiversity (e.g., other mammals, birds, and plants), social and economic factors. These considerations, including potential trade-offs between management for caribou conservation and other outcomes, were not discussed by the Expert Group. It is unclear how emphasizing the habitat requirements of caribou may influence the ecological diversity and overall health of the habitat for other species.

Experts noted that the *Agreement for the Conservation of Caribou, Boreal Population in Ontario* specifies several Conservation Measures which relate to scientific evidence supporting boreal caribou management. Specifically, other Conservation Measures (i.e., beyond 4.1) aim to increase the availability and rigor of scientific information (e.g., via monitoring), update or improve various models, identify informational gaps, and improve data sharing. Ongoing progress on these initiatives made for a 'moving target' for the Expert Group's assessment of the state of scientific evidence.

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This Science Assessment Report is the result of joint Canada – Ontario scientific review workshops held on November 8-9th, 2023 and December 5-7th, 2023.

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