

Bathurst Caribou Range Plan

Supporting Report:

Caribou Range Assessment and
Technical Information

January 2018

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Acknowledgements

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Disclaimer

This is a technical supporting document to the Bathurst Caribou Range Plan (BCRP). It describes the methods used and technical information considered or created while developing the BCRP. The audience for this report is intended to be technical specialists—a plain language summary has not been produced as key information is included in the Plan.

This report does not represent the results of community engagement nor Government policy direction. Separate supporting documents have been created for traditional knowledge and economic considerations.

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Executive Summary

This report is a technical supporting document for the Bathurst Caribou Range Plan (BCRP). It describes the science-based methods and information used in the development of the BCRP. Two other companion supporting reports to the BCRP describe the traditional knowledge (Traditional Knowledge of Caribou and Caribou People) and land use and economic information (Land Use Scenarios and Economic Considerations) used and considered by the BCRP Working Group. The report covers three major topics:

1. Section 2 describes how different natural and human factors may affect barren-ground caribou populations;
2. Section 3 is a range assessment, describing the current and potential future state of the Bathurst caribou herd and its range, with a focus on levels of human-caused disturbance; and
3. Section 4 describes how recommended human disturbance management thresholds were established in the range plan.

Key results are as follows.

1. Factors Affecting Barren-ground Caribou

A number of factors may affect barren-ground caribou populations. Natural factors include climate, wildfire, predation and insects and parasites. Human factors include hunting and land use. Traditional and scientific perspectives have similar views on how land use affects caribou (traditional knowledge on the subject is summarized in the Traditional Knowledge Report). Based on caribou simulation modeling results, the relative importance of different factors affecting barren-ground caribou can be described as follows:

- Caribou mortality rates (predation or hunting) appear to have the strongest overall influence on caribou population trend.
- Environmental variability (climate, insects and diseases, green-up) influences caribou population productivity, but to a lesser degree than direct mortality.
- Increasing levels of land use (i.e., increasing levels of development footprint and associated ZOI) result in incremental reductions in herd productivity, largely through a reduction in expected female caribou pregnancy rates.
- Lower pregnancy rates reduce overall population productivity, and have a synergistic effect with mortality rates. Combined, these two factors result in higher rates of population decline in scenarios with higher levels of industrial development.
- The relative effect of wildfire on population performance was not able to be directly assessed. However, the boreal woodland caribou recovery strategy (ECCC 2012) considers wildfire disturbance as a factor in determining disturbance management thresholds.

2. Range Assessment

2.1. Population Status

The Bathurst caribou population is currently estimated to be approximately 20,000 animals ($19,769 \pm 7,420$) (Boulanger et al. 2016), representing a decline of over 96% from a mid-1980s population estimate of approximately 450,000. Such dramatic population declines are also being experienced by some other Canadian barren-ground caribou herds, resulting in COSEWIC recently designating barren-ground caribou as a threatened wildlife species.

2.2. Important Areas and Habitat Features

To better understand the potential land use and management issues affecting caribou in the different parts of the range, the BCRP Working Group developed the concept of range assessment areas (RAAs). RAAs were created by considering human land use patterns, administrative boundaries, and Bathurst caribou range use and habitat conditions. The five RAAs include:

Tundra biome (calving and post-calving, and summer range):

- RAA1: Nunavut
- RAA2: NWT central tundra

Taiga biome (winter range):

- RAA3: NWT Winter Range – Northwest
- RAA4: NWT Winter Range – Central
- RAA5: NWT Winter Range – Southeast

Important areas are relatively large geographic areas of particular importance to the Bathurst herd such as seasonal ranges or parts of the range with high levels of consistent use during sensitive times of the caribou life-cycle. Important habitat features describe smaller, specific parts of the range considered to be of high importance to caribou.

- The calving and post-calving, and summer ranges are considered the most important and sensitive parts of the Bathurst annual range. Most of the calving and post-calving range is in RAA1 (Nunavut), with the core summer range occurring in both RAA1 (Nunavut) and RAA2 (NWT Central Tundra).
- In addition to the important range areas, water crossings, land bridges and unburned parts of the winter range have been consistently identified as important habitat features for barren-ground caribou that require special management consideration.
- To support range plan implementation, a center of habitation (COH) has been defined representing the current most favorable and secure portion of the range that includes important habitats and migration paths used at dwindling numbers in the natural cycle. The COH is defined based on the current core use area, which was estimated based on the distribution of satellite-collared Bathurst caribou from 2015-2017, coupled with traditional knowledge of important migratory, geographic, and habitat features.

2.3. Disturbance Assessment

The current amount of wildfire and human-caused disturbance within the Bathurst range was assessed based on disturbance mapping and GIS analysis. Potential levels of future disturbance resulting from three potential development scenarios were also explored. Results are reported by range assessment area (RAA). Key findings of the Bathurst disturbance assessment are as follows:

2.3.1. Current Situation

Given the large areas affected by wildfire on the taiga winter range, it is important to separately consider the tundra (RAA1 and RAA2) and taiga (RAA3, RAA4 and RAA5) portions of the annual range when calculating disturbance metrics.

Tundra (calving and post-calving, and summer range):

- Approximately 12% (6,610 km²) of the NWT central tundra (RAA2) is affected by human disturbance. This area includes the currently active diamond mines and a part of the Tibbit to Contwoyto Lake winter road.
- Less than 2% (1,080 km²) of RAA 1 (Nunavut) is affected by human disturbance.

Taiga (winter range):

- At approximately 17% (14,120 km²), RAA4 has the highest level of total human disturbance and the second highest area of recent wildfire disturbance. Combined, almost 50% (40,223 km²) of RAA4 is affected by human disturbance and recent wildfire.
- RAA5 has the highest level of recent wildfire disturbance. In total, 37% (35,459 km²) of RAA5 has been affected by recent wildfire but approximately 60-70% of the area south of treeline has been burned since 1965.
- Two parts of the taiga winter range, RAA3 and RAA5, have very low levels of human disturbance.

2.3.2. Potential Future Situation

Tundra (calving and post-calving, and summer range):

- RAA1 (Nunavut) has the highest potential to experience a large increase in the level of human disturbance. Given the development scenario assumptions, human disturbance could remain similar to the current level (1.4%, or 1,080 km²) but could potentially increase to 5-13% (4,000-10,000 km²) of the RAA if multiple proposed mine development and transportation projects proceed.
- The total level of human disturbance in RAA2 may remain similar to current, or could potentially decline over time if the current producing diamond mines close in the coming decades without being replaced by new mines. Closure of the existing mines would also likely lead to closure or dis-use of the Tibbit to Contwoyto Lake winter road.

Taiga (winter range):

- Given the development scenario assumptions, the total amount of future human disturbance in the central winter range (RAA4) may remain similar to current levels (14-19%, or 12,000- 16,000 km²). Replacing the southern part of the Tibbit to Contwoyto winter road with an all-season road would not significantly change the level of disturbance in RAA4, but would introduce many other human access management concerns and potentially facilitate higher levels of development than currently forecast.
- As a result of predicted climate change effects, the amount of future wildfire in the taiga portion of the Bathurst range is expected to remain similar to, or increase, compared with recent historical levels.

2.3.3. Potential Effects on Barren-ground Caribou

Results of the CARMA integrated caribou modelling suggest that human development has a negative incremental effect on caribou productivity (primarily through a reduction in pregnancy rates), with the magnitude of effect related to the amount of human disturbance the population is exposed to, as expressed as average encounters with human development and associated ZOI. As a higher proportion of the range becomes influenced by human disturbance, the probability of caribou encountering this disturbance increases. Modelling results did not identify any clear breakpoints in the level of acceptable human disturbance, but did identify an incremental negative relationship between disturbance levels and population performance.

2.3.4. Management Considerations by Range Assessment Area

The major current and potential future management considerations, and factors contributing to them, have been summarized for each range assessment area in the Bathurst caribou range planning area.

3. Management Thresholds

For the Bathurst Caribou Range Plan, management thresholds were established for each RAA based on the total disturbance footprint associated with human activities (which includes the ZOI).

In the tundra biome, RAA2 (NWT Central Tundra) was first deemed by the BCRP Working Group to be within the Cautionary Level. The critical threshold was set at 9,000 km² and the cautionary threshold was set at 50% of the critical threshold at a level of 4,500 km². The thresholds for RAA1 (Nunavut) were then benchmarked to RAA2 to account for the difference in proportion of area weighted by seasonal sensitivity. This resulted in a critical threshold of 12,000 km² and a cautionary threshold (set at 50%) of 6,000 km².

In the Taiga biome, similar to above, the RAA4 (NWT Winter Range – Central) was first deemed to be within the Cautionary Level. The critical threshold was set at 20,000 km² and the cautionary threshold was set at 50% of the critical threshold at a level of 10,000 km². The thresholds for RAA3 (NWT Winter Range – Northwest) were then benchmarked to RAA4 to account for the difference in proportion of area weighted by seasonal sensitivity. This resulted in a critical threshold of 19,000 km² and a cautionary threshold (set at 50%) of 9,500 km². Similarly, thresholds for RAA5 (NWT Winter Range – Southeast)

were then benchmarked to RAA4 to account for the difference in proportion of area weighted by seasonal sensitivity. This resulted in a critical threshold of 25,000 km² and a cautionary threshold (set at 50%) of 12,500 km².

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1 Introduction

1.1 Purpose

This report is a technical supporting document for the Bathurst Caribou Range Plan (the range plan). It describes the science-based methods and information used in the development of the range plan. Two companion background documents describe the traditional knowledge (Traditional Knowledge of Caribou and Caribou People) and land use and economic information (Land Use Scenarios and Economic Considerations Report) used and considered by the range plan. This report is organized into three main sections:

1. Section 2 describes how different natural and human factors may affect barren-ground caribou populations;
2. Section 3 is a range assessment, describing the current and potential future state of the Bathurst caribou herd and its range, with a focus on levels of human-caused disturbance; and
3. Section 4 describes how recommended human disturbance management thresholds were established in the range plan.

Methods for each topic are included in their relevant section. Five appendices provide additional detailed information or methods on specific topics, including human development footprint mapping, estimated zones of influence for human development features, range assessment areas, and the CircumArctic *Rangifer* Monitoring and Assessment (CARMA) integrated caribou model used to explore the potential effects of interacting human and natural factors on the Bathurst herd.

1.2 Background

The Bathurst herd is a population of migratory barren-ground caribou that traditionally calves near Bathurst Inlet in the Kitikmeot Region (i.e., central arctic) of Nunavut. Its annual range extends across a large part of the tundra and taiga biomes of Nunavut and the eastern Northwest Territories. In previous years its calving distribution extended to the east of Bathurst Inlet and its winter range reached to the boreal forests of northern Saskatchewan. The Bathurst range planning area is approximately 390,000 km² in size (Figure 1).¹

The Bathurst herd is an important component of the sub-arctic ecosystem from ecological, socio-economic and socio-cultural perspectives, and is a shared resource between many different aboriginal groups, including the Tłı̨chǫ, Łutsel K'e Dene First Nation, Yellowknives Dene First Nation, Métis, Athabasca Denesuline and Inuit.

¹ The BCRP range planning area is based on caribou radio-collar locations collected between 1996 and 2014. The boundary has been modified from Nagy (2011).



FIGURE 1. THE BATHURST CARIBOU RANGE PLANNING AREA AS DEFINED BY RADIO-COLLAR LOCATIONS COLLECTED BETWEEN 1996 AND 2014. THE BATHURST HERD HISTORICAL RANGE AS IDENTIFIED BY TRADITIONAL KNOWLEDGE IS ALSO SHOWN.

Within the last 30 years, the Bathurst herd caribou population has rapidly declined. Results of photographic calving ground surveys show that the Bathurst herd declined from an historic peak of over 450,000 in 1986 to an estimated ~35,000 caribou in 2009 (Nishi et al. 2014). Following management intervention (see WRRB 2016a), primarily in the form of harvest restrictions, the trend appeared to stabilize between 2009 and 2012. However, the population further declined approximately 40% from 2012 to 2015 and is now estimated at approximately 20,000 caribou (Boulanger et al. 2016). Overall the herd has decreased 96% since the peak population in 1986. Recently, in response to the dramatic population declines experienced by the Bathurst and other northern Canadian barren-ground caribou herds, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recently designated barren-ground caribou (*Rangifer tarandus groenlandicus*) as a threatened species².

During this 30-year period of population decline, improved road and trail access into the herd's winter range facilitated high levels of harvesting, and the level of mineral exploration and development activity on the herd's annual range increased. The combined concerns of human access and harvesting and increasing development lead to recommendations to establish and implement cumulative effects monitoring and management frameworks that would minimize negative impacts, to the extent possible (MVEIRB 2013).

In an attempt to address the cumulative impact concerns identified by community members as well as MVEIRB (2013) and other groups (see WRRB 2016b), the Government of Northwest Territories, Department of Environment and Natural Resources initiated a range planning process for the Bathurst herd, with a focus on managing levels of cumulative direct and indirect habitat disturbance. This report describes the technical information and methods used to support the range planning process and recommendations.

² COSEWIC definition of threatened: A species likely to become endangered if limiting factors are not reversed.

2 Factors Affecting Barren-ground Caribou

2.1 Methods

The BCRP Working Group collaborated with caribou biologists D. Russell and A. Gunn to use the CircumArctic *Rangifer* Monitoring and Assessment (CARMA) integrated computer simulation model (Russell et al. 2015) to explore and understand the relative influence of different natural and human-caused disturbances on Bathurst caribou herd health. The model was initially developed over several decades by D. Russell and colleagues for the Porcupine caribou herd that ranges across Alaska and northern Yukon and has been updated with relevant assumptions for barren-ground caribou in Nunavut and the Northwest Territories. The model is comprised of several interacting components, a movement model, energy-protein model and a population model. Based on available biological data, realistic assumptions for the Bathurst herd were incorporated.

The caribou modelling simulations were conducted in two stages. In the first set of simulations (Scenario Set 1), the following questions were explored:

1. What is the relative importance of initial caribou population size, population trend, and industrial development (amount and location) on a barren-ground caribou population?
2. How do predation and hunting affect barren-ground caribou population trend? and
3. How do environmental conditions affect barren-ground caribou population?

Key results from these model runs are reported in Section 2.5, below.

The second set of simulations (Scenario Set 2) was conducted to describe the relative potential impacts of industrial development and disturbance to caribou based on three refined future development scenarios. The human footprint mapping and its estimated zone of influence (ZOI) extents, and future development scenarios created as part of the land use assessment were used as inputs for the CARMA computer simulation model. Model results are reported as part of the range assessment exploring potential future conditions, in Section 3.5.2.4.

A detailed description of the two sets of computer simulation model assumptions and parameters are provided in Appendix D. Human development feature mapping which formed the basis for the different model runs is described in Section 3.1.4.2 and Appendix A. The estimated ZOI for each human development features used as inputs for the model runs are described in Section 3.1.4.2 and Appendix B. The three future development scenarios that formed the basis for Scenario Set 2—CASE 1 (declining development), CASE 2 (continuing development), and CASE 3 (increasing development)—are summarized in Section 3.1.4.3 and fully described in the Land Use Scenarios and Economic Considerations Report.

2.2 Scientific and Traditional Perspectives

Figure 2 provides a conceptual model of how different natural and human factors affect caribou habitat and populations from a scientific perspective. Natural and human factors are considered to influence caribou populations through either direct or indirect effects on habitat quality and availability, caribou productivity (births) and caribou mortality (deaths).

Both science and traditional knowledge recognize natural and human factors affect caribou; traditional perspectives also consider the spiritual connection between people and caribou, and about ways of doing and behaving around caribou. A traditional perspective on how different natural and human factors combine to affect caribou and indigenous residents is detailed in the Traditional Knowledge Report.

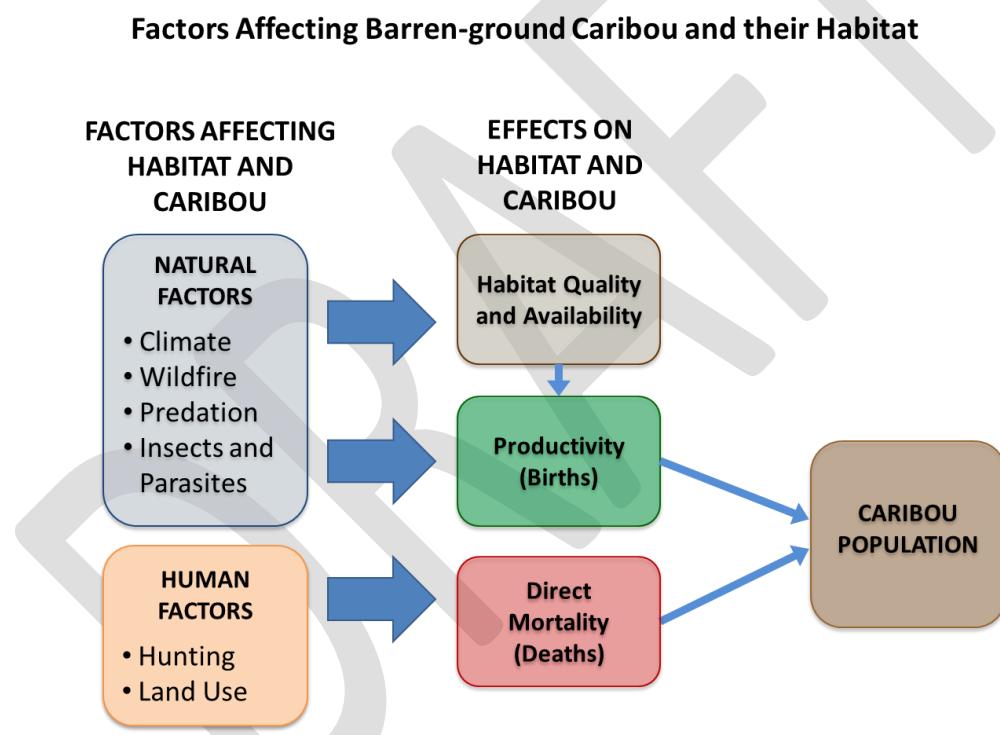


FIGURE 2: A CONCEPTUAL SCIENTIFIC MODEL OF FACTORS AFFECTING BARREN-GROUND CARIBOU AND THEIR HABITAT, AND EFFECTS ON POPULATION.

2.3 Natural Factors Affecting Caribou

2.3.1 Climate

Climate is the primary environmental factor affecting that affects temperature and precipitation conditions, and ultimately influences vegetation (habitat) type and productivity. Climate also directly affects barren-ground caribou through winter snow conditions (depth, icing events and timing), the timing of vegetation green green-up during the spring calving and post-calving period, and through summer temperature and precipitation. Activity of parasitic insects (see Section 2.3.4), parasites and diseases, important factors influencing individual caribou fitness, are also strongly linked to summer temperature and precipitation conditions. High insect harassment levels influence caribou behavioral patterns (decrease feeding time and increase activities such as walking and running) that may in turn reduce body condition of individual caribou. Summer temperature regimes and annual precipitation patterns also affects the amount and intensity of wildfire in the forested winter range.

Arctic ecosystems are especially vulnerable to global climate change as temperature and precipitation regimes are altered. Migratory caribou appear to prefer regions with higher snowfall and lichen availability in the fall and winter. In the summer, caribou prefer cooler and windier areas that have a lower abundance of insects. In winter, caribou avoid or use disturbed and recently burned areas less frequently. Direct and indirect consequences of climate change on migratory caribou possibly include alteration in habitat use, migration patterns, foraging behaviour, and demography. In addition, changing climatic conditions may have very real implications on social and economic stress to Arctic and Subarctic Aboriginal human populations.

2.3.2 Wildfire

Wildfire is an important natural disturbance agent that shapes and rejuvenates northern boreal (taiga) forests. Wildfire affects barren-ground caribou winter habitat availability and quality by creating a natural mosaic patches of different forest ages; thus wildfire both creates and temporarily disturbs barren-ground caribou winter habitat. As spruce-dominated forests age and become over-mature (130+ years), lichen abundance, the primary winter food source for caribou, can decrease as a result of understory shading (Maikawa and Kershaw 1976). Wildfire is therefore necessary for the renewal of lichen growth. However, caribou are also known to avoid or use recently burned areas (forests less than 50-80 years old) less frequently than mature forests (Schaefer and Pruitt 1991, Thomas et al. 1996, Anderson and Johnson 2014). A large amount of recently burned area may therefore reduce the carrying capacity of a winter range and shift the distribution of caribou away from historically used areas.

Community members have become very concerned about the amount of recent wildfire in the Bathurst winter range, particularly resulting from the 2014 fire season. While this amount of wildfire has likely occurred in the past, for many residents it was the most extreme fire season in recent memory. Compounded with human disturbance resulting from mineral exploration and mining, transportation, direct mortality from hunting and predators, and a potentially changing climate, communities are

concerned the high level of recent fire has resulted in inadequate suitable winter range habitat to support a recovering Bathurst caribou population. Recent research on the winter range of the Bathurst herd indicated that fire was not considered to be limiting the availability of winter habitat (Barrier and Johnson 2012), but this research was completed prior to the 2014 fire season.

Unburned patches and corridors often remain inside of large fires, and these unburned remnants can be important for caribou as forage and for movement through burned areas. In the extensive upland jack pine and black spruce forests of the Boreal Shield ecozone in northern Saskatchewan, Kansas et al. (2016) found that on average 19% of the area within wildfire perimeters was composed of unburned forest remnants. In studies from other western Canadian regions, 5-20% residual retention within wildfire areas has also been reported.

With warmer temperatures and longer growing seasons predicted for northern Canada under a climate change scenario, forest fires are expected to increase in frequency, intensity, duration (length of fire season) and ultimately increase the area burned on an annual basis (Flannigan et al. 2005). The Bathurst caribou herd shifts its distribution in the winter range in response to burns and its ability to move across the landscape to select unburned areas is an important adaptive strategy. It is uncertain how a change in fire frequency, intensity and area burned might affect the Bathurst herd in the future.

2.3.3 Predation

Barren-ground caribou are part of a natural predator-prey system that has evolved since the end of the last Ice Age, approximately 8,000 to 10,000 years ago. Seasonal migration is thought to be an important strategy used by caribou to avoid predators during different parts of their annual life cycle. Humans, wolf, grizzly bear and wolverine are the most important predators. Traditional knowledge and science tell us that predators are the largest natural source of direct mortality for Bathurst caribou.

Predation by wolves is the predominant source of natural mortality in migratory barren-ground caribou. Due to the continued recent decline of the Bathurst herd and its current critical state, the Wek'èezhìi Renewable Resources Board (WRRB 2016a) recommended that GNWT and Tł'chǫ Government conduct a collaborative feasibility assessment of options for wolf management³. Tł'chǫ communities have reported that wolves are abundant and increasing in and around communities, and are concerned about potential conflicts with people and pets (including working dogs) as well as high levels of predation on caribou (WRRB 2016d). If conducted effectively for several years and in combination with harvest management and community participation, the rationale for reducing wolves is to increase caribou survival, which would contribute to increased caribou herd growth (WRRB 2016c).

³ <https://www.wrrb.ca/news/wolf-technical-feasibility-assessment-options-managing-wolves-range-bathurst-barren-ground>

2.3.4 Insects and Parasites

Harassment from parasitic insects (i.e., mosquitoes, warble flies, and black flies) may affect activity budgets and habitat use by caribou during late spring and summer, to the extent that in years with high insect harassment caribou have reduced body condition due to less time spent feeding and more energetic costs from walking and running. Community members have commented on how stressful insects can be for caribou, explaining that animals can run around “crazy” until they suddenly collapse. Insect harassment is closely linked to summer temperature, wind conditions, and other environmental variables. Recent studies on the Bathurst range have showed the importance of insect harassment on influencing foraging behavior of caribou (Witter et al. 2012). Combined with variation in summer forage quality, harassment from biting insects is an important natural factor that influences summer body condition and fall pregnancy rates in migratory barren-ground caribou. Traditional knowledge tells us that caribou are skinnier in the years when there are many insects.

2.4 Human Factors Affecting Caribou

2.4.1 Hunting

In the boreal forest and on the tundra, caribou hunting has been the basis of Aboriginal traditional economy and culture for millennia. Most groups across the range of the Bathurst herd have published their traditional rules around hunting caribou (Legat et al. 2001).

In the modern era, caribou hunting has since become an important part of northern residents’ lifestyle, with guide outfitting and non-Aboriginal harvest being important economic and recreational activities. Hunting can be an important source of direct mortality for caribou. Hunting may contribute to herd decline if total harvest is large relative to herd size, is predominantly comprised of breeding females, and if the herd has high natural mortality and low productivity. With the availability of modern firearms and off-road vehicles (including snow machines), hunting pressure is often closely associated with the amount of road and trail access on caribou range.

The Tiffet to Contwoyto Winter Road (TCWR) was originally built in 1982 to supply the Lupin Gold Mine at Contwoyto Lake in what is now Nunavut, and has since become the busiest heavy-haul ice road in the world. In addition to being the only overland supply route for mines in the central barrens, the TCWR also provided unprecedented hunting access to the winter range of the Bathurst caribou herd and facilitated relatively high levels of harvest observed from the mid-1980s to the early-2000s.

As a result of the rapid rate of decline observed in the Bathurst caribou population from 2006-2009, commercial guide outfitting and resident harvest in the Northwest Territories have been closed for the herd since winter 2009. An annual harvest target of 300 caribou was implemented for Aboriginal harvesters in the Northwest Territories from winter 2010 to 2014, and the Bathurst herd has been effectively closed to all hunting since winter 2015; in spring 2016 the WRRB recommended a total allowable harvest (TAH) of zero for the Bathurst herd (WRRB 2016a). In recent years, the annual harvest

of Bathurst caribou in Nunavut has been estimated at ~70 bulls taken under a commercial allocation to the community of Bathurst Inlet and used for late-summer sports hunts. In spring 2016, the Government of Nunavut recommended that the Nunavut Wildlife Management Board (NWMB) establish a Nunavut TAH of 30 male caribou for the Bathurst Herd.

2.4.2 Land Use

Human land use includes the physical features that people build and the activities of people on or around them. Scientific and traditional perspectives about how land use affects caribou are quite similar, and each corroborates the other. The following provides a description of scientific perspectives on land use; traditional perspectives are discussed in the companion Traditional Knowledge Report.

Figure 3 illustrates an impact pathway of how human land use (and other factors) may affect barren-ground caribou. The CARMA integrated caribou computer model (described in Section 2.5, below) simulates land use effects on barren-ground caribou based on the number of encounters and amount of time that caribou interact with and are influenced by the direct footprint and associated activities of industrial and human activity on the landscape (see Figure 7 in Section 3.1.4.1, below). The residency time of caribou within a ZOI (i.e., the number of days a caribou occurs within a ZOI) represents the total time throughout the year when a caribou's daily food intake (i.e., energy and protein intake) and activity budget may be influenced by human-caused disturbance.

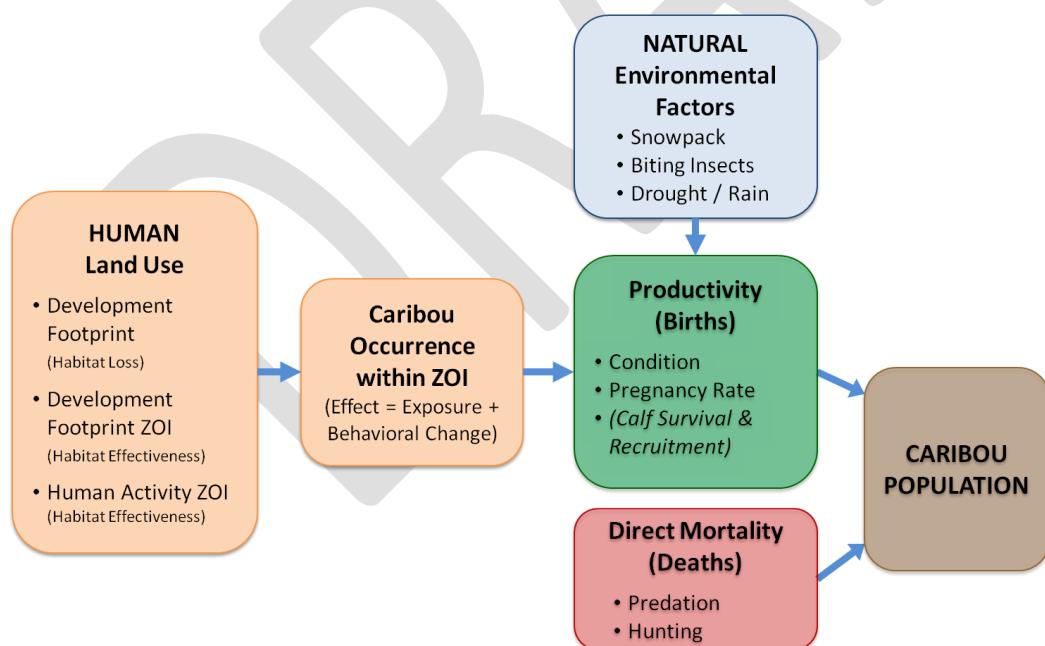


FIGURE 3: A CONCEPTUAL SCIENTIFIC IMPACT PATHWAY OF HOW DISTURBANCE RESULTING FROM HUMAN LAND USE AND OTHER NATURAL AND HUMAN FACTORS INFLUENCE BARREN-GROUND CARIBOU VITAL RATES AND POPULATION HEALTH.

Thus residency time, or exposure of caribou to a ZOI is a key evaluation criterion and input value for the CARMA integrated caribou model, which in turn provides a transparent and logical means of simulating how cumulative effects on daily food intake and activity budgets may influence population productivity through impacts on pregnancy rate and calf survival (Figure 3). In addition to evaluating the magnitude of disturbance effects to population productivity, the integrated caribou modeling framework also permits an assessment of the relative contributions of changing environmental conditions, as well as assumptions about direct sources of mortality that are attributed to predation and/or hunting (Figure 3).

2.5 How Different Natural and Human Factors May Affect Barren-ground Caribou Population Health

The CARMA integrated caribou model was used to explore the following three questions.⁴

QUESTION 1: What is the relative importance of initial caribou population size, population trend, and industrial development (amount and location) on a barren-ground caribou population?

Based on model runs to address this question, the key finding was increased levels of industrial development reduced population growth by reducing pregnancy rates and herd productivity. This effect was small compared to assumptions on direct mortality rates, but the effect is significant and important especially when a population would otherwise be stable or declining in the absence of industrial development (i.e., during a declining phase of a natural population cycle).

Within a development level, population trend was not affected by initial population size and was driven primarily by mortality levels. Similarly when comparing scenarios across development levels, population trend was not affected by initial population size and was driven primarily by mortality levels. However, development levels had a synergist effect with mortality levels and reduced population trend further, as development levels changed from no development to a future-high scenario (Figure 4). This was most clearly shown for populations that had a medium level of mortality where under a no development scenario the population would be increasing. However, when the population was simulated with the same assumptions except that it was in a future-high development scenario, the population switched to a declining trend.

⁴ These results are from Scenario Set 1 of the CARMA integrated caribou model (see Section 2.1 and Appendix D for detailed methods and assumptions).

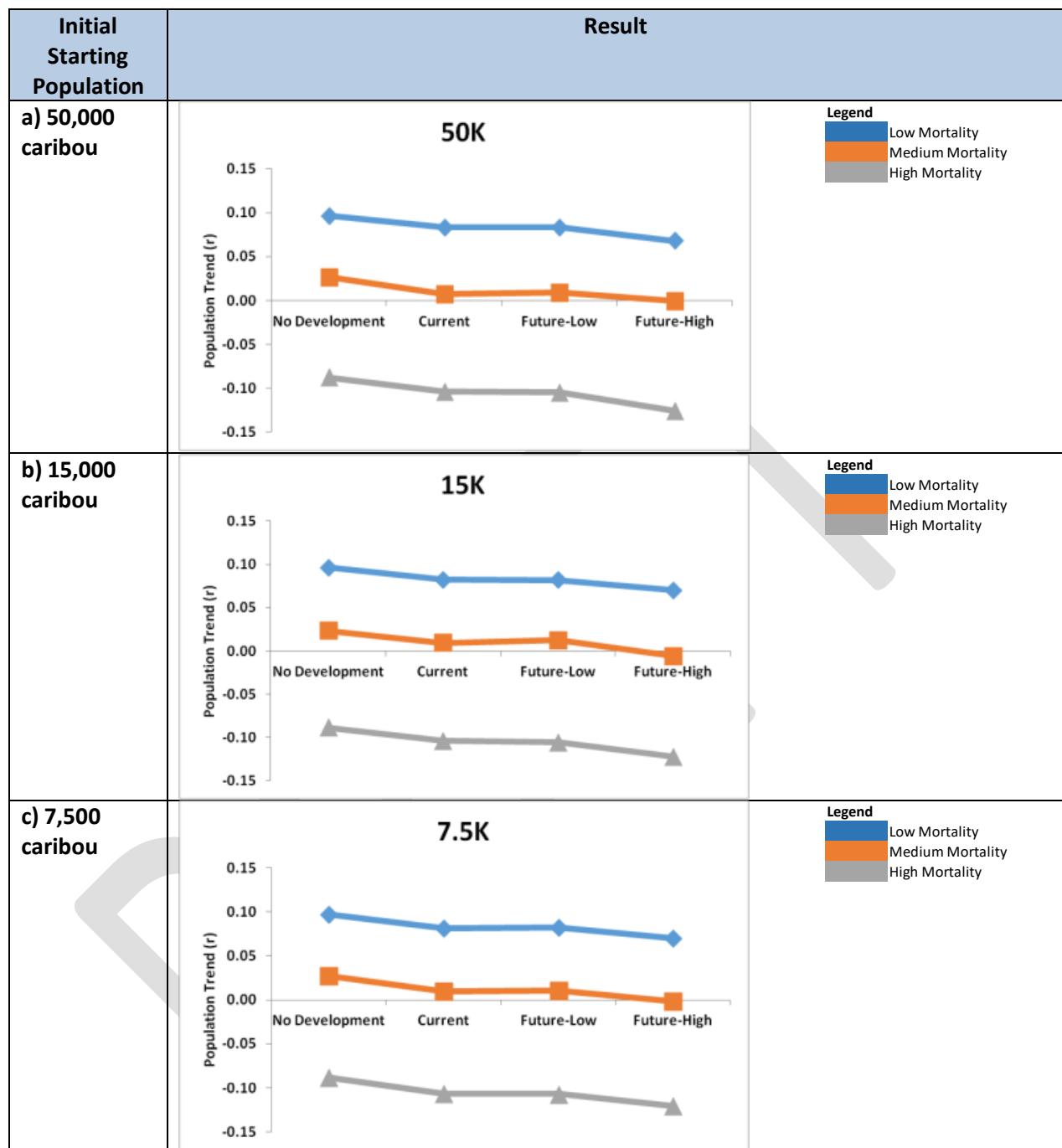


FIGURE 4: INFLUENCE OF INDUSTRIAL DEVELOPMENT LEVELS AND RATES OF NATURAL MORTALITY ON SIMULATED CARIBOU POPULATION GROWTH RATES, WITH SCENARIOS STARTED AT DIFFERENT POPULATION SIZES.

Increased levels of industrial development resulted in incrementally higher encounter rates of caribou with human footprints, which in turn imposed higher energetic costs to adult females and reduced their fall pregnancy rates. The reduction in pregnancy rates reduced overall population productivity and had a synergistic effect with mortality rates, which together resulted in higher rates of population decline in scenarios with more industrial development.

QUESTION 2: How do predation and hunting affect caribou population trend?

The model simulations used to explore this question provided three key findings:

- a) Predation and hunting may have additive effects on population health by increasing total mortality in a caribou herd. In the simulation model, the additive effect of hunting may accelerate a decline for a population that has pre-existing medium and/or high rates of natural mortality from predation (and other causes).
- b) A harvest that removes the same number of animals annually may accelerate a rate of decline as the population gets smaller, because a constant harvest rate may result in an increasing proportion of animals that are removed as a population declines.
- c) High and selective harvest mortality of females may have strong additive and negative effects on population trend because it not only contributes to increasing mortality rates, but also reduces future rates of productivity (i.e., numbers of newborn calves).

The additive and interactive effect of hunting with natural mortality rates is illustrated in Figure 5, which summarizes scenarios that applied three harvesting strategies to two populations with different initial sizes and contrasts three levels of mortality. The overall patterns are consistent between the two starting populations and show that the rates of mortality had the strongest overall influence on population trend. For example, under the assumption of low mortality a population will continue to grow under both harvesting strategies regardless of whether the initial population size is 15,000 or 7,500 caribou, while the high harvest strategy had the greatest influence on reducing population growth rate (r). Under medium mortality assumptions and no hunting the population increased at ~2% per year (i.e., $r = 0.02$). Population growth rate decreased when the low hunting strategy was applied, and shifted to a declining trend for the small initial population (Figure 5b). In comparison, the high hunting strategy shifted both scenarios (with different initial population sizes) to a declining trend. Under high mortality assumptions and no hunting, the population was declining at ~ -9% per year (i.e., $r = -0.09$). Under this mortality assumption, both the low and high hunting strategies increased the rate of decline. In the scenario with a small initial population size, the low hunting strategy had a greater additive effect on the rate of decline because the constant annual harvest rate of 200 became an increasingly larger proportion of the small population as it declined over the 16-year simulation period.

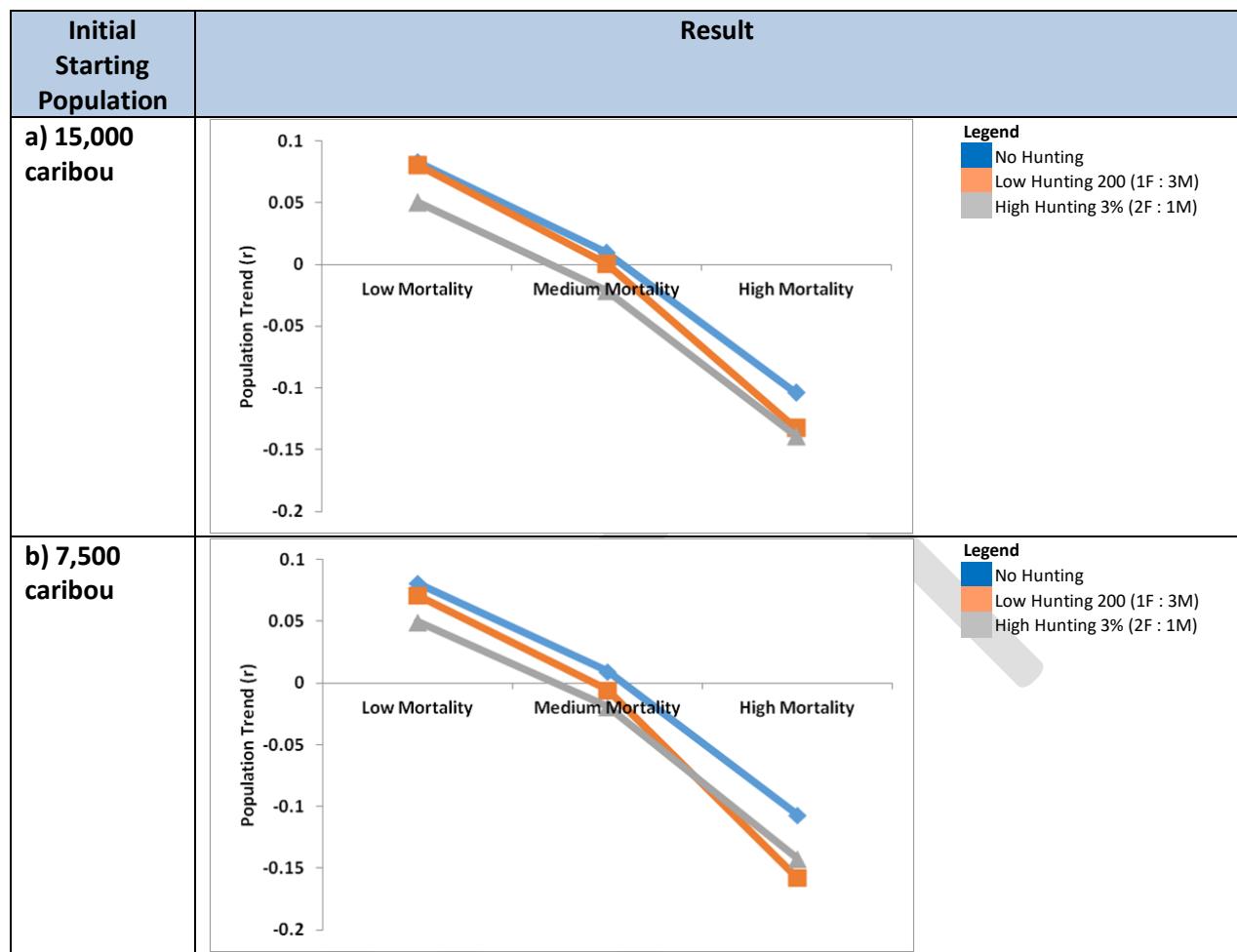


FIGURE 5: COMPARING THE INFLUENCE OF MORTALITY AND HUNTING LEVELS ON POPULATION RATE OF GROWTH WITH INITIAL POPULATION SIZE AT A) 15,000 CARIBOU AND B) 7,500 CARIBOU.

QUESTION 3: How do environmental conditions affect a barren-ground caribou population?

The model simulation results used to explore the influence of environmental conditions on caribou population suggest that environmental variability influences caribou population productivity, but to a lesser degree than direct mortality. Environmental conditions affect caribou through changes in nutrition (i.e., timing of plant green-up which provides early nutrition for lactation and re-gaining body condition, drought impacts on plant biomass and nutritive quality), and activity budgets (i.e., environmental conditions may increase harassment from biting and parasitic insects, which can reduce foraging time and increase energy expenditures).

Figure 6 illustrates the relative costs of development and environmental conditions by comparing the numerical difference in caribou population trends at the end of the 16-year simulation period. The middle bar represents the number of caribou that declined over the simulation in comparison to a reference case with identical assumptions except that there was no anthropogenic footprint on the range. Figure 6 expresses the opportunity costs between different scenarios as the number of caribou that were foregone either due to increased development, or the costs associated with the influence of environmental factors.

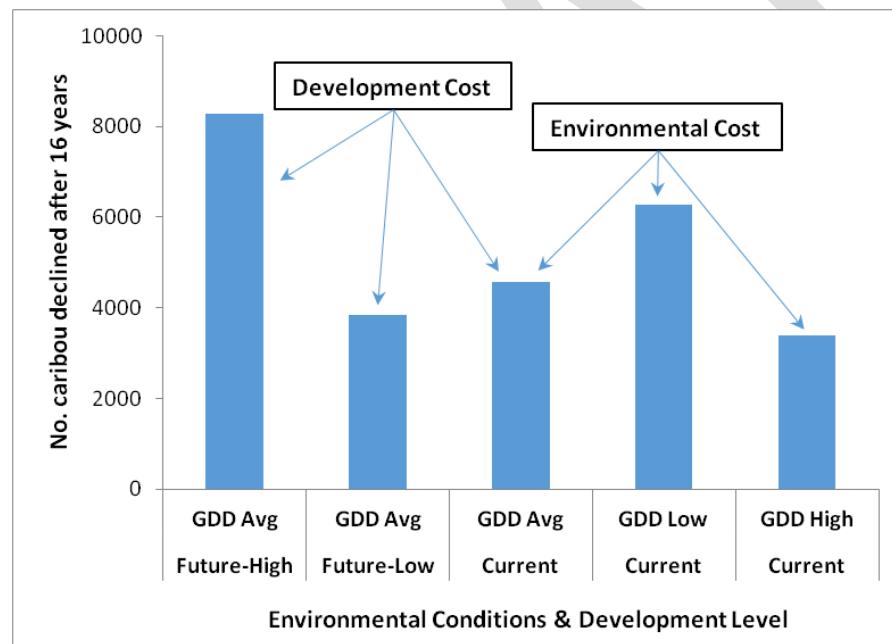


FIGURE 6: RELATIVE DECLINE IN CARIBOU ABUNDANCE AFTER 16-YEAR SIMULATION PERIOD COMPARED TO A REFERENCE CASE SCENARIO WITH AVERAGE MORTALITY ASSUMPTIONS, AVERAGE GROWING DEGREE DAYS (GDD) ENVIRONMENTAL CONDITIONS, AND NO DEVELOPMENT FOOTPRINT.

2.6 Summary

A number of factors may affect barren-ground caribou populations. Natural factors include climate, wildfire, predation and insects and parasites. Human factors include hunting and land use. Traditional and scientific perspectives have similar views on how land use affects caribou (traditional knowledge on the subject is summarized in the Traditional Knowledge Report). Based on caribou simulation modeling results, the relative importance of different factors affecting barren-ground caribou can be described as follows:

- Caribou mortality rates (predation or hunting) appear to have the strongest overall influence on caribou population trend.
- Environmental variability (climate, insects and diseases, green-up) influences caribou population productivity, but to a lesser degree than direct mortality.
- Increasing levels of land use (i.e., increasing levels of development footprint and associated ZOI) result in incremental reductions in herd productivity, largely through a reduction in expected female caribou pregnancy rates.
- Lower pregnancy rates reduce overall population productivity, and have a synergistic effect with mortality rates. Combined, these two factors result in higher rates of population decline in scenarios with higher levels of industrial development.
- The relative effect of wildfire on population performance was not able to be directly assessed. However, the boreal woodland caribou recovery strategy (ECCC 2012) considers wildfire disturbance as a factor in determining disturbance management thresholds.

3 Bathurst Caribou Range Assessment

3.1 Methods

The Bathurst caribou range assessment was conducted in two parts:

1. Describing and understanding the current population and range conditions, and
2. Exploring potential future population and range conditions.

The current situation was completed by integrating existing information about the population trend, habitat conditions and human land use. Future conditions were explored by developing different land use scenarios and exploring potential effects on population health with the CARMA model. Each step is described below.

3.1.1 Population Status

The historical population trend and current estimated status were reported from Government of Northwest Territories survey results for the period 1986 to 2015.

3.1.2 Range Use and Migration

The annual range represents the total area used by the herd over the course of a year, whereas seasonal ranges describe the areas used by caribou at different times within a year. Range use as documented from a long-term caribou collar data set (1996 to 2017) and traditional knowledge has been used to understand the seasonal ranges and caribou movements within and between ranges. Seasonal range, range utilization, and migration analyses were completed by Caslys Consulting for the Government of Northwest Territories, Department of Environment and Natural Resources. Changes in range use over time were also examined.

3.1.3 Important Areas and Habitat Features

A synthesis of caribou collar-derived range use, available traditional knowledge, and new information gathered during the BCRP process was used to represent knowledge of recent and historical caribou range use, and important habitat features for caribou. The concept of range sensitivity was also incorporated; barren-ground caribou are considered to be more or less sensitive to disturbance during different times of the year.

Important areas are considered to be relatively large geographic areas of greater importance to the Bathurst herd such as seasonal ranges or parts of the range with high levels of consistent use during sensitive times of the caribou life-cycle. Important habitat features describe smaller, specific parts of the range considered to be of high importance to caribou (e.g., water crossings). Given the landscape-level focus of the Bathurst range plan, fine-scale habitat selection was not assessed but has been reported on extensively as part of environmental assessment processes and other studies.

3.1.4 Disturbance Assessment

The disturbance assessment conducted in support of the Bathurst Caribou Range Plan generally followed the range assessment methods developed by Environment and Climate Change Canada for boreal woodland caribou (ECCC 2011), but were tailored to reflect the tundra and taiga environments of the Bathurst range. Direct and indirect human-caused disturbance and recent wildfire disturbance were mapped and summarized to calculate the cumulative area affected. At this time, non-footprint based human land use activities (e.g., mineral staking with aircraft support, or recreational travel) have not been considered in the human-caused disturbance assessment.

3.1.4.1 Human-caused Disturbance Concepts

Human land use can result in disturbance⁵ to caribou. Human disturbance effects can be considered as either **direct** or **indirect**. Land use features, such as roads, settlements or mine sites, have a direct physical footprint that results in habitat loss or alteration. An area of indirect disturbance may exist around these physical footprints, where noise, dust, smells or other factors influence caribou's use of habitat. This area of indirect disturbance around a human development feature is known as the zone of influence (ZOI). Caribou may avoid these zones of influence, use them less frequently, exhibit altered behavior, or have a higher mortality risk from harvest or predation within them. In GIS mapping, ZOI is estimated as a spatial buffer of a defined distance around a human development feature.

Figure 7 illustrates concepts for the direct footprint of physical features and its estimated ZOI. In this example the Snap Lake diamond mine is shown; the property is currently under care and maintenance, and is considered to have a 5 km ZOI surrounding the mine site. Its associated winter road is assigned a 1 km ZOI on either side of the road (2 km total width), which would only be active during the January-April haul period when the road is in use. Based on human development feature mapping and its estimated ZOI extents, the amount of direct and indirect disturbance within the Bathurst range can be calculated using GIS.

⁵ Disturbance is a temporary or permanent change in environmental conditions that might influence wildlife abundance and distribution. It is comprised of two aspects: direct disturbance is physical change (e.g. trees cut down or burned) whereas indirect disturbance is a change to non-physical aspects of the environment (e.g. noise, smell, light, etc.)

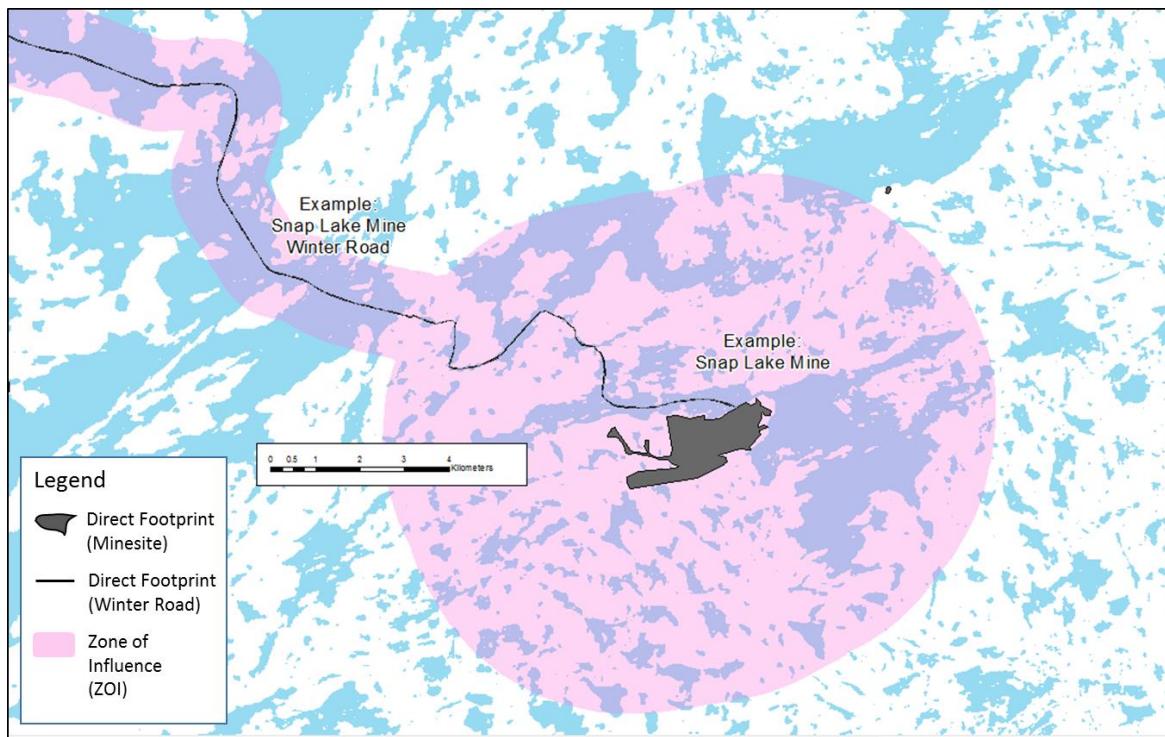


FIGURE 7: HUMAN DISTURBANCE CONCEPTS—EXAMPLE OF DIRECT HUMAN DEVELOPMENT FOOTPRINTS AND THEIR ESTIMATED ZONES OF INFLUENCE (ZOI).

3.1.4.2 *Disturbance Assessment - Current Situation*

Human-caused Disturbance

The amount of direct and indirect human-caused disturbance in the Bathurst range planning area was calculated from an integrated GIS data set of human land use features/surface disturbances developed as part of the range planning exercise. The human land use feature mapping was created by compiling and merging available GIS information including the Government of Northwest Territories Cumulative Impact and Monitoring Program (CIMP) database, the National Road Network, and mineral industry-provided information used to support project assessment and permitting activities. Detailed mapping methods are described in Appendix A. Table 1 lists the different linear and polygonal feature types represented in the Bathurst planning area human development database, and their corresponding estimated ZOIs. The ZOI extent around each human development feature was estimated based on literature reviews and values used in recent environmental assessments. The rationale and literature sources used to estimate ZOI extents are listed in Appendix B.

TABLE 1: HUMAN LAND USE FEATURE TYPES REPRESENTED IN THE BATHURST RANGE PLANNING AREA HUMAN DEVELOPMENT DATABASE, AND THEIR ESTIMATED ZONES OF INFLUENCE (ZOI) ON BARREN-GROUND CARIBOU.

Feature Type	Feature Class	Description	Estimated ZOI (km)
Linear	All-season Access Road	Any all-season road, including roads in Settlements (average 10m width)	5
	Major Electrical Transmission Corridor	Any major electrical utility corridor (e.g., Snare River) (average 30m clearing width)	4
	Public All-season Paved Highway	Any all-season paved highway (e.g., NWT Highway #3 and #4) (average 60m clearing width)	5
	Mainline All-season Access (Haul) Road	Any major all-season access or haul road (e.g., current Ekati Misery Road or potential future Izok Corridor road) (average 20m width)	5
	Winter Road	All winter roads (except main Tibbit to Contwoyto Winter Road) (average 12m width)	1
	Tibbit to Contwoyto Winter Road	Mainline Tibbit to Contwoyto Winter Road (average 40m width)	4
Polygonal	Airstrip	Active airstrip with paved or unpaved surface	5
	Camp	Mineral exploration camp, lodges or similar	5
	Communication Tower	Communication tower	1
	General Industrial	Variety of general industrial features	1
	Mineral Exploration	Mineral exploration-related infrastructure and disturbances	5
	Minesite (Active)	Minesites under construction or in production	14
	Minesite (Past or Closed)	Past or closed minesites, either abandoned or under active reclamation	5
	Miscellaneous	Variety of uncertain industrial or non-industrial surface disturbances or infrastructure.	1
	Marine Port	Future proposed or conceptual marine port/laydown facilities in Nunavut on the Arctic coast (e.g., Grays Bay or Bathurst Inlet)	5
	Power Generation Facility	Hydro power generation facilities (dams, spillways, powerhouses, and associated)	5
	Quarry	Any excavation site used for the purpose of developing aggregate, sand, crushed rock, etc.	5
	Settlement	Any permanent settlement with a recognized municipal boundary (e.g., City of Yellowknife, Whati, etc.)	15

Wildfire Disturbance

Wildfire is the dominant natural disturbance in the taiga portion of the Bathurst winter range. The Government of Northwest Territories and Government of Saskatchewan wildfire history databases were used to map and calculate the amount of area affected by wildfire in the planning area for the period 1965-2015. The wildfire history mapping generally represents large (>200 ha) wildfires and is known to have reduced fire detection and mapping accuracy in the early period of records (1960s-1970s). Literature describing the historical and current wildfire regimes of the Taiga Shield ecozone and surrounding areas were also referenced.

Total Disturbance

Total range disturbance was calculated in GIS by overlaying the non-overlapping extent of total human-caused disturbance (direct development footprint plus estimated zone of influence) and wildfire disturbance for the period 1965 to 2015.

3.1.4.3 Disturbance Assessment – Potential Future Situation

Human-caused Disturbance

Future development (land use) scenarios provide insight into the amount and location of human activities that may occur in different parts of the range in the future. Three scenarios were created using information based on known or reasonably foreseeable future mineral development and transportation projects that may occur in the next 24 years (2016 to 2040)⁶. Early-stage mineral exploration (mineral staking and grass-roots exploration activities) was not addressed in the future development scenarios, but may be examined in the future. The BCRP Working Group considered three potential situations:

- CASE 1: Declining development;
- CASE 2: Continuing development; and
- CASE 3: Increasing development.

⁶ The BCRP Working Group worked closely with the Mineral Task Group to develop assumptions and project parameters for the three development scenarios.

Table 2 summarizes the major assumptions for each scenario. CASE 1 represents a situation of declining development, where the existing operating diamond mines and Tibbit to Contwoyo Lake winter road cease operations by 2040, and no new mines are brought to production. CASE 2 projects a similar level of development into the future as current, where the existing diamond mines are replaced by new mineral development projects in the coming decades, and the southern part of the Tibbit to Contwoyo Lake winter road is replaced by a new all-season road into the central Slave Geological Province. CASE 3 represents an increasing level of development with new all-season road infrastructure in Nunavut and several new mines being developed, both in Nunavut and Northwest Territories. For each case, a detailed timeline of construction, operations and reclamation was created for each project considered in the scenario. Please see the Land Use Scenarios and Economic Considerations Report detailed scenario descriptions and assumptions. The amount of human-caused disturbance resulting from each scenario was calculated in the same manner as used for the current situation.

Wildfire Disturbance

The amount of potential future wildfire disturbance was not formally assessed. However, with warmer temperatures and longer growing seasons predicted for northern Canada under a climate change scenario, forest fires are expected to increase in frequency, duration and ultimately increase the area burned on an annual basis (Flannigan et al. 2005). It is therefore unlikely the amount of future wildfire disturbance will decrease compared with recent burn rates. The amount of recently burned area was therefore considered to be a minimum baseline for understanding potential future wildfire and cumulative disturbance levels.

Total Disturbance

The amount of potential future total disturbance (direct and indirect human-caused plus wildfire) was not formally assessed. The human disturbance component was represented by the three development scenarios, and as discussed above, the amount of future wildfire is not anticipated to decrease compared with current or recent historical levels.

TABLE 2: OVERVIEW OF THE BATHURST RANGE PLAN FUTURE DEVELOPMENT SCENARIOS.

Scenario Assumptions	CASE 1: Declining Development	CASE 2: Continuing Development	CASE 3: Increasing Development
General Assumptions	CASE 1 assumes the existing producing mines are closed at the end of their projected life-span and no new mines are built, leading to the discontinuation of the Tibbit to Contwoyto Lake Winter Road. Mineral exploration declines or remains similar to current, with no other changes in transportation or electrical utility infrastructure.	CASE 2 assumes that only a few of the existing advanced mineral exploration projects will become producing mines in the coming 24 years, mineral exploration will remain similar to current, and there will be limited change in current transportation and electrical utility infrastructure.	CASE 3 assumes that many of the existing advanced mineral exploration projects will become producing mines in the coming 24 years, the level of mineral exploration may increase, and the amount of transportation infrastructure will increase, but electrical generation will remain similar to current.
Advanced Mineral Exploration*	<ul style="list-style-type: none"> Current mineral exploration projects. 	<ul style="list-style-type: none"> Current mineral exploration projects are maintained except those that advance to producing mines. 3 new Advanced Exploration projects 	<ul style="list-style-type: none"> Current mineral exploration projects are maintained except those that advance to producing mines. 7 new Advanced Exploration projects (CASE 2 plus 4 new)
Mineral Development	<p>3 active mines:</p> <ul style="list-style-type: none"> 3 producing diamond mines (Ekati, Diavik and Gahcho Kué) 1 diamond mine under care and maintenance (Snap Lake). <p>The 3 producing diamond mines become past mines as they reach closure in 10-20 years future.</p>	<p>6 active mines:</p> <ul style="list-style-type: none"> Back River Project (Goose) Snap Lake (re-opens) Kennedy North Lupin-Ulu NICO Courageous Lake <p>The 3 producing diamond mines become past mines as they reach closure in 10-20 years future.</p>	<p>12 active mines (CASE 2 plus the following 6):</p> <ul style="list-style-type: none"> Izok Lake High Lake Hackett River Indin Lake Nechalacho Tyhee Gold
Transportation	<p>Current all-season and winter road transportation network.</p> <p>After the Ekati, Diavik and Gahcho Kué mine sites are closed, the Tibbit to Contwoyto Winter Road is no longer used.</p>	<p>Current road network maintained <u>except</u> construction of new all-season roads:</p> <ul style="list-style-type: none"> Hwy #3 to Whati (Tłı̨chǫ All-Season Road – TSAR) (replaces existing winter road); NICO to Whati; Tibbitt to Lockhart Lake (replaces approximately 150km southern section of existing winter road) <p>Construction of Back River Project winter road to Bathurst Inlet and Marine Laydown facility proceeds.</p>	<p>Future low scenario <u>plus</u> new Nunavut minesite access roads:</p> <ul style="list-style-type: none"> IZOK road and port BIPAR road and port (Phase I) Back River utilizes BIPAR road and port
Electrical Generation and Transmission	<p>Current facilities and transmission:</p> <ul style="list-style-type: none"> Snare; Bluefish; and Taltson 	No change; current situation is maintained.	No change; current situation is maintained.
Settlements	Current situation	No change; current situation is maintained.	No change; current situation is maintained.

*Early-stage mineral exploration (staking and grass-roots exploration) is not currently addressed in the BCRP Development Scenarios.

3.1.4.4 Potential Effects of Future Development Scenarios on Bathurst Caribou Population Health

CARMA model results (Scenario Set 2) were used to explore the potential effects of the three future development scenarios (CASE 1, 2 and 3) and other mortality factors on Bathurst caribou population health. Results are reported in Section 3.5.2.4.

3.1.5 Interim Range Assessment Areas

To better understand the potential land use and management issues affecting caribou in the different parts of the range, the BCRP Working Group developed the concept of range assessment areas (RAAs)⁷. Five RAAs were created (Figure 8) by considering human land use patterns, administrative boundaries, and Bathurst caribou range use and habitat conditions (Appendix C). The RAAs formed reporting units for the disturbance assessment results, and were later adopted as the interim spatial units of the Cumulative Land Disturbance Framework, a key management tool in the Bathurst Caribou Range Plan.

⁷ The RAAs and the overall BCRP planning area are not legal boundaries and have no relationship to traditional territories, interim land withdrawals, or land claim negotiations; they were created for use only in the Bathurst Caribou Range Plan.



FIGURE 8: INTERIM RANGE ASSESSMENT AREAS IN THE BATHURST CARIBOU RANGE PLANNING AREA.

3.2 Population Status

The Bathurst herd is a population of migratory barren-ground caribou (*Rangifer tarandus groenlandicus*) that traditionally calves near Bathurst Inlet in the Kitikmeot Region (i.e., central Arctic) of Nunavut. Its annual range extends across the tundra and taiga (boreal forest) biomes occurs within Nunavut and the eastern Northwest Territories. The Bathurst herd shares portions of its annual range with at least three other migratory caribou herds: the Bluenose East, Beverly-Ahiak and Dolphin Union⁸ (Figure 9). Barren-ground caribou are considered an ecological keystone species because of their simultaneous roles as large migratory grazers and primary prey for carnivores.

For the Bathurst herd, the scientific understanding of recent patterns of abundance are based on multiple aerial surveys of the annual calving ground, which is a photographic survey methodology that was standardized in the mid-1980s to estimate abundance of breeding females (Heard 1985). Figure 10 shows the gradual decline in population size of the Bathurst caribou herd from the 1980s to the early 2000s followed by a high rate of annual decline from the mid-2000s to present. The most recent June 2015 calving ground photographic survey resulted in an overall herd estimate of $19,769 \pm 7,420$ caribou in the Bathurst herd (Boulanger et al. 2016), which is a decrease of almost 96% over the time frame of the surveys.

Other demographic indicators for the Bathurst herd consistent with a declining trend between 2012 and 2015 (ENR 2014a) include:

- late-winter calf:cow ratios have averaged below 30 calves:100 cows (ratios of 30-40 calves: 100 cows or more are associated with stable herds);
- estimated cow survival has been well below the 80% needed for a stable herd; and
- there is evidence of low pregnancy rates in at least some years, including winter 2014- 2015.

⁷ Dolphin and Union Caribou (*R. t. groenlandicus x pearyi*) are morphologically and behaviourally distinct from other barren-ground populations and from Peary caribou, and are considered a discrete 'Designatable Unit' for caribou in Canada (COSEWIC 2011, ECCC 2017).



FIGURE 9. OTHER MIGRATORY CARIBOU HERDS OVERLAP WITH THE BATHURST HERD ANNUAL RANGE (SOURCE: GOVERNMENT OF NORTHWEST TERRITORIES, DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES).

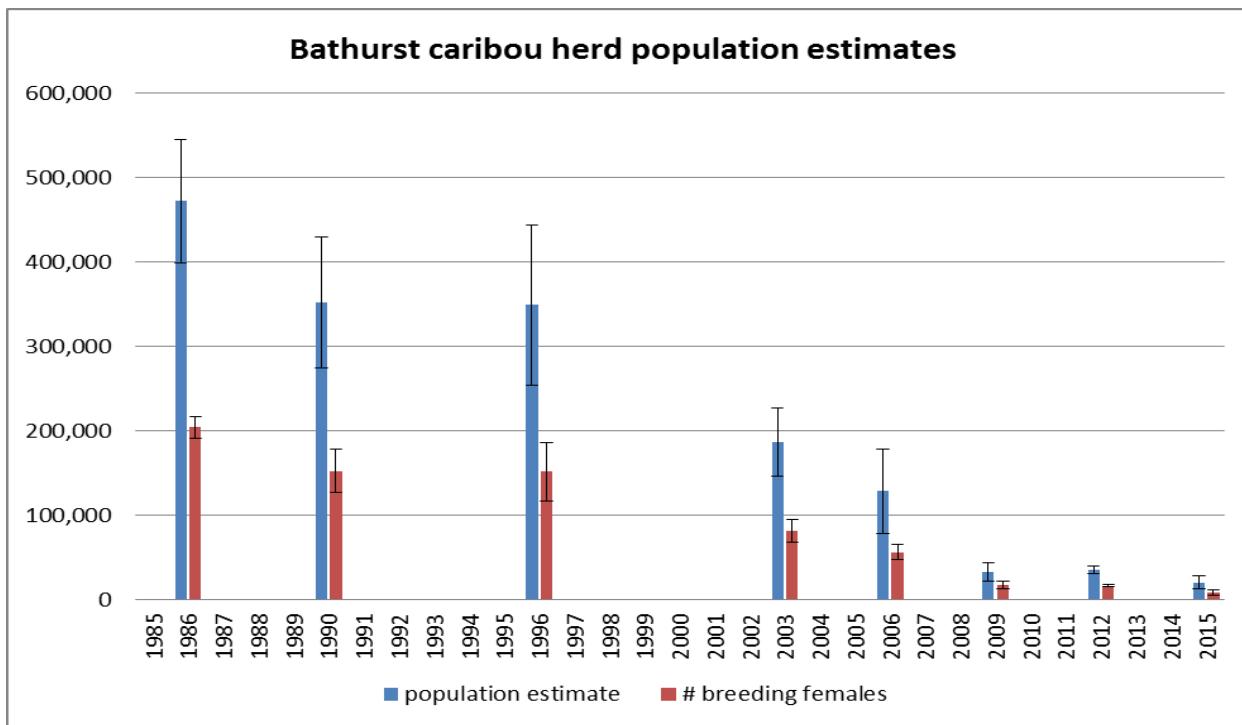


FIGURE 10: BATHURST CARIBOU POPULATION SIZE AND NUMBER OF BREEDING FEMALES FROM 1985 TO 2015 (SOURCE: BOULANGER ET AL. 2016).

3.3 Range Use and Migration

3.3.1 Annual and Seasonal Ranges

In the BCRP, five seasonal ranges and periods are recognized: spring migration, calving and post-calving, summer, fall (including fall migration and breeding) and winter. Figure 11 illustrates the timing of the five general seasons within the Bathurst herd annual life cycles, and their correspondence to caribou activity periods.

The date ranges for the general seasons were based on activity periods identified by Russell et al. (2003) for migratory Porcupine caribou, and defined by Nagy (2011) for Bathurst caribou based on an analysis of movement rates of 52 collared cows from 1996–2008, over sequential 5-day periods. Although there is considerable annual variability in seasonal range use and associated movement rates for caribou (McNeil et al. 2005, Nagy 2011, Gunn et al. 2013), the general seasons are presented here as a basic description of typical seasonal changes in range use by Bathurst caribou. For example, calving typically occurs during a two-week period in early-June, followed by an early post-calving period for the remainder of that month. The summer season spans from late-June to early-September. Combined, the fall and winter seasons account for almost two thirds of the year.

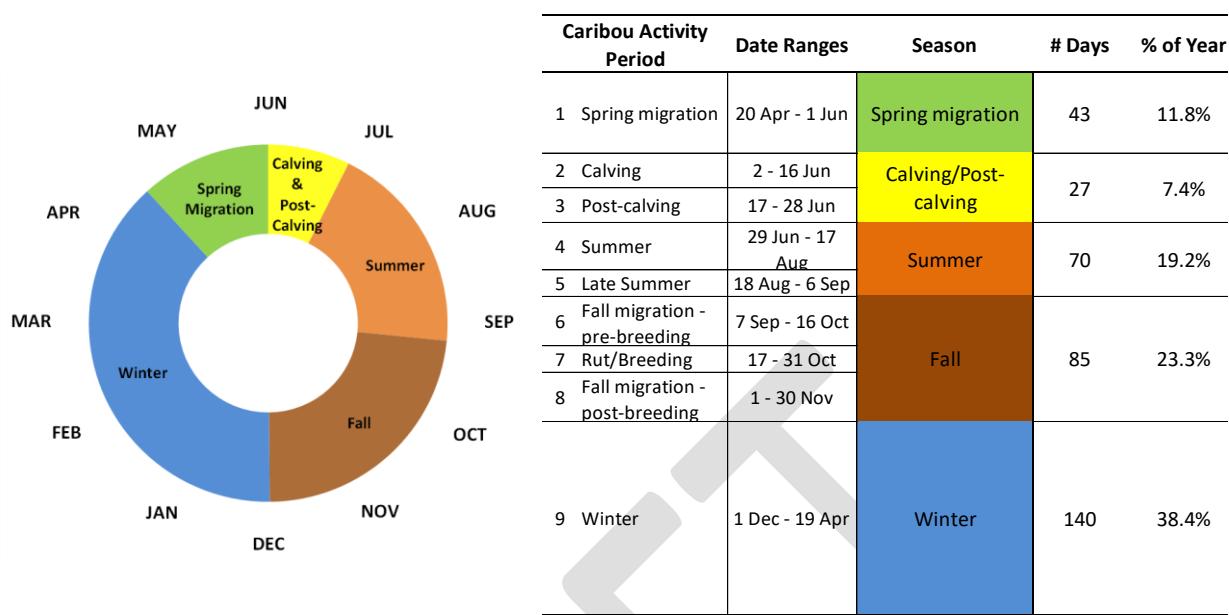


FIGURE 11: THE FIVE GENERAL SEASONS OF THE BATHURST HERD ANNUAL LIFE CYCLE, WITH ASSOCIATED DATE RANGES (ADAPTED FROM NAGY 2011).

The annual and seasonal ranges of the Bathurst herd, and their intensity of use by caribou, based on the analysis of available satellite collar information between 1996 and 2014 (19 years of data), is shown in Figure 12.

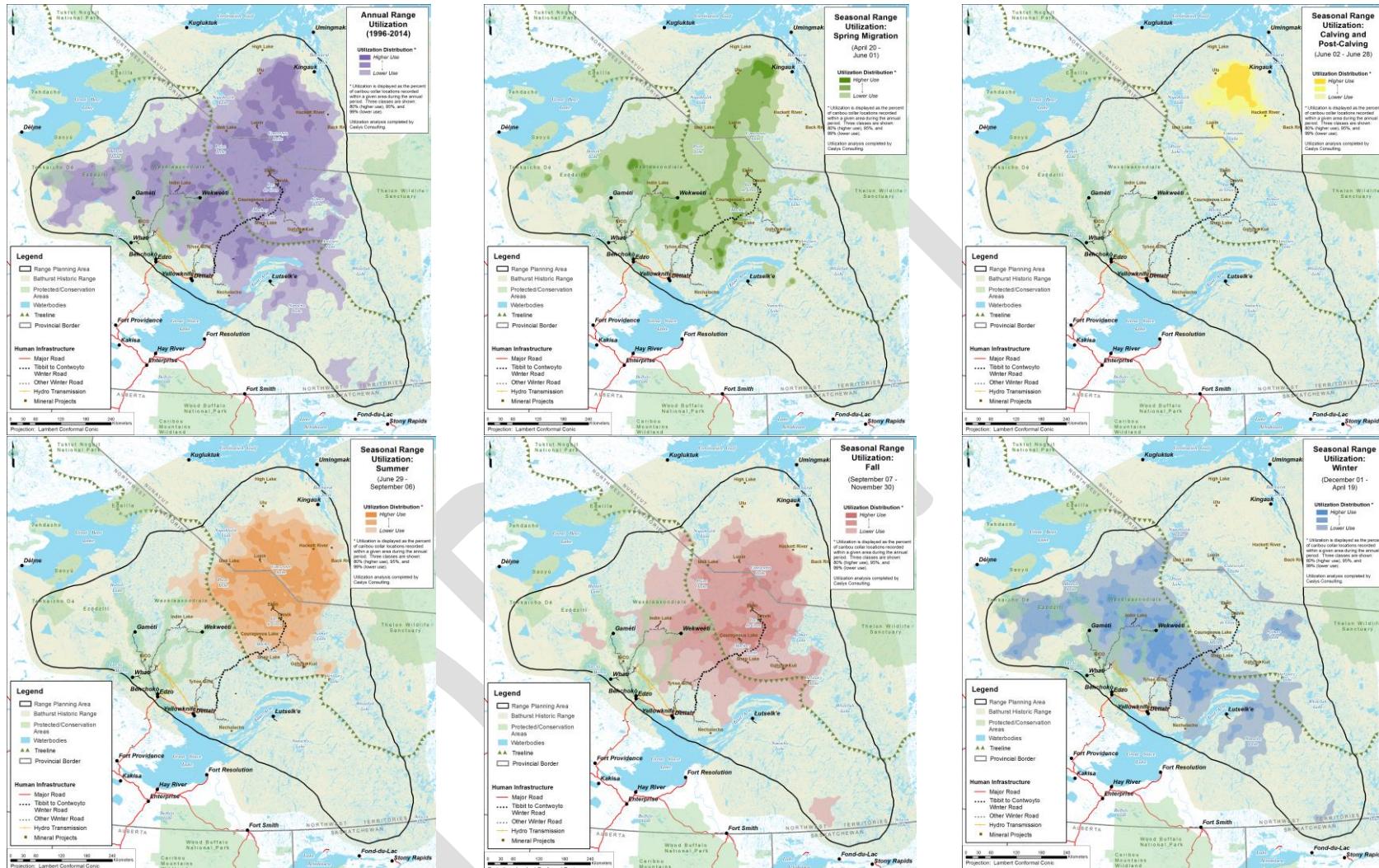


FIGURE 12: ANNUAL AND SEASONAL RANGES OF THE BATHURST CARIBOU HERD BASED ON SATELLITE TELEMETRY DATA FROM 1996 TO 2014. DARKER COLOURS INDICATE HIGHER USE BY CARIBOU.

3.3.2 Migration

Mobility is the ultimate adaptation of migratory barren-ground caribou that allows them to seek space to cope with an every-changing environment (Bergerud et al. 1984). Seasonal migration is the strategy that allows Bathurst caribou to avoid or minimize predation (Heard and Williams 1992), and to select resources within different parts of their range that have changing temporal and spatial patterns in forage productivity and nutritional value during the growing season (Griffith et al. 2001), and high variability depending on snow conditions and forest age that influence forage availability during the non-growing season (Anderson and Johnson 2014, Barrier and Johnson 2012, Chen et al. 2012, Rickbeil et al. 2017). The size of a herd's annual range reflects the caribou's need for space, which is expressed most strikingly by the extensive spring migration of breeding females from typical winter range areas in the boreal forest to the tundra calving grounds (Gunn et al. 2001, Gunn et al. 2013).

3.3.3 Changes in Range Use

Barren-ground caribou use of space is variable over time, and the Bathurst annual and seasonal ranges represent a dynamic process that is also influenced by population size. As caribou numbers increase, the herd requires more habitat and the area used by caribou becomes larger. As the Bathurst herd population has declined, patterns of range use by collared-caribou clearly show a smaller area of the annual and seasonal ranges being utilized. Figure 13 illustrates the multi-year change and contraction in range use since 1996.

In recent years, only the central part of the Bathurst range has recorded use; Bathurst caribou have not been observed in northern Saskatchewan for many years. The extent of the range as identified by traditional knowledge corroborates the range retraction observed through radio collar information. Also, in the late-1990s, the Bathurst core calving area shifted from the east side of Bathurst Inlet to its current location (Gunn et al. 2008).

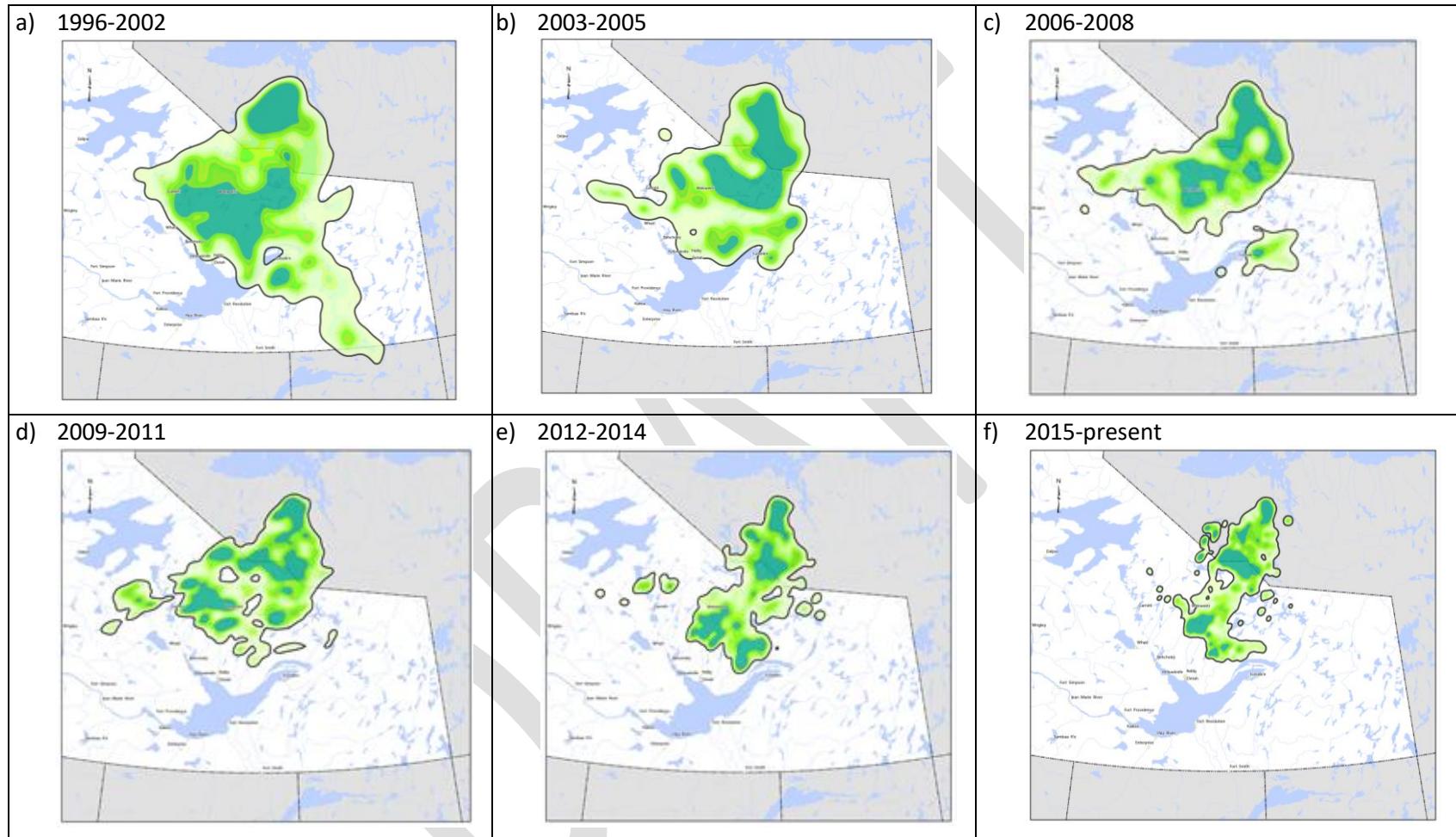


FIGURE 13: CONTRACTION IN ANNUAL RANGE OF BATHURST CARIBOU BASED ON KERNEL DENSITY HOME RANGE ESTIMATES FROM SATELLITE OR GPS COLLARED FEMALE ADULT CARIBOU FOR THE PERIOD 1996 TO 2017.

3.4 Important Areas and Habitat Features

Important areas for caribou are considered to be parts of the annual range that are essential to individual caribou or population-level health, or where and when caribou are most sensitive to sensory disturbance. Sensitive areas were identified through the combined analyses of range utilization, range sensitivity, traditional knowledge, and existing literature.

Important habitat features refer to place-specific locations and were identified through traditional knowledge and available literature. Given the landscape-level focus of the BCRP, site-level habitat quality and selection (e.g., specific vegetation communities or esker landforms) was not formally considered as part of the important habitat identification.

3.4.1 Important Areas

3.4.1.1 *Centre of Habitation (COH)*

For migratory barren-ground caribou, the center of habitation represents the most favorable and secure portions of a caribou population's range (Skoog 1968 and see Bergerud et al. 2008). The center of habitation can be considered a core use or refuge area that includes important habitats and migration paths, which a population occupies and uses when it is at dwindling numbers in its natural cycle. As a caribou population increases from a nadir in abundance in its natural cycle, the animals extend their seasonal movements from the center of habitation and gradually use more areas and travel greater distances.

We defined the center of habitation based on current core use area, which was estimated based on the distribution of satellite-collared Bathurst caribou from 2015-2017, coupled with traditional knowledge of important migratory, geographic, and habitat features. The main steps in defining the COH for the Bathurst range are summarized below:

- The current core use area was delineated based on a 95% annual utilization distribution (UD) polygon depicting annual range use by cows for a total of 70.5 caribou-years between 2015 and 2017 (Figure 14). The utilization distribution was based on a kernel density estimator with the reference bandwidth (A. Smith pers. comm.). The 2015-2017-time frame was considered to reflect the COH because of the current critically low abundance of Bathurst caribou⁹, and the striking contraction in annual range use that has occurred in concert with the population decline (Figure 13).
- The 95% annual UD was superimposed over available traditional knowledge datasets that were made available through the Working Group and represented seasonal migration routes (Figure

⁹ The most recent Bathurst calving ground survey in June 2015 resulted in an estimate of $8,075 \pm 1650$ (SE) breeding females and a population estimate of $19,769 \pm 3532$ (SE) 1+ year-old caribou (Boulanger et al. 2016). Relative to abundance estimates in the mid-1980s, current surveys show the population has declined by >95%, and the Bathurst herd is at its lowest abundance in recent memory.

15), as well as water crossings and land bridges (described as “tataa” by Tłı̨chǫ knowledge holders) (Figure 16).

- Based on the overlay with traditional knowledge datasets, we expanded the 95% annual UD in two areas to include land bridges, priority water crossings and associated migration pathways (Figure 16). The expansion was hand drawn in as a best fit-smoothed line to incorporate the features identified through traditional knowledge. The resulting polygon is proposed as the centre of habitation for the Bathurst herd (Figure 16).
- As a final illustrative step, the COH was overlayed with the weighted relative range sensitivity map (see Section 4.2.3.2) and the range assessment areas (see Section 3.1.5) to further highlight important areas for Bathurst caribou at the annual range scale.
- The boundaries of the COH should be considered preliminary and revisited as new information becomes available and through the regular assessments of the BCRP.

In summary, we suggest that the COH for the Bathurst herd is not just an important area for the caribou themselves but that it also provides a useful context for managing disturbance to the land and to caribou. The proposed boundaries of the COH are based on a) recent caribou collar location data that reflects its current contracted annual range use at a time when the population is critically low, and b) GIS data that comprise locations and characteristics of important areas and habitats for caribou that have been identified and shared by traditional knowledge holders on the range of the Bathurst herd.

The COH for Bathurst caribou reflects the population’s need for space to persist over the long term and also aligns with the lifeways of Caribou People and their traditional hunting areas. This relationship between caribou’s dynamics use of its range, and the people that relied on them is reflected in traditional knowledge of the Bathurst herd and more generally in the published literature (Gordon 1996, Legat et al. 2001, Stewart et al. 2004, Bergerud et al. 2008, and Andrews 2011).

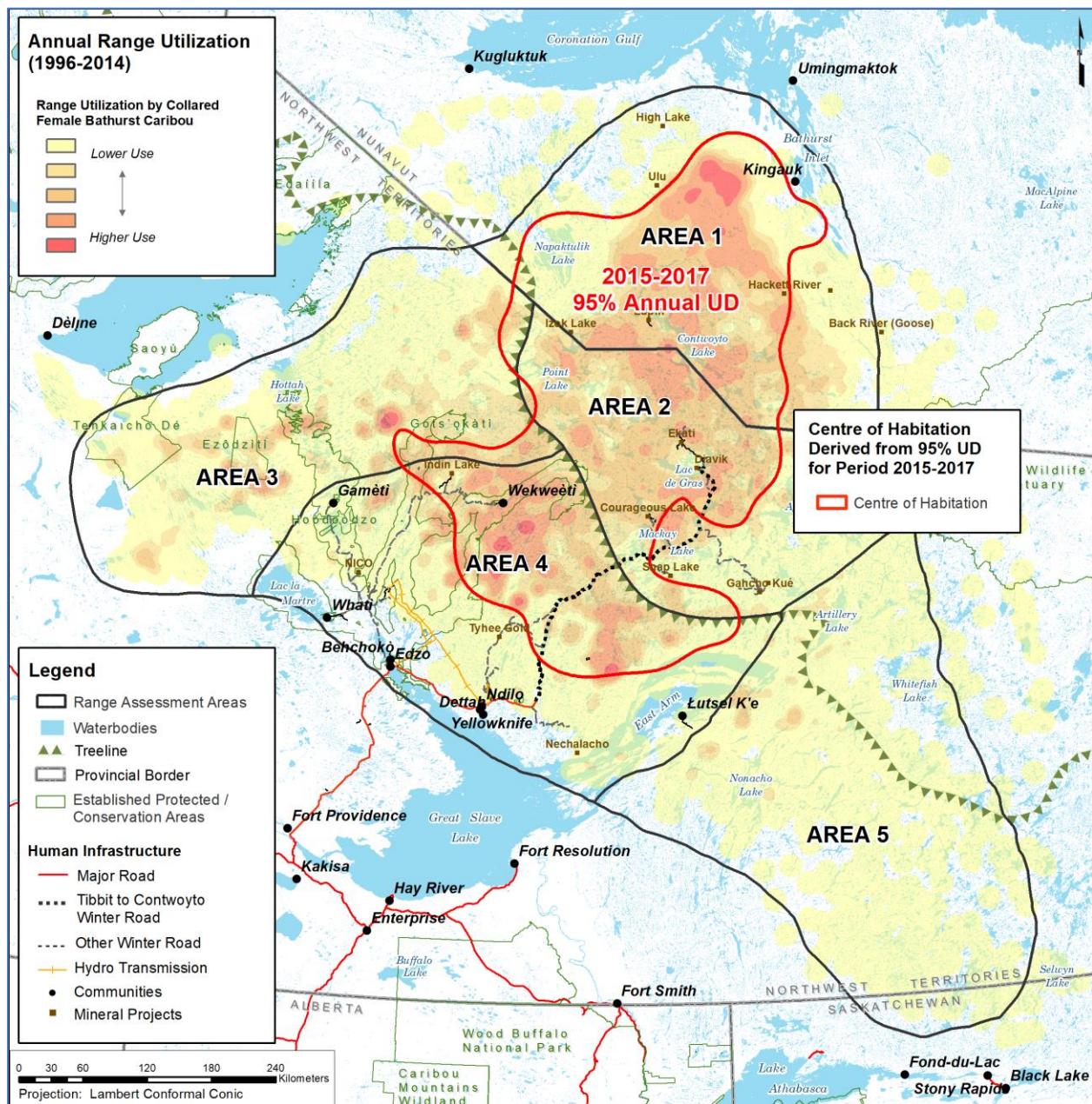


FIGURE 14. INITIAL DELINEATION OF CENTRE OF HABITATION BASED ON 95% UTILIZATION DISTRIBUTION OF ANNUAL RANGE DERIVED FROM KERNEL DENSITY ESTIMATION OF BATHURST CARIBOU COLLAR DATA FROM 2015-2017.



FIGURE 15. OVERLAY OF 95% UTILIZATION DISTRIBUTION OF BATHURST CARIBOU WITH TRADITIONAL KNOWLEDGE OF SEASONAL MIGRATION ROUTES.



FIGURE 16: PROPOSED BOUNDARY FOR THE CENTRE OF HABITATION BASED ON EXPANSION OF 95% UTILIZATION DISTRIBUTION OF RECENT BATHURST CARIBOU ANNUAL RANGE TO INCLUDE KEY WATER CROSSINGS AND LAND BRIDGES IDENTIFIED THROUGH TRADITIONAL KNOWLEDGE.

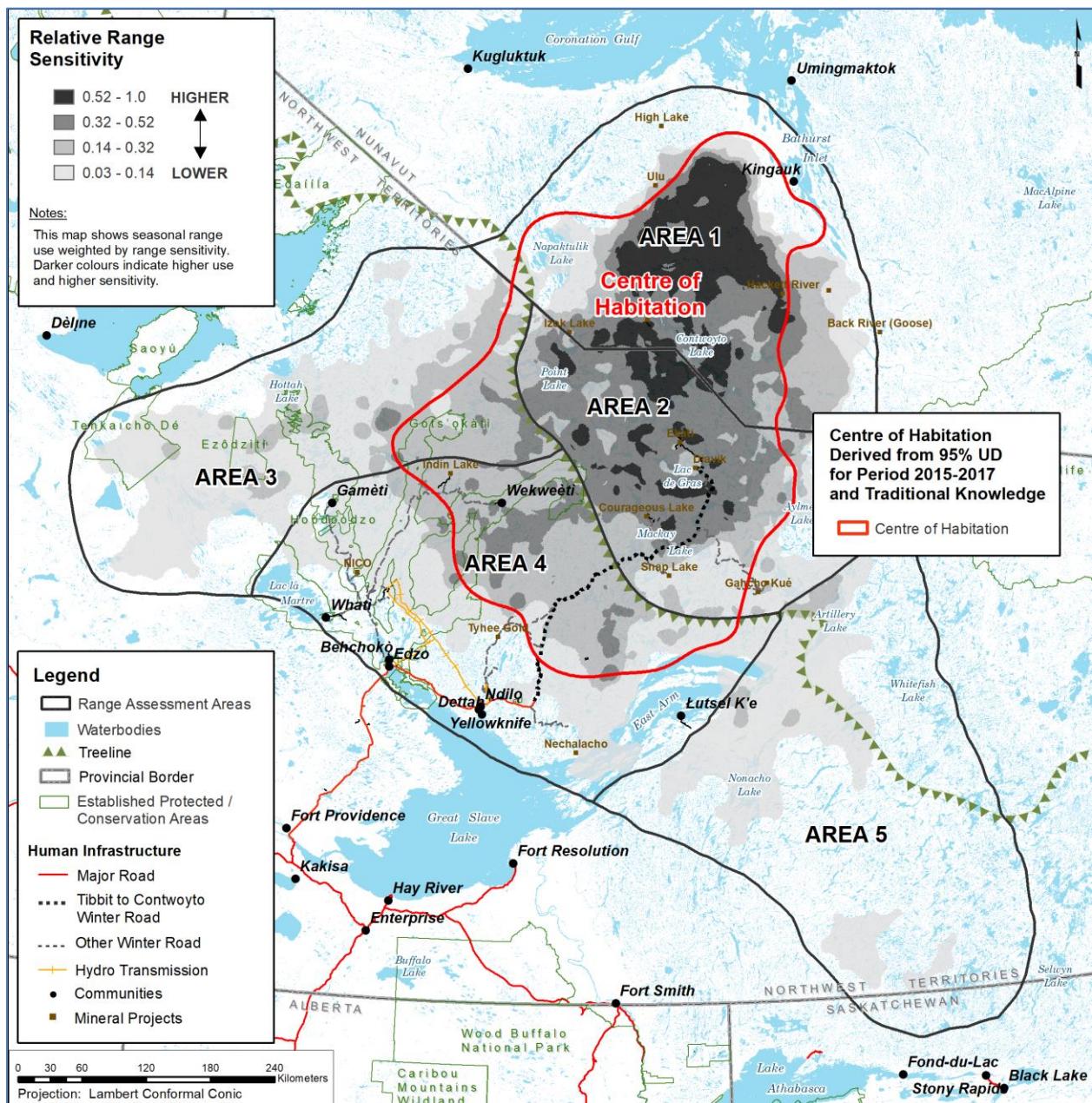


FIGURE 17. OVERLAY OF PROPOSED BATHURST CARIBOU CENTRE OF HABITATION WITH WEIGHTED RELATIVE RANGE SENSITIVITY.

3.4.1.2 *Calving and Post-calving Range*

The calving and post-calving range is considered to be a time and place that is the most sensitive for migratory barren-ground caribou cows and newborn calves. Although caribou calving-grounds may shift over longer decadal time scales, inter-annual spatial variation in location of annual calving grounds is relatively low and cows show fidelity to a calving area (Russell et al. 2002, Bergerud et al. 2008, Taillon et al 2012). For the Bathurst herd, the extent of concentrated calving has been on the west side of Bathurst Inlet since the mid-1990s, whereas in previous decades it was observed on the east side of the inlet (Gunn et al. 2008). Although size of the calving area varies with population abundance, it is a relatively small portion of the annual range and leads to a predictable location of high densities of cows at the lowest part in their condition cycle with newborn calves (Poole and Gunn 2015). The mean calving date for Bathurst caribou is the 8 June, with 95% of calves born between the 31 May and the 16 June (Nagy 2011). During the calving and post-calving period newborn calves are dependent on their maternal cows, which are responsive to disturbance, increasing the chances of calf injury or abandonment.

3.4.1.3 *Summer Range*

The summer period is considered the second most sensitive part of the range as caribou gather in to large groups to reduce harassment from biting insects. Caribou are sensitive to disturbance at water crossings and young calves are susceptible to abandonment or loss from disturbance (Poole and Gunn 2015). The summer growing season is critically important for barren-ground caribou, especially breeding females that need to maximize forage and nutrient intake so that they are in sufficient body condition for the fall breeding season (Russell et al. 1993, White et al. 2014). Since pregnancy rate of caribou cows is tied to their fall body size and condition, disturbance of cows in summer has the potential to affect population growth. Disturbance of caribou in summer may therefore reduce the amount of time spent feeding and increase the amount of time spent in energetically costly activities (i.e., walking and running), which in turn can result in cows that have a reduced likelihood of conceiving during the rut due to lower than average body weights (White et al. 2014).

3.4.2 *Important Habitat Features*

Water crossings, land bridges and unburned winter range have consistently been identified as important habitat features on the Bathurst range. Some water crossings and land bridges are used almost annually, and some have been used for very long periods of time—potentially thousands of years. Many traditional and cultural values are associated with these features, as indicated by the numerous archaeological sites located near these crossing locations (Gordon 1996, Stewart et al. 2004, Andrews 2011). Water crossings and land bridges allow caribou to pass over or around large water bodies or other physical barriers, allowing movement between their different seasonal ranges during the annual caribou-cycle. Mature forests within the winter range provide adequate forage and cover for caribou to persist through the long northern winter. Important habitat features are described below.

3.4.2.1 Water Crossings

Water crossings identify specific locations where caribou swim or wade across rivers or lakes. Based on field surveys in the Thelon river area, caribou most frequently cross at narrows caused by peninsulas or other shoreline irregularities, or where there is water turbulence or exposed rocks and gravel bars in the water (Williams and Gunn 1982). Given the long-term, consistent use of some water crossing locations, maintaining these areas relatively free of human infrastructure and disturbance is important to successful migration.

In the Bathurst range, water crossings have been identified and recorded through a number of different traditional knowledge and scientific sources. Figure 18 shows water crossings identified by Tłı̨chǫ (Tłı̨chǫ Research and Training Institute 2016), Kitikmeot Inuit (Nunavut Planning Commission 2016) and Athabasca Denesuline 2017) traditional knowledge. While many water crossing locations are identified, the Tłı̨chǫ information identified some locations as ‘priority crossings’ (shown in pink), as being especially important to maintain relatively free of human disturbance. Similarly, the Nunavut Planning Commission recommends full protection for the crossings identified in the Draft Nunavut Land Use Plan (2016) (shown as light blue circles on Figure 18).



FIGURE 18: EXAMPLE OF WATER CROSSINGS AND LAND BRIDGES IDENTIFIED BY TŁ'CHØ GOVERNMENT, NUNAVUT PLANNING COMMISSION AND ATHABASCA DENESULINE TRADITIONAL KNOWLEDGE. INFORMATION IN OTHER PARTS OF THE BATHURST RANGE IS NOT CURRENTLY AVAILABLE FOR DISPLAY.

3.4.2.2 *Land Bridges*

Land bridges refer to areas where caribou pass between major lakes. The Tłı̨chǫ word for land bridge is tataa. Figure 18 shows major land bridges identified by Tłı̨chǫ traditional knowledge in the central Bathurst range (Tłı̨chǫ Research and Training Institute 2016). Similar to water crossings, maintaining these areas relatively free of human infrastructure and disturbance is important to successful migration. The location of tataa in RAA2 highlights the importance of this central tundra area for movement between the spring calving and post calving, summer and winter ranges.

3.4.2.3 *Unburned Winter Range*

In the past decades, large parts of the central and southern winter range have been affected by wildfire (see Section 3.5.1.2, below). Approximately 36% and 60-70% of the forested portions of RAA4 and RAA5, respectively, have been affected by wildfire in the past 50 years. In RAA4, almost half of the recently burned area resulted from the 2014 fire season, while a large proportion of RAA5 was burned in 1994 and older fires from the 1970s. RAA5 has received limited use by Bathurst caribou over the past decade, potentially in response to the large amount of area burned. In comparison, RAA3, the northeastern part of the winter range, has experienced a lower amount of wildfire (20% burned in past 50 years) and has received increasing use by Bathurst caribou. Caribou have been observed to use recent burns less frequently than unburned areas (Joly et al. 2007; Anderson and Johnson 2014), and community members are concerned the declining amount of unburned forest in the central winter range may be contributing to the population decline of the Bathurst caribou herd.

3.5 Disturbance Assessment

3.5.1 Disturbance Assessment - Current Situation

3.5.1.1 *Human-caused Disturbance*

Figure 19 shows the location of current direct human footprint and its associated ZOI resulting from land use.

Table 3 summarizes the amount of human disturbance within the Bathurst range, and by range assessment area. Using available mapping, the BCRP Working Group determined that less than 0.05% (179.5 km²) of the Bathurst annual range is currently affected by direct development footprint. Some of the disturbance is seasonal. For example, the Tibbit to Contwoyto Lake winter road is only operational between January and early-April of each year, and crosses frozen waterbodies for much of its length. Settlements (e.g., City of Yellowknife) and active mine sites (e.g., Ekati, Diavik and Gacho Kué) are the largest sources of direct footprint, followed by linear features such as all-season and winter roads, trails and electrical transmission corridors.

While the direct footprint of human land use in the Bathurst herd range may be very small, in some areas the total human ZOI is substantial. Using the ZOI assumptions described in Appendix B, the BCRP

Working Group estimated that approximately 5.6% (21,898 km²) of the Bathurst range is currently affected by direct and indirect human disturbance (direct footprint with associated ZOI) (Table 3). The highest levels of human disturbance occur in the Northwest Territories, in RAA4 (central winter range), where all of the permanent settlements and all-season highways are located, and RAA2 (central tundra) where the current operating diamond mines are located (Figure 19). Although linear features have a relatively small direct footprint, they are a major contributor to total human ZOI on the Bathurst annual range, and facilitate access for humans into previously difficult to travel areas.

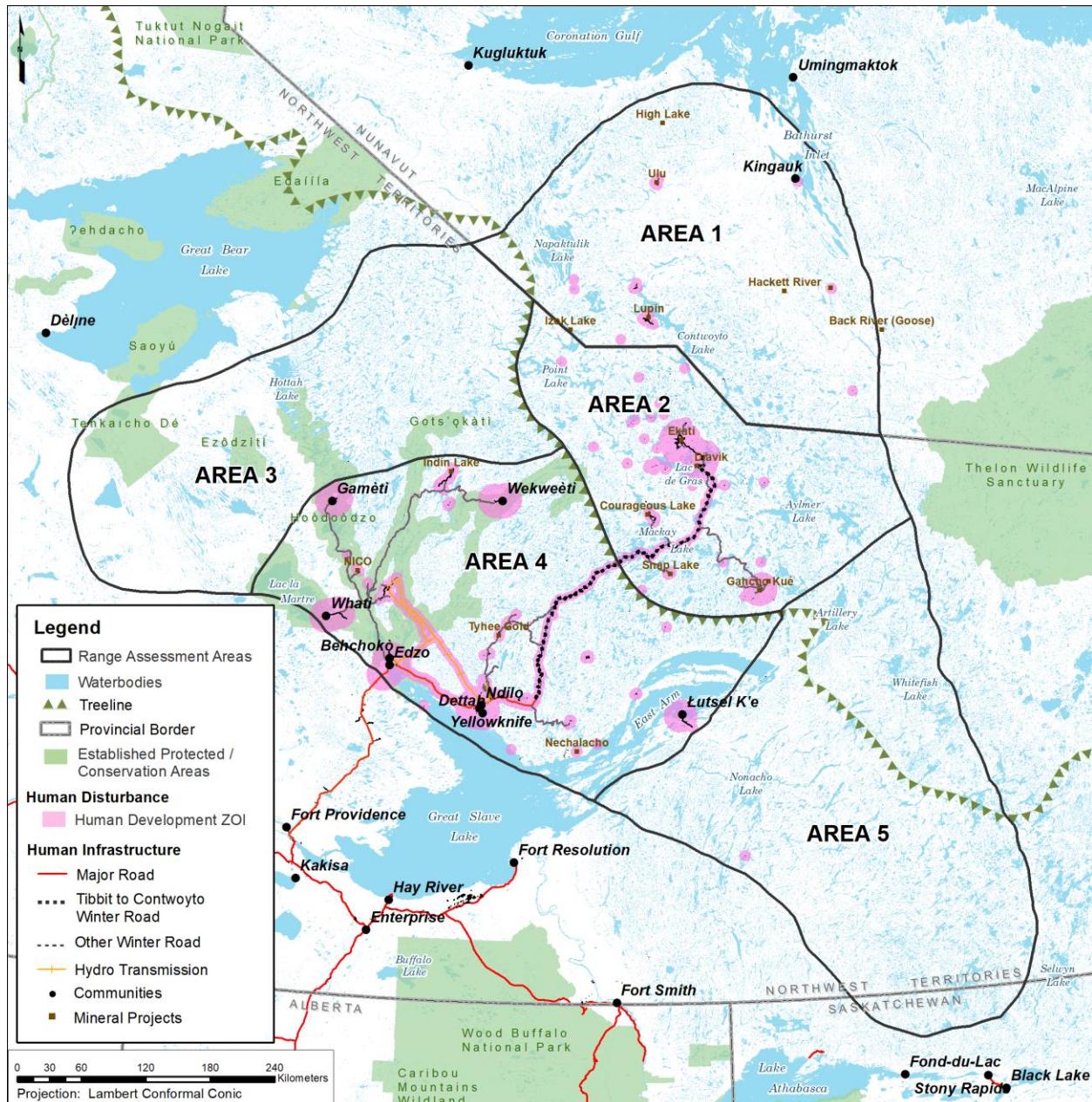


FIGURE 19: CURRENT HUMAN DISTURBANCE (DIRECT FOOTPRINT AND ASSOCIATED ZONE OF INFLUENCE) IN THE BATHURST RANGE.

TABLE 3: CURRENT STATUS OF HUMAN DISTURBANCE BY RANGE ASSESSMENT AREA.

Range Assessment Area	Range Assessment Area Size (km ²)	Direct Human Development Footprint		Total Human Disturbance (includes ZOI)	
		(km ²)	(% of RAA)	(km ²)	(% of RAA)
Area 1 : Nunavut	75,902 km ²	20 km ²	<1%	1,080 km ²	1.4%
Area 2: NWT Central Tundra	56,134 km ²	70 km ²	<1%	6,610 km ²	11.8%
Area 3: NWT Winter Range - Northwest	77,001 km ²	<1 km ²	<1%	<1 km ²	<1%
Area 4: NWT Winter Range – Central	84,858 km ²	90 km ²	<1%	14,120 km ²	16.6%
Area 5: NWT Winter Range – Southeast	95,127 km ²	<1 km ²	<1%	88 km ²	<1%
TOTALS	389,022 km ²	181 km ²	<1%	21,898 km ²	5.6%

3.5.1.2 Wildfire Disturbance

Taiga Shield Wildfire Regime

The Bathurst winter range is mainly within the Taiga Shield ecozone (ESWG 1995), a broad region spanning the northern forested portion of the Canadian Shield, both to the west and east of Hudson Bay. The Taiga Shield is commonly broken into two separate areas for fire analysis due to the different climatic conditions between western and eastern Canada (Krezek-Hanes et al. 2011). The western portion of the Taiga Shield has more severe summer fire weather than the east (warm dry summers conducive to the generation of intense lightning storms), resulting in a vigorous fire regime characterized by frequent, large, high intensity wildfires (Stocks et al. 2003; Parisien et al. 2006; Burton et al., 2008; Boulanger et al. 2014), similar to the adjacent Taiga Plains.

Figure 20 shows area burned by fire year for the entire Taiga Shield ecozone. This figure highlights the stochastic and variable nature of wildfire regimes in northern Canada. Based on fire records for the period 1960 to 2000, estimated fire cycles for the Taiga Shield west of Hudson Bay range from approximately 110 to 130 years (these fire cycles equal an annual area burned of 0.91 to 0.77 percent). Parisien et al. (2004) estimated a fire cycle of 113 years (0.88 percent annual area burned) for the Taiga Shield portion of northern Saskatchewan, while Burton et al. (2008) calculated a 120 year fire cycle (0.83 percent annual area burned; 2,632 km² area burned per year) for the entire Taiga Shield west of Hudson Bay.

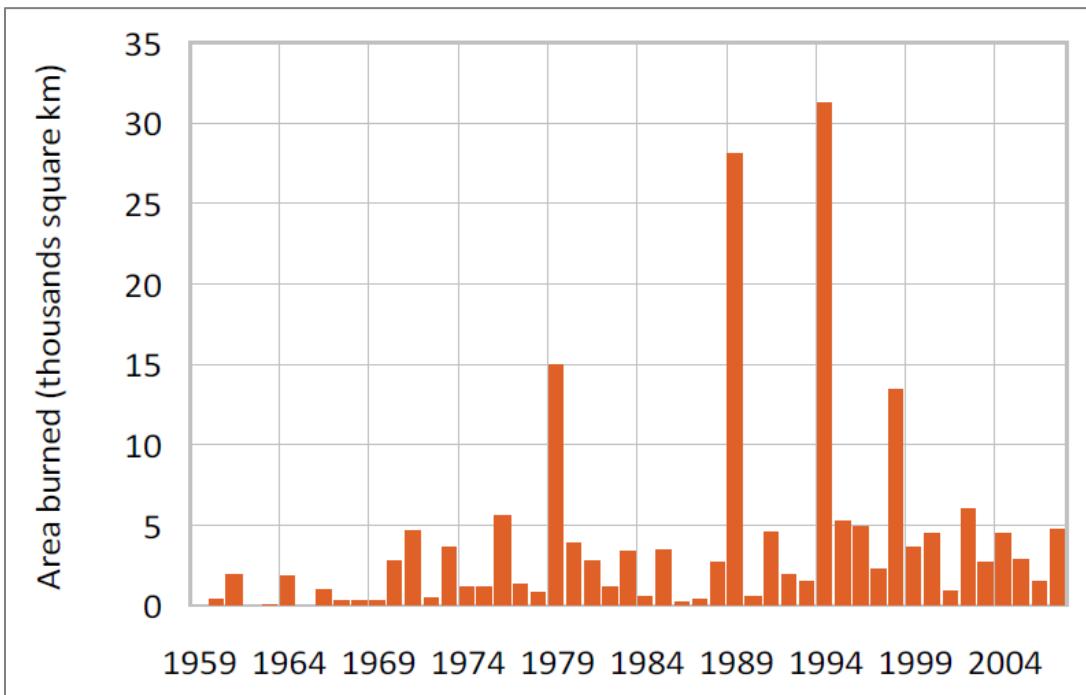


FIGURE 20. ANNUAL AREA BURNED BY LARGE FIRES IN THE TAIGA SHIELD ECOZONE, 1959-2007. (SOURCE: FIGURE 16 FROM KREZEK-HANES ET AL. 2011).

Recent Wildfire Disturbance in the Bathurst Range

In the Bathurst range planning area, GNWT wildfire mapping indicates that approximately 81,500 km² has been affected by wildfire since 1965¹⁰ (Figure 21). Table 4 summarizes results by range assessment area. The area disturbed by wildfire represents 21% of the total range planning area, or approximately 36% of the forested portion of the winter range¹¹. This rate of burning over the past 50 years suggests an approximate 120 to 140 year fire cycle for the forested portion of the winter range, which is within the range of the calculated values for the western Taiga Shield. As shown in Figure 21 and Table 4, the majority of recent wildfire activity has affected a disproportionately large area of the central and southern parts of the Bathurst winter range; 36% of RAA4 and approximately 60-70% of the forested portion of RAA5 has been affected by wildfire in the past 50-years, with much occurring since the early-1990s.

¹⁰ 81,500 km² represents the total extent of area affected by wildfire; the total area burned calculated from individual fire years is 86,400 km², as some recent fire extents overlap with older re-generating burns.

¹¹ Approximately 30% (28,538 km²) of RAA5 in the vicinity of Artillery and Whitefish Lakes occurs north of treeline and has experienced limited wildfire since 1965. If this area north of treeline is not considered winter range, the percent of forested winter range affected by wildfire increases to approximately 36%. Including this portion of RAA5 in the area calculations results in 32% of the winter range being affected by wildfire since 1965.

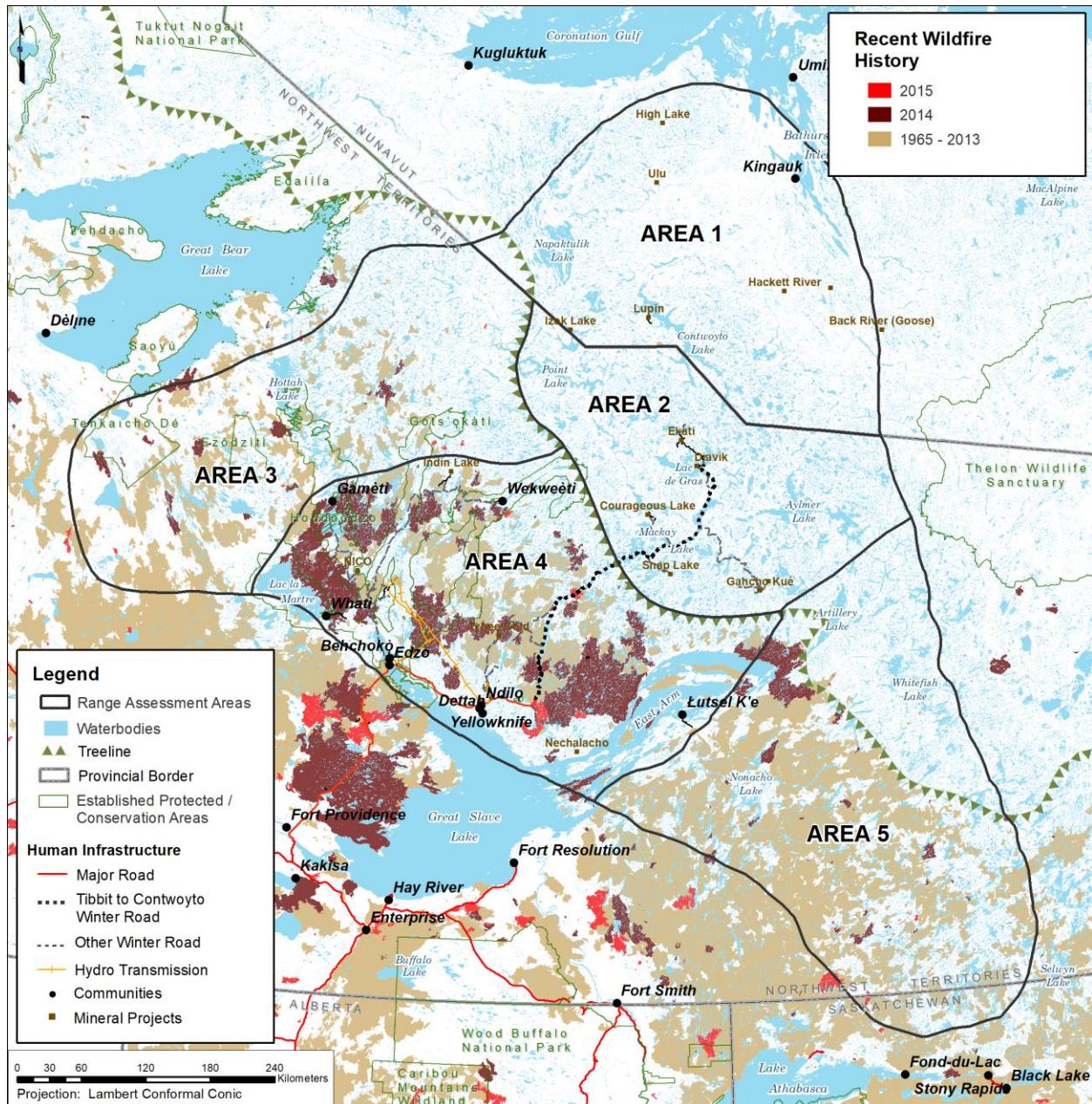


FIGURE 21. AREA AFFECTED BY WILDFIRE BETWEEN 1965 AND 2015. (SOURCE: GOVERNMENT OF NORTHWEST TERRITORIES, ALBERTA AND SASKATCHEWAN WILDFIRE HISTORY DATABASES).

TABLE 4: SUMMARY OF RECENT WILDFIRE DISTURBANCE (1965-2015) BY RANGE ASSESSMENT AREA.

Range Assessment Area	Range Assessment Area Size (km ²)	Recent Wildfire Disturbance (1965-2015)	
		(km ²)	(% of RAA)
Area 1 : Nunavut	75,902 km ²	20 km ²	<1%
Area 2: NWT Central Tundra	56,134 km ²	5 km ²	<1%
Area 3: NWT Winter Range – Northwest	77,001 km ²	15,178 km ²	19.7%
Area 4: NWT Winter Range – Central	84,858 km ²	30,839 km ²	36.3%
Area 5: NWT Winter Range – Southeast *	95,127 km ²	35,459 km ²	* 37.3%
TOTALS	389,022 km ²	81,501 km ²	21.0%

*Note: approximately one third of Area 5 occurs north of treeline. The area burned south of treeline since 1965 represents approximately 60-70% of the forested area.

The area burned by year within the Bathurst range planning area for the period 1965 to 2015 is shown in Figure 22. In the Bathurst range two fire years, 1994 and 2014, account for approximately 37% (31,375 km²) of the total area burned during the 50-year fire record. The summer of 2014 was an exceptional fire season throughout much of central NWT, and can be attributed to specific continental-scale weather conditions with high summer temperatures, low precipitation and abundant lightning ignition sources. The 1979, 1989 and 1994 fire years were large fire years across the entire Taiga Shield (Figure 20), but in 1989 very little area burned within the Bathurst winter range.

While uncertain, it is likely the amount of recent wildfire activity on the winter range has also occurred in past times. However, there is evidence suggesting the amount of area burned in northern Canada is increasing in response to a warming climate, and the frequency of large fire years, such as the 2014 fire season, is projected to increase (Flannigan et al. 2000; Flannigan et al. 2005).

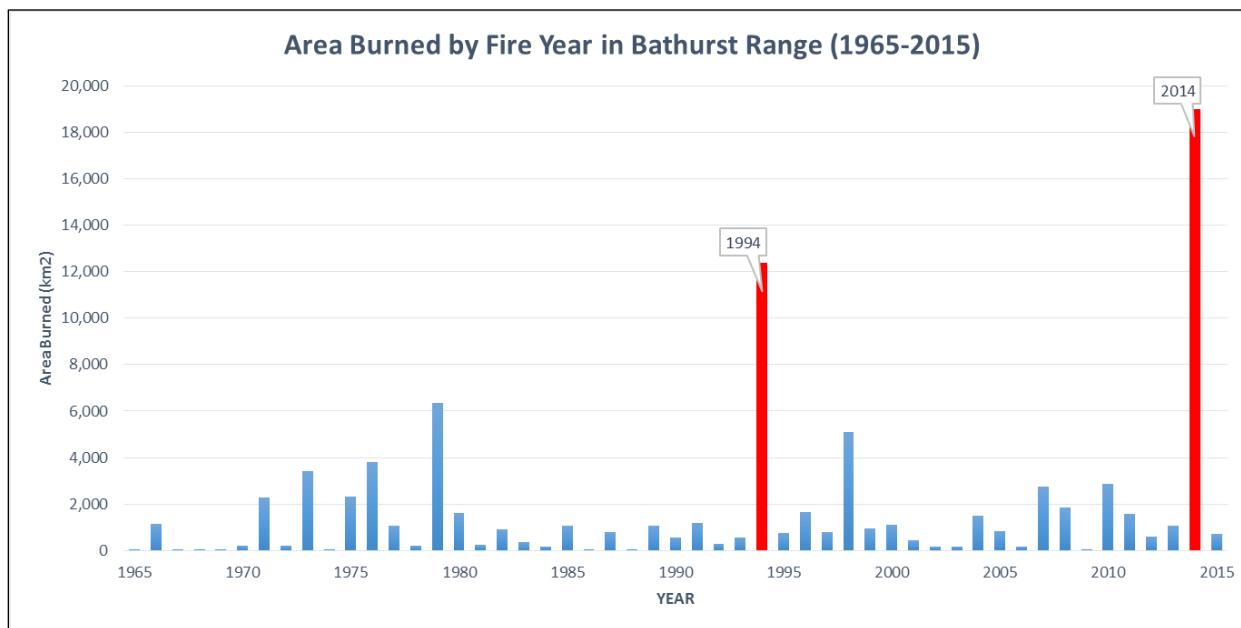


FIGURE 22: AREA BURNED BY FIRE YEAR IN THE BATHURST RANGE PLANNING AREA (1965-2015). SOURCE: GNWT ENR, WILDFIRE HISTORY DATABASE.

3.5.1.3 *Total Disturbance*

Total disturbance combines the results of the current human disturbance mapping and recent wildfire mapping. Table 5 summarizes the current level of human, recent wildfire and total disturbance within the Bathurst range planning area. Total disturbance represents the extent of non-overlapping total human and recent wildfire disturbance. Key results are as follows:

- At approximately 17%, RAA4 has the highest level of total human disturbance and the second highest area of recent wildfire disturbance. Combined, almost 50% of RAA4 is affected by human disturbance and recent wildfire.
- RAA5 has the highest level of recent wildfire disturbance. In total, 37% of RAA5 has been affected by recent wildfire but approximately 60-70% of the area south of treeline has been burned since 1965.
- RAA3 and RAA5 have very low levels of current human-caused disturbance.
- Approximately 12% of RAA2 is affected by human disturbance.

Given the large areas affected by wildfire disturbance on the taiga winter range, it is important to separately consider the tundra (RAA1 and RAA2) and taiga (RAA 3, 4 and 5) portions of the annual range when calculating total disturbed area.

TABLE 5. CURRENT LEVEL OF HUMAN, WILDFIRE AND TOTAL DISTURBANCE IN THE BATHURST RANGE PLANNING AREA, REPORTED BY RAA.

Range Assessment Area	Range Assessment Area Size (km ²)	Direct Human Development Footprint	Total Human Disturbance (includes ZOI)	Recent Wildfire Disturbance (1965-2015)	Total Disturbance (total human disturbance + wildfire) *
		(% of RAA and km ²)	(% of RAA and km ²)	(% of RAA and km ²)	(% of RAA and km ²)
Area 1 : Nunavut	75,902 km ²	<1% (20 km ²)	1.4% (1,080 km ²)	<1% (20 km ²)	1.4% (1,063 km ²)
Area 2: NWT Central Tundra	56,134 km ²	<1% (70 km ²)	11.8% (6,610 km ²)	<1% (5 km ²)	11.7% (6,568 km ²)
Area 3: NWT Winter Range - Northwest	77,001 km ²	<1% (<1 km ²)	<1% (<1 km ²)	19.7% (15,178 km ²)	19.7% (15,169 km ²)
Area 4: NWT Winter Range – Central	84,858 km ²	<1% (90 km ²)	16.6% (14,120 km ²)	36.3% (30,839 km ²)	47.4% (40,223 km ²)
Area 5: NWT Winter Range – Southeast **	95,127 km ²	<1% (<1 km ²)	<1% (88 km ²)	37.3% ** (35,459 km ²)	37.3% (35,482 km ²)
TOTALS	389,022 km ²	<1% (181 km ²)	5.6% (21,898 km ²)	21.0% (81,501 km ²)	25.3% (98,580 km ²)

* Note: Due to overlap, total disturbance does not equal the sum of total human and recent wildfire disturbance.

**Note: approximately one third of Area 5 occurs north of treeline. The area burned south of treeline since 1965 represents approximately 60-70% of the forested area.

3.5.2 Disturbance Assessment - Potential Future Situation

3.5.2.1 *Human-caused Disturbance*

Figure 23 illustrates the potential location and extent of human-caused disturbance at year 2040 resulting from the three development scenarios—CASE 1, CASE 2 and CASE 3. Figure 24 shows how the amount of annual human-disturbance resulting from each development scenario in RAA1, RAA2 and RAA4 changes throughout the scenario period¹². Given the scenario assumptions, RAA1 (Nunavut) has the greatest potential to experience large increases in human development ZOI. RAA2 and RAA4 may remain similar to current levels, or potentially decrease if the current operating mines are not replaced with similar operations in the future.

¹² Very low levels of human development were projected for RAA3 and RAA5 in all development scenarios and are therefore not shown on Figure 23.

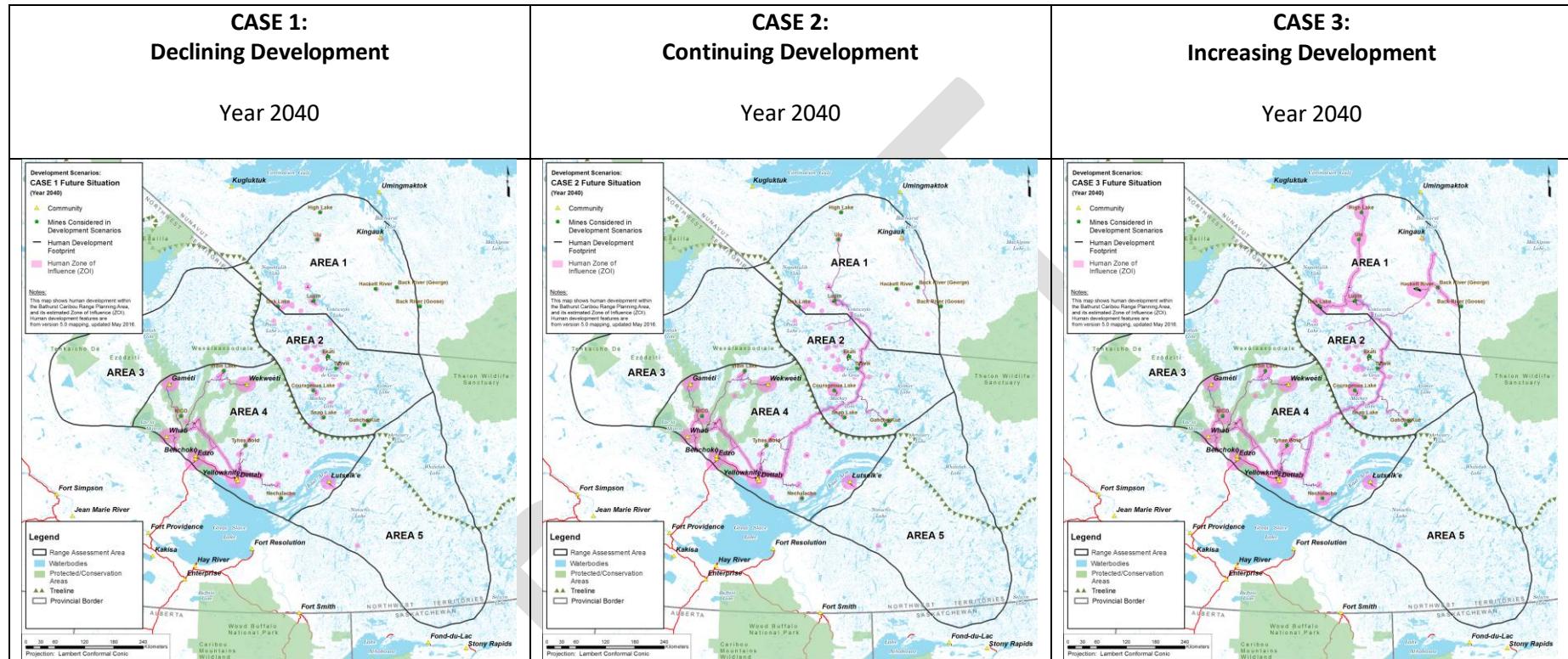


FIGURE 23: POTENTIAL FUTURE HUMAN-CAUSED DISTURBANCE IN THE BATHURST RANGE: CASE 1 (DECLINING DEVELOPMENT), CASE 2 (CONTINUING DEVELOPMENT), AND CASE 3 (INCREASING DEVELOPMENT). ALL MAPS SHOW RESULTS AT YEAR 2040.

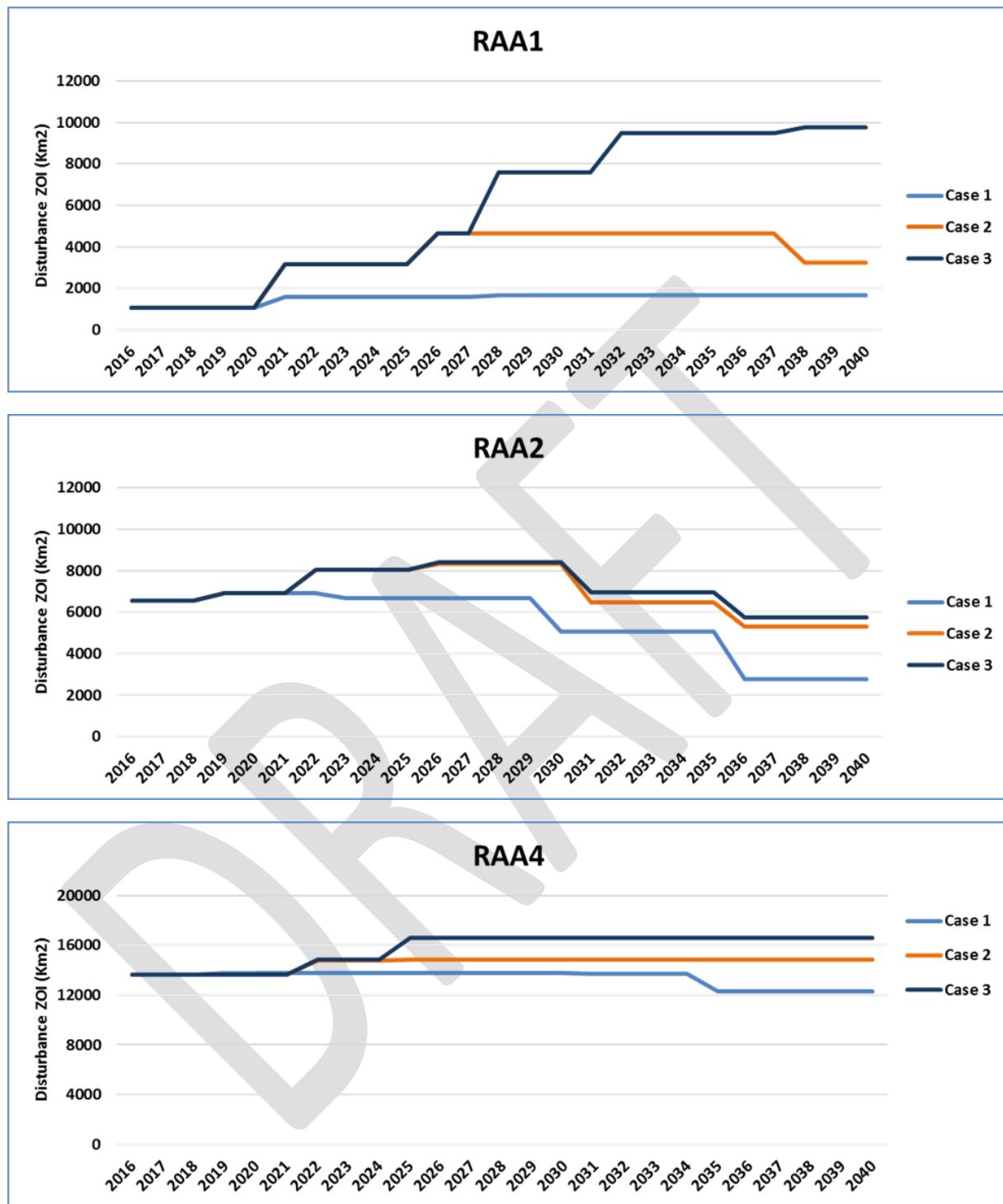


FIGURE 24: TOTAL HUMAN-CAUSED DISTURBANCE RESULTING FROM THREE FUTURE DEVELOPMENT SCENARIOS—CASE 1 (DECLINING DEVELOPMENT), CASE 2 (CONTINUING DEVELOPMENT), AND CASE 3 (INCREASING DEVELOPMENT)—IN RAA1, RAA2 AND RAA4.

3.5.2.2 Wildfire Disturbance

Most recent wildfire models (e.g. Boulanger et al. 2014) predict higher rates of wildfire for the forested portion of the Bathurst annual range and surrounding Taiga Shield (and most other areas of northern Canada) than experienced in recent decades. Fire seasons like 2014 are anticipated to occur more frequently, resulting in a potential doubling or tripling of the average annual area burned in the coming 50 to 100 years. Increasing fire rates may lead to changes in forest composition (e.g., greater amounts of deciduous forest with different understory vegetation) and accelerate vegetation shifts that may occur in response to changing temperature and precipitation patterns alone (Weber and Flannigan 1997). Under such predicted future fire regimes, the amount and quality of suitable winter range for caribou may become a limiting factor for barren-ground caribou populations.

3.5.2.3 Total Disturbance

The amount of future total disturbance (combined area affected by human direct and indirect disturbance, plus wildfire) within the Bathurst planning area is likely to increase, largely as a result of increasing wildfire rates. The human disturbance contribution to the total area disturbed will be dependent on future levels of land use activity and land management practices (e.g., differences in level of activity between CASE 1 and CASE 3 development scenarios).

3.5.2.4 Potential Effects of Future Development Scenarios on Bathurst Caribou Population Health

These results are from Scenario Set 2 of the CARMA integrated caribou model (see Section 2.1 and Appendix D for methods and detailed assumptions).

Scenario Set 2 examined the relative effects of the three BCRP future development scenarios (CASE 1—declining development, CASE 2—continuing development, and CASE 3—increasing development) on the population-level response of caribou. Please see Appendix D for a detailed discussion of results and assumptions. Key findings are as follows:

1. Caribou average encounter rates with human development ZOI increased with increasing development footprint (i.e., encounter rates were lowest in Case 1 and highest in Case 3).
2. Female caribou pregnancy rates declined inversely to increasing average encounter rates (Figure 25), but the amount of decline was small (expected pregnancy rates declined from 90% under a ‘No Development’ scenario to approximately 87.5% under Case 3).
3. Each development case scenario results in a lower rate of population growth compared to a ‘No Development’ scenario, but the relative decline is smaller than the effect of direct mortality (Figure 26).

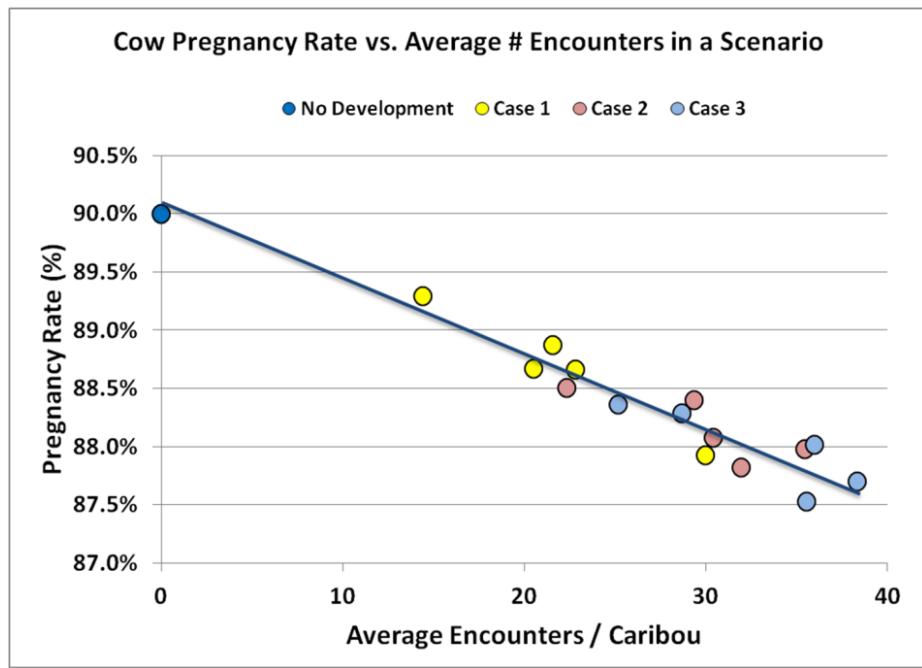


FIGURE 25: SIMULATED RELATIONSHIP BETWEEN EXPECTED PREGNANCY RATE AND AVERAGE ANNUAL ENCOUNTER RATE OF A BATHURST CARIBOU COW WITH ANTHROPOGENIC FOOTPRINTS ON THE ANNUAL RANGE.

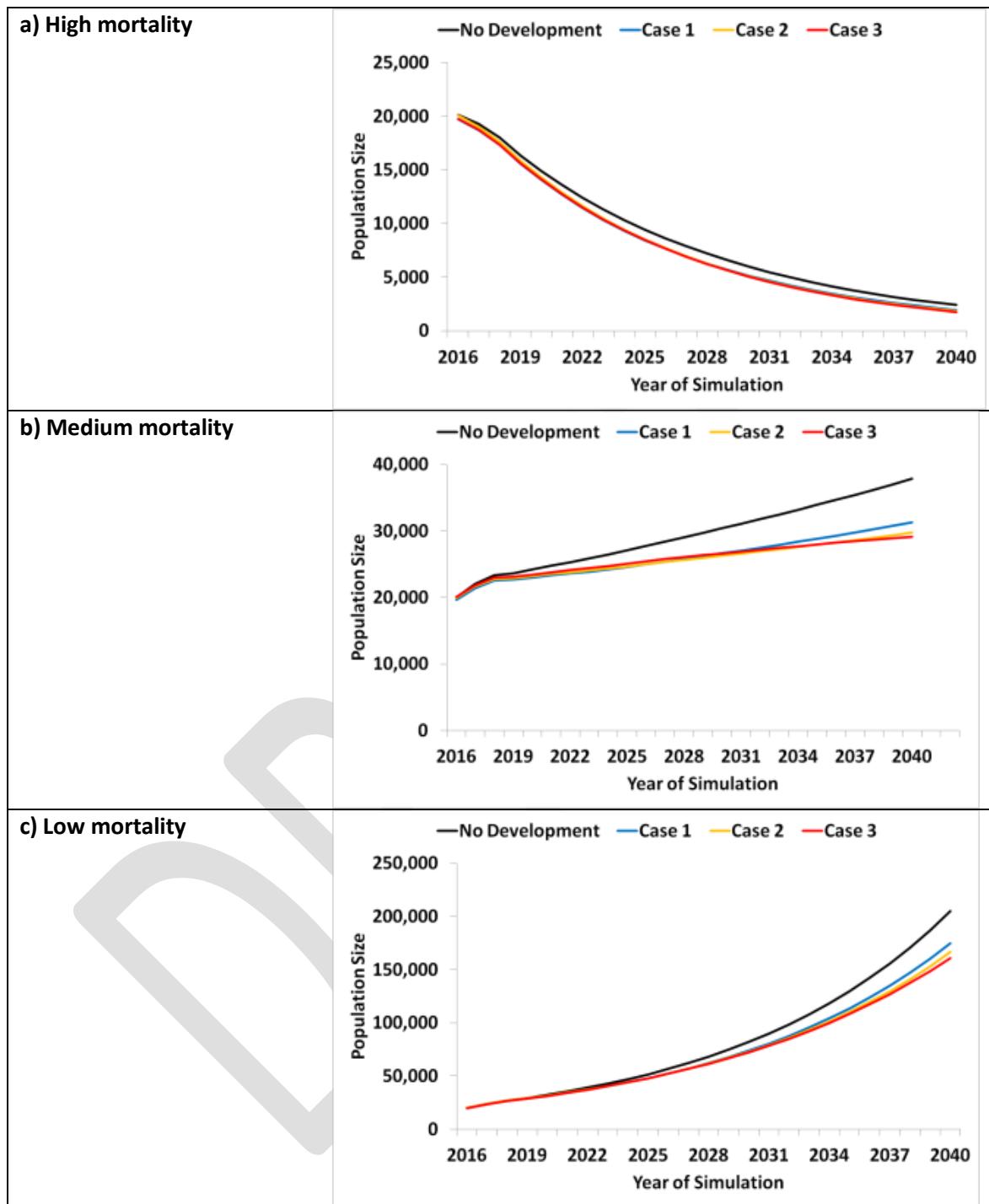


FIGURE 26: COMPARATIVE POPULATION TRENDS OF BATHURST CARIBOU STARTING FROM AN INITIAL SIZE OF 20,000 ANIMALS AND SIMULATED 24-YEARS INTO THE FUTURE BASED ON THREE DIFFERENT INDUSTRIAL DEVELOPMENT CASE SCENARIOS (CASE 1, 2 AND 3), AND ORGANIZED BY (A) HIGH, (B) MEDIUM, AND (C) LOW RATES OF NATURAL MORTALITY.

3.6 Summary

3.6.1 Population Status

The Bathurst caribou population is currently estimated to be approximately 20,000 animals ($19,769 \pm 7,420$) (Boulanger et al. 2016), representing a decline of over 96% from a mid-1980s population estimate of approximately 450,000. Such dramatic population declines are also being experienced by some other Canadian barren-ground caribou herds, resulting in COSEWIC recently designating barren-ground caribou as a threatened wildlife species.

3.6.2 Important Areas and Habitat Features

Major findings regarding important areas and habitat features are as follows:

- The calving and post-calving, and summer ranges are considered the most important and sensitive parts of the Bathurst annual range. Most of the calving and post-calving range is in RAA1 (Nunavut), with the core summer range occurring in both RAA1 (Nunavut) and RAA2 (NWT Central Tundra).
- In addition to the important range areas, water crossings, land bridges and unburned parts of the winter range have been consistently identified as important habitat features for barren-ground caribou that require special management consideration.
- To support range plan implementation, a center of habitation (COH) has been defined representing the current most favorable and secure portion of the range that includes important habitats and migration paths used at dwindling numbers in the natural cycle. The COH is defined based on the current core use area, which was estimated based on the distribution of satellite-collared Bathurst caribou from 2015-2017, coupled with traditional knowledge of important migratory, geographic, and habitat features.

3.6.3 Disturbance Assessment

The current amount of wildfire and human-caused disturbance within the Bathurst range was assessed based on disturbance mapping and GIS analysis. Potential levels of future disturbance resulting from three potential development scenarios were also explored. Results are reported by range assessment area (RAA). Key findings of the Bathurst disturbance assessment are as follows:

Current Situation

Given the large areas affected by wildfire on the taiga winter range, it is important to separately consider the tundra (RAA1 and RAA2) and taiga (RAA3, RAA4 and RAA5) portions of the annual range when calculating disturbance metrics.

Tundra (calving and post-calving, and summer range):

- Approximately 12% (6,610 km²) of the NWT central tundra (RAA2) is affected by human disturbance. This area includes the currently active diamond mines and a part of the Tibbit to Contwoyto Lake winter road.
- Less than 2% (1,080 km²) of RAA 1 (Nunavut) is affected by human disturbance.

Taiga (winter range):

- At approximately 17% (14,120 km²), RAA4 has the highest level of total human disturbance and the second highest area of recent wildfire disturbance. Combined, almost 50% (40,223 km²) of RAA4 is affected by human disturbance and recent wildfire.
- RAA5 has the highest level of recent wildfire disturbance. In total, 37% (35,459 km²) of RAA5 has been affected by recent wildfire but approximately 60-70% of the area south of treeline has been burned since 1965.
- Two parts of the taiga winter range, RAA3 and RAA5, have very low levels of human disturbance.

Potential Future Situation

Tundra (calving and post-calving, and summer range):

- RAA1 (Nunavut) has the highest potential to experience a large increase in the level of human disturbance. Given the development scenario assumptions, human disturbance could remain similar to the current level (1.4%, or 1,080 km²) but could potentially increase to 5-13% (4,000-10,000 km²) of the RAA if multiple proposed mine development and transportation projects proceed.
- The total level of human disturbance in RAA2 may remain similar to current, or could potentially decline over time if the current producing diamond mines close in the coming decades without being replaced by new mines. Closure of the existing mines would also likely lead to closure or dis-use of the Tibbit to Contwoyto Lake winter road.

Taiga (winter range):

- Given the development scenario assumptions, the total amount of future human disturbance in the central winter range (RAA4) may remain similar to current levels (14-19%, or 12,000- 16,000 km²). Replacing the southern part of the Tibbit to Contwoyto winter road with an all-season road would not significantly change the level of disturbance in RAA4, but would introduce many other human access management concerns and potentially facilitate higher levels of development than currently forecast.
- As a result of predicted climate change effects, the amount of future wildfire in the taiga portion of the Bathurst range is expected to remain similar to, or increase, compared with recent historical levels.

Potential Effects on Barren-ground Caribou

Results of the CARMA integrated caribou modelling suggest that human development has a negative incremental effect on caribou productivity (primarily through a reduction in pregnancy rates), with the magnitude of effect related to the amount of human disturbance the population is exposed to, as expressed as average encounters with human development and associated ZOI (Section 2.5). As a higher proportion of the range becomes influenced by human disturbance, the probability of caribou encountering this disturbance increases. Modelling results did not identify any clear breakpoints in the level of acceptable human disturbance, but did identify an incremental negative relationship between disturbance levels and population performance.

3.6.4 Management Considerations by Range Assessment Area

Table 6 summarizes the major current and potential future management considerations, and factors contributing to them, for each range assessment area in the Bathurst caribou range planning area.

TABLE 6: SUMMARY OF CARIBOU HABITAT AND RANGE USE, DISTURBANCE, AND MANAGEMENT CONSIDERATIONS BY RANGE ASSESSMENT AREA.

RAA	Caribou Habitat and Range Use	Human Land Use and Disturbance	Wildfire Disturbance	Management Considerations	
				Current Situation	Future Situation
Area 1: Nunavut 75,902 km ² (20% of planning area)	<ul style="list-style-type: none"> The most sensitive parts of the Bathurst annual range, the calving and post-calving area, is in RAA1. RAA1 is also important summer habitat. Parts of RAA1 may also be used in winter by other caribou herds (Dolphin and Union, and Beverly-Ahiak). 	<ul style="list-style-type: none"> There is currently a low level of human land use with limited winter road access 	<ul style="list-style-type: none"> Wildfire is not a major source of disturbance on the tundra. 	<ul style="list-style-type: none"> There are few current management concerns related to human land use and disturbance. The Draft Nunavut Land Use Plan (2016) proposed land use designation requires consideration. 	<ul style="list-style-type: none"> RAA1 has the potential to experience the largest increase in new mine and transportation infrastructure development, all within the most sensitive part of the Bathurst range A new all-season road spanning from the Arctic Coast to near Contwoyo Lake is being considered, and multiple large mine projects have been proposed.
Area 2: NWT Central Tundra 56,134 km ² (14% of planning area)	<ul style="list-style-type: none"> RAA2 is central to the Bathurst herd annual range, with summer, fall and spring migration all occurring in this area. Much of the most sensitive summer range is in RAA2 	<ul style="list-style-type: none"> The four diamond mines developed since the late-1990s are located in RAA2. Current human disturbance is estimated to affect 12% of RAA2. The Tibbit to Contwoyo Winter Road provides annual winter 	<ul style="list-style-type: none"> Wildfire is not a major source of disturbance on the tundra. 	<ul style="list-style-type: none"> The combined effects of multiple mines, other exploration projects and the Tibbit to Contwoyo Lake winter road has contributed to relatively high levels of human disturbance. The location of mines in the Lac de Gras area, on or around land bridges and water crossings, has influenced caribou 	<ul style="list-style-type: none"> The level of future development and resulting human disturbance is uncertain. If existing mines are closed in the coming 10-15 years without new mines being developed, disturbance levels will decline. If new mines are developed to replace

RAA	Caribou Habitat and Range Use	Human Land Use and Disturbance	Wildfire Disturbance	Management Considerations	
				Current Situation	Future Situation
		access.		migration paths.	<p>the existing mines, disturbance levels will remain similar to current, or increase.</p> <ul style="list-style-type: none"> A new all-season road to the southern fringe of RAA2 is being considered, which would facilitate year-round human access to parts of the central tundra.
Area 3: NWT Winter Range - Northwest 77,001 km ² (20% of planning area)	<ul style="list-style-type: none"> RAA3 has been used as winter habitat by Bathurst caribou with increasing frequency over the past decade, potentially in response to high levels of wildfire in other areas. The Bathurst and Bluenose East herds overlap in this wintering area. 	<ul style="list-style-type: none"> RAA3 currently receives low levels of human land use. Winter roads in RAA4 provide access to parts of RAA3. 	<ul style="list-style-type: none"> Wildfire has been less active in this part of the winter range. Approximately 20% of RAA3 has been affected by wildfire since 1965. 	<ul style="list-style-type: none"> There are few current management concerns related to human land use and disturbance. In the past, overlap with the Bluenose East herd has resulted in harvest concerns. 	<ul style="list-style-type: none"> The amount of future human disturbance is anticipated to remain low. The amount of future wildfire is uncertain but is anticipated to be similar to current, or increase.
Area 4: NWT Winter Range - Central 84,858 km ²	<ul style="list-style-type: none"> This part of the winter range has received consistent winter use by Bathurst caribou. 	<ul style="list-style-type: none"> RAA4 has the highest amount of human disturbance in the Bathurst range. The City of Yellowknife, all of 	<ul style="list-style-type: none"> A large part (18%) of RAA4 was burned in 2014, with approximately 36% of the area being affected by wildfire since 1965. 	<ul style="list-style-type: none"> RAA4 has the highest level of human (17%) and combined human and wildfire disturbance (47%) in the Bathurst annual range. 	<ul style="list-style-type: none"> Given the large amount of permanent infrastructure and communities, in the future RAA4 is anticipated to continue to have the highest

RAA	Caribou Habitat and Range Use	Human Land Use and Disturbance	Wildfire Disturbance	Management Considerations	
				Current Situation	Future Situation
(22% of planning area)		the communities, Hwy 3 and Hwy 4, a number of winter roads, and the Snare and Bluefish electrical transmission lines are all in RAA4.		<ul style="list-style-type: none"> RAA4 also has the highest amount of winter and all-season roads, facilitating high levels of human access into this part of the Bathurst winter range. 	<p>level of human disturbance within the Bathurst range.</p> <ul style="list-style-type: none"> A new all-season road to replace the southern part of the Tibbit to Contwoyo Lake winter road is being considered. The new all-season road would facilitate year-round human access to parts of RAA4 and RAA2.
Area 5: NWT Winter Range - Southeast 95,127 km ² (24% of planning area)	<ul style="list-style-type: none"> This part of the winter range has received lower use by caribou in recent years. RAA5 is also part of the winter range of the Beverly-Ahiak herd. Occasional and variable overlap between Bathurst and Qamanirjuaq caribou have also occurred in this area. 	<ul style="list-style-type: none"> RAA5 currently receives very low levels of human land use. 	<ul style="list-style-type: none"> RAA5 has experienced many large wildfires over the past decades; 60-70% of the forested area south of treeline has experienced a burn since 1965. 	<ul style="list-style-type: none"> There are few current management concerns related to human land use and disturbance. The large amount of wildfire may be affecting Bathurst caribou use in this part of the winter range. 	<ul style="list-style-type: none"> In the future, human land use is anticipated to remain low. The amount of future wildfire is uncertain but is expected to be similar to or greater than current.

4 Establishing Management Thresholds

4.1 Background

A key management tool in the Bathurst caribou range plan is a cumulative land disturbance framework (CLDF). The CLDF includes management thresholds for levels of human-caused land (surface) disturbance. In the CLDF, the management thresholds provide regulatory limits (*sensu* Kennett 2006) to manage the cumulative magnitude and extent of human footprints and development projects in the Bathurst caribou range planning area. The threshold levels serve as decision or management thresholds (*sensu* Martin et al. 2009), which reflect a balance of the ecological, cultural, and socio-economic values. As such, the threshold values are as much based on cultural considerations as they are on ecological considerations. The level of socio-cultural / ecological risk and landscape change that communities, governments and industry consider to be acceptable may change over time as values and circumstances change. Important considerations in the development of the CLDF thresholds were:

- The Bathurst caribou herd is currently considered to be in a state of serious conservation concern due to its small population size, continuing high rate of decline in breeding females, and the damaged relationship between people and caribou. This coupled with concerns of future uncertain climate change impacts, justifies a precautionary approach to management.
- Both the federal Committee on the Status of Endangered Wildlife in Canada and the NWT Species at Risk Committee recently assessed barren-ground caribou as “threatened”.
- All harvest – including hunting by Aboriginal people – has essentially ceased and a feasibility assessment of wolf management actions is being considered. These management actions focus on improving caribou survival.
- The linkages between habitat disturbance, land use activity and caribou population were evaluated based on computer modeling of future case land use scenarios (see Section 3.5.2.4, above). The reduction in herd productivity due to encounters with human disturbance resulted in a population effect that was additive to the direct mortality effects of predation and hunting.
- Aboriginal community members and TK holders have long stated that there is a link between increasing levels of industrial development on the range and declines in herd size. There have been many formal requests to implement land disturbance thresholds. With declining caribou populations, there have been parallel declines in the traditional economy, food security, connection to the land, and ultimately cultural identity.
- Implementation of the CLDF is considered to be a useful way to manage the cumulative and incremental impacts from land use at the range scale. At the same time, the CLDF provides management direction on acceptable levels of range disturbance and human activity that support sustainable development.

This section describes the approaches and methods used to establish the recommended CLDF management thresholds contained in the Bathurst caribou range plan.

4.2 Methods

In the Bathurst caribou range plan, management thresholds were established in the following manner:

- Using the range assessment results, the amount of current and potential future direct human development footprint and its estimated zone of influence, was calculated for each range assessment area (Section 3.1.4, and Appendix A and Appendix B).
- Interim range assessment areas organized into tundra and taiga areas were adopted as the spatial units for the CLDF (Section 3.1.5, and Appendix C).
- Based on the three scenarios of potential future development, the BCRP Working Group defined initial disturbance thresholds in tundra and taiga biomes for RAA2 and RAA4 respectively (Section 4.2.1 and 0).
- Weighted seasonal range sensitivities (Section 4.2.2) were then used to benchmark the initial disturbance thresholds to tundra RAA1, and taiga RAA3 and RAA5 respectively (Section 4.2.3 and see Appendix E).

4.2.1 CLDF Threshold Levels

The initial disturbance thresholds in the Tundra biome, RAA1 and RAA2, are based on the total disturbance footprint associated with human activities (which includes the ZOI).

Based on the rationale and considerations described above (Section 4.1), along with the experience of the recent Jay Project Environmental Assessment, the NWT Central Tundra RAA2 was first deemed by the BCRP Working Group to be within the Cautionary Level. The current total disturbance footprint of nearly 6,600 km² lies below the critical threshold, which is set at 9,000 km². The cautionary threshold is set at 50% of the critical threshold at a level of 4,500 km².

The Nunavut Tundra RAA1 area was then benchmarked to the RAA2 thresholds to account for the difference in proportion of area weighted by seasonal sensitivity, resulting in a critical threshold of 12,000 km² (Section 4.2.3). The current total disturbance of just over 1,000 km² in RAA1 lies well below the cautionary threshold, which is set at 50% of the critical threshold at a level of 6,000 km². Taiga Biome CLDF Threshold Levels

The disturbance thresholds in the Tundra biome, RAA3, RAA4 and RAA5, are based on the total disturbance footprint associated with human activities (which includes the ZOI).¹³

¹³ Note that burned area resulting from wildfire is not included in the disturbance threshold itself as it was in the previous Interim Discussion Document (BCRP 2016a).

In the Taiga biome, similar to above, the NWT Central Winter Range RAA4 was first deemed to be within the Cautionary Level. The current total disturbance footprint of just under 14,000 km² lies below the critical threshold, which is set at 20,000 km². The cautionary threshold is set at 50% of the critical threshold at a level of 10,000 km².

The NWT Northwest Winter Range RAA3 was then benchmarked to the RAA4 thresholds to account for the relative difference in weighted seasonal range sensitivity (Section 4.2.3). This results in a critical threshold of 19,000 km²; the cautionary threshold is set at 50% of the critical threshold at a level of 9,500 km². There is currently very little human disturbance footprint in RAA4.

The NWT Southeast Winter Range RAA5 was similarly benchmarked to the RAA4 thresholds to account for relative differences in weighted seasonal range sensitivity (Section 4.2.3). This results in a critical threshold of 25,000 km²; the cautionary threshold is set at 50% of the critical threshold at a level of 12,500 km². There is currently very little human disturbance footprint in RAA5.

4.2.2 Seasonal Range Sensitivity and Relative Importance to Caribou

4.2.2.1 Seasonal Range Sensitivity

Barren-ground caribou are considered to be more or less sensitive to disturbance at different times of the year, an observation strongly supported by community members. It is therefore possible to rank the sensitivity of caribou and caribou habitat to disturbance during the different caribou periods and seasonal ranges. From a management perspective, ranking the sensitivity of caribou and caribou habitat can assist in developing recommendations for managing land use and disturbance accordingly.

Sensitivity of caribou and caribou habitat may vary seasonally, with the best example of this being the general acknowledgement that caribou cows and newborn calves are highly sensitive to human disturbance during the calving and post-calving periods. The BCRP Working Group adapted previous work by the Porcupine Caribou Technical Committee (PCTC 1993) and the Beverly and Qamanirjuaq Caribou Management Board (BQCMB 1999) who rated relative sensitivity of a) caribou to disturbance during its annual life cycle and b) sensitivity of range used by caribou during those life cycle periods. The ratings were combined to produce a caribou-range sensitivity rating, which was provided as a general guide for assessing potential negative impacts of land use activities on caribou and caribou range at particular times of the year (Table 7).

TABLE 7: GENERALIZED RATING FOR SENSITIVITY OF MIGRATORY BARREN-GROUND CARIBOU AND CARIBOU RANGE TO LAND USE (SOURCE: BQCMB 1999).

CARIBOU LIFE CYCLE PERIOD	CARIBOU SENSITIVITY RATING ²	RANGE SENSITIVITY RATING ³	CARIBOU - RANGE SENSITIVITY RATING ⁴
Spring migration	Moderate (3)	Moderate (3)	Moderate (6)
Calving	Very high (5)	Very high (5)	Very high (10)
Post-calving	High (4)	High (4)	High (8)
Late summer	Low (2)	Low (2)	Low (4)
Fall migration/rut	Low (2)	Low (2)	Low (4)
Early winter	Very low (1)	Low (2)	Low (3)
Late winter	Low (2)	Low (2)	Low (4)

¹ Factors used to develop generalized ratings are provided in Appendix C.

² Ratings range from 1 (very low) to 5 (very high).

³ Ratings range from 1 (very low) to 5 (very high).

⁴ Caribou-range sensitivity rating = (caribou sensitivity rating) + (range sensitivity rating). Ratings range from 3 (low) to 10 (very high).

The approach developed by the BQCMB (1999) (Table 7) was used to rank the sensitivity of caribou and caribou habitat during the different seasons of the year (Figure 11), and a numerical rank was applied to each of the seasonal ranges. Table 8 displays the resulting seasonal range sensitivity ranks.

The calving and post-calving seasonal range is considered to be a time and place that is the most sensitive for caribou cows and newborn calves. During the calving period cow caribou are easily startled and become agitated, increasing the chances of still born calves or calf abandonment. The summer period is considered to be the second most sensitive part of the range, with the fall and winter periods considered the least sensitive periods.

The BQCMB range sensitivity ratings were adjusted for the summer period from low to moderate, to reflect recent studies that highlighted the sensitivity and importance of the summer period for barren-ground caribou (Russell et al. 1993) and the need for breeding females to maximize forage and nutrient intake so that they are in sufficient body condition for the fall breeding season (White et al. 2014) (Table 8). Since pregnancy rate of caribou cows is tied to their fall body size and condition, human-caused and/or natural disturbance of cows in summer has the potential to affect population growth.

Disturbance of caribou in summer may therefore reduce the amount of time spent feeding and increase the amount of time spent in energetically costly activities (i.e., walking and running), which in turn can

result in cows that have a reduced likelihood of conceiving during the rut due to lower than average body weights (White et al. 2014).

TABLE 8: GENERALIZED SENSITIVITY RATINGS FOR BATHURST CARIBOU AND THEIR SEASONAL RANGES TO LAND USE.

Season	Start - End Dates	Period	Range	Sensitivity to Disturbance			Sensitivity Scores to Disturbance		
				Habitat	Caribou	Overall	Habitat	Caribou	Overall
Spring Migration	20 Apr - 01 Jun	Spring	Migration	Moderate	Moderate	Moderate	3	3	6
Calving & Post-calving	02 Jun - 28 Jun	Spring	Calving & Post-calving	Very High	Very High	Very High	5	5	10
Summer	29 Jun - 06 Sep	Summer	Tundra	Moderate-High	High	High	4	4	8
Fall	07 Sep - 30 Nov	Fall	Tundra	Low	Low	Low	2	2	4
Winter	01 Dec - 19 Apr	Winter	Taiga	Low	Low	Low	1	2	3

4.2.2.2 Weighted Seasonal Range Sensitivity

To integrate the concepts of range use and range sensitivity drawing from scientific findings and community input, the BCRP Working Group developed a range utilization map weighted by seasonal sensitivity. This approach builds on the seasonal sensitivity ranks (Section 4.2.2.1, above) where the calving and post-calving and summer ranges were determined to be the most sensitive parts of the Bathurst range.

The weighted seasonal sensitivity map was created using annual and seasonal range use patterns analyzed by Caslys Consulting based on available satellite and GPS collar data (1996-2013). Kernel analyses were used to define the utilization distributions (UD) of collared caribou, where a UD is defined as a probability density that gives an animal's relative frequency of occurrence. Multiple probability density levels (50%, 80%, 90%, 95%, and 99% UD) were generated based on a composite of available collar data for the 17-year period, as well as analyses that aggregated data at 3-year intervals.

The spatial data from Caslys's five composite seasonal range were subsequently combined by weighting the seasonal range areas by their UD values and respective overall sensitivity scores. The sum of products of the UD values and sensitivities scores were normalized and used to develop a single utilization-sensitivity layer that maintained the information of all seasonal spatial layers over each location of the annual range. The normalized utilization-sensitivity data were depicted at frequency distribution categories of 0.03, 0.14, 0.32, 0.52, and 1.0, based on natural break classes in the non-zero

data using the Jenks method in ArcGIS¹⁴. This analysis resulted in a map that showed caribou range utilization weighted by seasonal range sensitivity.

The Bathurst weighted seasonal range sensitivity map is shown in Figure 27. Darker areas on the map indicate areas of higher use and higher sensitivity. This map highlights the concentrated use of the calving and post-calving, and summer ranges by Bathurst caribou, and the heightened sensitivity of habitat and caribou to disturbance during these periods (as per Table 8 and see Appendix E).

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¹⁴ The Jenks natural breaks classification method assigns class breaks that best group similar data values and maximize the differences between classes. Class boundaries are set where there are relatively big differences in data values.

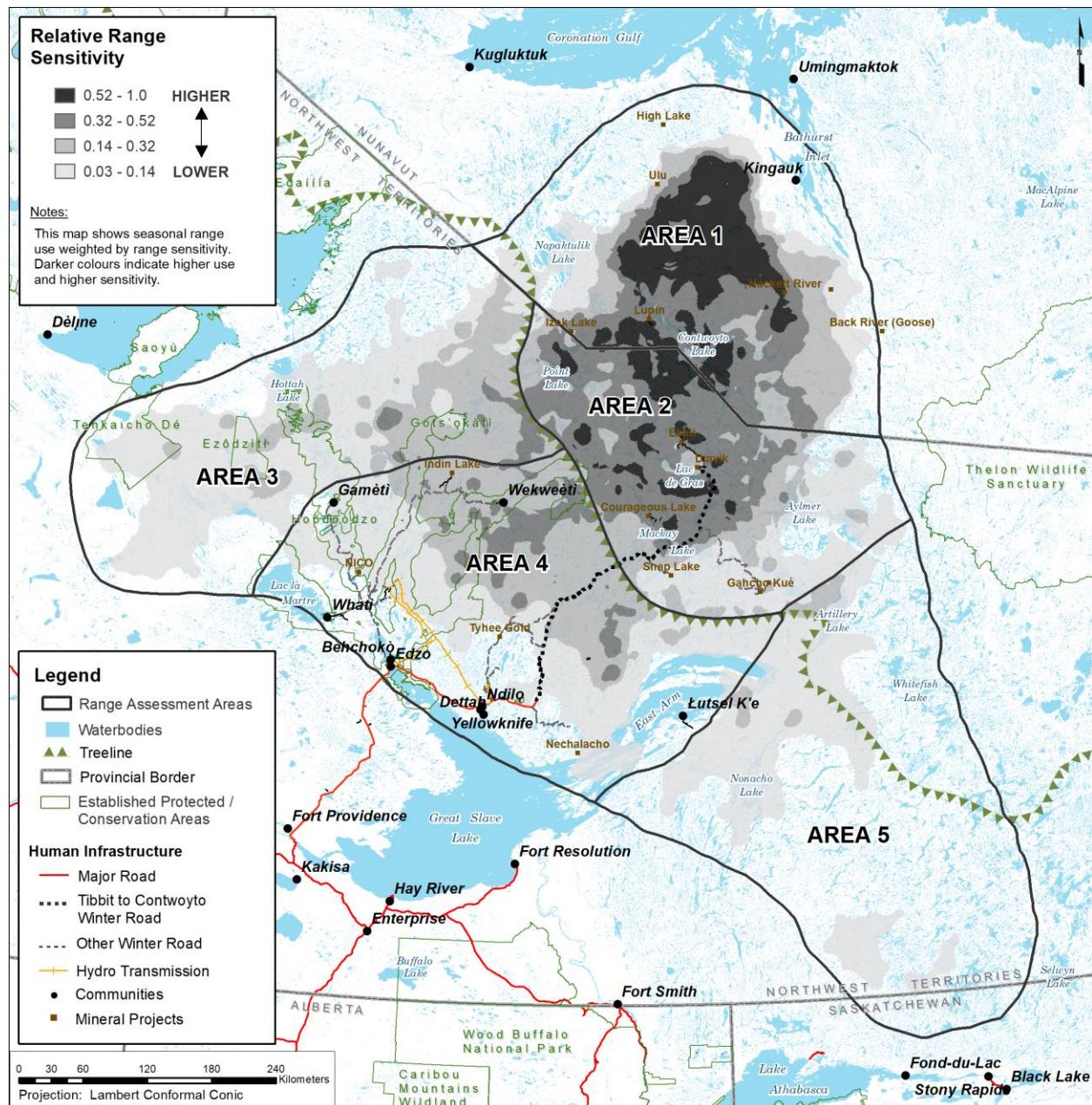


FIGURE 27: BATHURST CARIBOU RANGE USE WEIGHTED BY RANGE SENSITIVITY. DARKER COLOURS SHOW AREAS WITH HIGHEST USE WITHIN THE MOST SENSITIVE SEASONAL RANGES.

4.2.3 Benchmarking Disturbance Thresholds

The initial disturbance thresholds that were established in reference areas RAA2 and RAA4, were benchmarked to tundra RAA1 and taiga RAA3 and RAA4 respectively based on the following steps:

- The disturbance threshold values (km^2) were converted into a % total disturbance value based on the size of the respective RAAs. For RAA2, the set disturbance threshold of 9,000 km^2 was equivalent to a 16% total disturbance value (Table 9). Similarly, for RAA4 the set threshold of 20,000 km^2 equated to a 24% total disturbance value (Table 9).
- For each RAA, the area within each weighted range sensitivity class (shown in Figure 27) was determined using ArcGIS. The upper value for each range sensitivity class was then multiplied by the respective area (km^2) and summed (i.e., the “Sum of Products” in Table 9). The Sum of Products was then expressed as a percentage relative to the size of the respective RAAs (i.e., the % Sum of Products” in Table 9).
- The difference between the “% Sum of Products” between RAAs was then used to adjust the “% Total Disturbance”. For example, the difference in “% Sum of Products” between RAA1 and RAA2 was 2% (i.e., 39% - 37%) (Table 9). Therefore, the benchmarked “% Total Disturbance” in RAA1 was equal to the “% Total Disturbance” in RAA2 multiplied by a factor of 1.02.
- To further illustrate by example, the benchmarked “% Total Disturbance” in RAA1 (16%) was multiplied by the “Total RAA Area” (75,894 km^2) to estimate the “Total Disturbance Threshold” ($\sim 12,000 \text{ km}^2$) (Table 9).
- Table 9 similarly shows that the relative difference between the “% Sum of Products” in the weighted areas between RAA4 and RAA3 was minimal ($\sim 2\%$), so the benchmarked value for % total disturbance was virtually identical to the reference threshold value. In comparison, the difference in “% Sum of Products” between RAA5 and RAA4 resulted in a 26% total disturbance threshold for RAA5, which resulted in a disturbance threshold of $\sim 25,000 \text{ km}^2$.

TABLE 9: CALCULATION OF BENCHMARKED THRESHOLDS BASED ON INITIAL DISTURBANCE THRESHOLDS.

Weighted Sensitivity Value	Area (km ²)					Total RAA Area	Total Disturbance Threshold ¹	% Total Disturbance	Sum of Products (Weighted Sensitivity Value x Area)	Remaining Area	Total RAA Area	% Sum of Products (Weighted Area)
		Weighted	Sensitivity	Class								
RAA 2	3944	13875	11830	21,545	4,939	56,133	9,000	16%	21,989	34,144	56,133	39%
RAA 1	26365	9173	11417	14,439	14,500	75,894	12,000	16%	27,737	48,157	75,894	37%
RAA 4	31002	26763	21345	5,749	3	84,862	20,000	24%	14,500	70,362	84,862	17%
RAA 3	27267	32031	15644	2,055	0	76,997	19,000	24%	11,377	65,620	76,997	15%
RAA 5	69209	24136	1781	0	0	95,126	25,000	26%	6,025	89,101	95,126	6%
Total	157,787	105,978	62,017	43,788	19,442	389,012	85,000	22%	81,628	307,384	389,012	21%

Inputted values; Derived values

¹ Benchmarked (i.e., derived) threshold values were rounded to the nearest 1,000 km²

5 References

Anderson, T. A., and C. J. Johnson. 2014. Distribution of barren-ground caribou during winter in response to fire. *Ecosphere* 5(10):140. <http://dx.doi.org/10.1890/ES14-00010.1>

Andrews, T. D. 2011. "There will be many stories", museum anthropology, collaboration and the Tł'chǫ. Unpublished Phd Thesis. University of Dundee, Dundee, Scotland, UK. 283 pp.

Athabasca Denesuline. 2017. Bathurst Caribou Range Plan – traditional ecological knowledge report. 10 pp.

Barrier, T. and C. Johnson. 2012. The influence of fire history on selection of foraging sites by barren-ground caribou. *Ecoscience* 19 (2): 177-188.

Bergerud, A.T., R.D. Jakimchuck, D.R. Carruthers. 1984. The buffalo of the north: caribou (*Rangifer tarandus*) and human developments. *Arctic* 37: 7-22.

Bergerud, A.T., S.N. Luttich, and L. Camps. 2008. The Return of Caribou to Ungava. Montreal and Kingston, Canada: McGill-Queens University Press. 586 pp.

Beverly and Qamanirjuaq Caribou Management Board (BQCMB). 1999. Protecting Beverly and Qamanirjuaq caribou and caribou range. Part I: Background Information. Beverly and Qamanirjuaq Caribou Management Board, Ottawa, ON. 40 pp.

Boulanger, Y., S. Gauthier, and P.J. Burton. 2014. A refinement of models projecting future Canadian fire regimes using homogenous fire regime zones. *Canadian Journal of Forest Research* 44: 365-376.

Boulanger, J., B. Croft, J. Z. Adamczewski, H. D. Cluff, M. Campbell, D. S. Lee, and N. C. Larter. 2016. An estimate of breeding females and analyses of demographics for the Bathurst herd of barren-ground caribou: 2015 calving ground photographic survey (Draft - February 12, 2016). Department of Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT. 76 pp.

Burton, P.J., Parisien, M.A., Hicke, J.A., Hall, R.J. and Freeburn, J.T. 2008. Large fires as agents of ecological diversity in the North American boreal forest. *International Journal of Wildland Fire* 17:754-767.

Chen, W., D. E. Russell, A. Gunn, B. Croft, W. R. Chen, R. Fernandes, H. Zhao, J. Li, Y. Zhang, K. Koehler, I. Olthof, R. H. Fraser, S. G. Leblanc, G. R. Henry, R. G. White, and G. L. Finstad. 2012. Monitoring habitat condition changes during winter and pre-calving migration for Bathurst Caribou in northern Canada. *Biodiversity*: 1-9.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC) 2011. Designatable units for caribou (*Rangifer tarandus*) in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. 89 pp.

Dedats'eetsa: Tłı̨chǫ Research and Training Institute. 2016. A Summary Report of Tłı̨chǫ Traditional Knowledge of Ekwó (Barren-ground Caribou) for the Bathurst Caribou Range Plan. Submitted by Petter Jacobsen. Submitted to the Government of the Northwest Territories. April 5, 2016. 66 pp.

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

Environment and Climate Change Canada (ECCC). 2012. Recovery Strategy for the Woodland Caribou (*Rangifer tarandus caribou*), Boreal Population, in Canada. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa. 138pp.

Environment and Climate Change Canada (ECCC). 2017. Management Plan for the Barren-ground Caribou (*Rangifer tarandus groenlandicus*), Dolphin and Union population, in Canada: Adoption of the Management Plan for the Dolphin and Union Caribou (*Rangifer tarandus groenlandicus x pearyi*) in the Northwest Territories and Nunavut [Proposed Final]. Species at Risk Act Management Plan Series Environment and Climate Change Canada, Ottawa, ON. 105 pp.

Environment and Natural Resources (ENR). 2014. Bathurst & Bluenose-East Caribou Herds: Overview of Population Trends 2009-2014. Unpublished Report Sep 2014. Department of Environment and Natural Resources, Government of Northwest Territories, Yellowknife, NT, Canada.

Ecological Stratification Working Group (ESWG). 1995. A national ecological framework for Canada. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Resources Research and Environment Canada, State of the Environment Directorate, Ecozone Analysis Branch. Ottawa/Hull, ON. 125 p. Report and national map at 1:7 500 000 scale.

Flannigan, M.D., Stocks, B.J. and Wotton, B.M. 2000. Climate change and forest fires. The Science of the Total Environment 262:221-230.

Flannigan, M., Logan, K., Amiro, B., Skinner, W. and Stocks, B. 2005. Future area burned in Canada. Climatic Change 72:1-16.

Gordon, B. C. 1996. People of sunlight: people of starlight: Barrenland archaeology in the Northwest Territories of Canada. Archeological Survey of Canada Paper 154, Canadian Museum of Civilization. Hull, PQ. 332 pp.

Griffith, B., A. Gunn, J. F. Johnstone, K. Kielland, S. Wolfe, and D. C. Douglas. 2001. Bathurst caribou calving ground studies: influence of nutrition and human activity on calving ground location. West Kitikmeot Slave Study, Yellowknife, NT. 118 pp.

Gunn, A., J. Dragon, and J. Boulanger. 2001. Seasonal movements of satellite-collared caribou from the Bathurst herd. West Kitikmeot Slave Study, Yellowknife, NT. 72 pp.

Gunn, A., K.G. Poole, and J. Wierzchowski. 2008. A geostatistical analysis for the patterns of caribou occupancy on the Bathurst calving grounds 1966-2007. Prepared for Indian and Northern Affairs Canada, Yellowknife, Northwest Territories. Project CFA 0708-00-000105.

Gunn, A., A. D'Hont, J. Williams, and J. Boulanger. 2013. Satellite collaring in the Bathurst herd of barren-ground caribou, 1996-2005. Manuscript Report No. 225, Government of the Northwest Territories, Yellowknife, NT. 139 pp.

Heard, D.C. 1985. Caribou census methods used in the Northwest Territories. Pages 229-238 in T. C. Meredith and A. M. Martell, editors. Caribou management - Census techniques - Status in Eastern Canada: Proceedings of the Second North American Caribou Workshop. McGill University, Val Morin, Québec.

Heard, D.C., and T. M. Williams. 1992. Distribution of wolf dens on migratory caribou ranges in the Northwest Territories, Canada. Canadian Journal of Zoology 70:1504-1510.

Joly, K., P. Bente and J. Dau. 2007. Response of overwinter caribou to burned habitat in northwest Alaska. Arctic 60(4): 401-410.

Kansas, J., J. Vargas, H.G. Skatter, B. Balicki, and K. McCullum. 2016. Using Landsat imagery to backcast fire and post-fire residuals in the Boreal Shield of Saskatchewan: implications for woodland caribou management. International Journal of Wildland Fire. <http://dx.doi.org/10.1071/WF15170>.

Kennett, S. 2006. From science-based thresholds to regulatory limits: Implementation issues for cumulative effects management. Prepared for Environment Canada. Yellowknife, NWT. 23pp.

Krezek - Hanes, C.C., Ahern, F., Cantin, A. and Flannigan, M.D. 2011. Trends in large fires in Canada, 1959 - 2007. Canadian Biodiversity: Ecosystem Status and Trends 2010, Technical Thematic Report No. 6. Canadian Councils of Resource Ministers. Ottawa, ON. v + 48 p.

<http://www.biodivcanada.ca/default.asp?lang=En&n=137E1147-0>

Legat, A., G. Chocolate, B. Gon, S. A. Zoe, and M. Chocolate. 2001. Caribou migration and the state of their habitat. Submitted by Dogrib Treaty 11 Council, West Kitikmeot Slave Study, Yellowknife, NT. 90 pp + Appendices.

Legat, A., Chocolate, G., Mackenzie-Scott, G., Sprecher, D., and S. A. Zoe. 2000. A Tłı̨chǫ Perspective on Biodiversity. Prepared for BHP Diamonds.

Mackenzie Valley Environmental Impact Review Board (MVEIRB). 2013. Report of environmental impact review and reasons for decision. EIR 0607-001. Gahcho Kué Diamond Mine Project, DeBeers Canada Inc. July 19, 2013. Yellowknife, NT. 207pp.

Mackenzie Valley Environmental Impact Review Board. 2016. Report of Environmental Assessment and Reasons for Decision: Dominion Diamond Ekati Corp. Jay Project. Yellowknife, NT. 350pp.

Maikawa, E. and K. Kershaw. 1976. Studies on lichen-dominated systems. XIX. The postfire recovery sequence of black spruce-lichen woodland in the Abitau Lake Region, NWT. Canadian Journal of Botany 54: 2679 – 2687.

Martin, J., M.C. Runge, J.D. Nichols, B.C. Lubow, and W.L. Kendall. 2009. Structured decision making as a conceptual framework to identify thresholds for conservation and management. Ecological Applications 19: 1079-1090.

McNeil, P., D. E. Russell, B. Griffith, A. Gunn, and G. Kofinas. 2005. Where the wild things are: Seasonal variation in caribou distribution in relation to climate change. Rangifer Special Issue No. 16:51-63.

Nagy, J. 2011. Use of space by caribou in northern Canada. PhD Thesis, University of Alberta, Edmonton, AB 184pp.

Nishi, J. S., B. Croft, J. Boulanger, J. Z. Adamczewski, and A. Kelly. 2014. An estimate of breeding females in the Bathurst herd of barren-ground caribou, June 2009. File Report No. 144, Government of the Northwest Territories, Yellowknife, NT. 101 pp.

Nunavut Planning Commission. 2016. Nunavut land use plan (2016 draft). Schedules A and B.

Parisien, M.A, K.G. Hirsh, S.G. Lavoie, J.B. Todd, and V.G. Kafka. 2004. Saskatchewan fire regime analysis. Information Report NOR-X-394. Canadian Forest Service, Northern Forestry Centre. Edmonton, AB.

Parisien, M.A., V.S. Peters, Y. Wang, J.M. Little, E.M. Bosch, and B.J. Stocks. 2006. Spatial patterns of forest fires in Canada, 1980-1999. International Journal of Wildland Fire 15:361-374.

Poole, K. G., and A. Gunn. 2015. Mobile Caribou Protection Measures for the Kivalliq Region, Nunavut. Final Report for Kivalliq Inuit Association, Aurora Wildlife Research, Nelson, British Columbia. 21 pp.

Porcupine Caribou Technical Committee (PCTC). 1993. Sensitive habitats of the Porcupine caribou herd. Report accepted by the International Porcupine Caribou Board from the Porcupine Caribou Technical Committee, Porcupine Caribou Management Board Whitehorse, YT. 28 pp.

Russell, D. E., A. M. Martell, and W. Nixon. 1993. Range ecology of the Porcupine Caribou herd in Canada. Rangifer Special Issue No. 8. 168 pp.

Rickbeil, G. J. M., T. Hermosilla, N. C. Coops, J. C. White, and M. A. Wulder. 2017. Barren-ground caribou (*Rangifer tarandus groenlandicus*) behaviour after recent fire events; integrating caribou telemetry data with Landsat fire detection techniques. Global Change Biology:23: 1036-1047

Russell, D., G. Kofinas, and B. Griffith. 2002. Barren-ground Caribou Calving Ground Workshop: Report of Proceedings. Technical Report No. 390, Canadian Wildlife Service, Ottawa, ON. 40 pp.

Russell, D., A. Gunn, L. Frid, C. Daniel and R.G. White. 2015. CARMA's Knowledge to action: developing and testing thresholds and monitoring for cumulative impacts on caribou. Annual Project Status Report Project Completion Report, 2013-15 (12 May 2015), Northwest Territories Cumulative Impact Monitoring Program (NWT CIMP), Government of the Northwest Territories, Yellowknife, NT. 42 pp.

Schaefer, J. A., and W. O. Pruitt, Jr. 1991. Fire and woodland caribou in southeastern Manitoba. *Wildlife Monographs* 116: 1-39.

Skoog, R. O. 1968. Ecology of the caribou (*Rangifer tarandus granti*) in Alaska. Unpublished PhD Thesis. University of California, Berkeley, California. 699 pp.

Stewart, A. M., D. Keith, and J. Scottie. 2004. Caribou crossings and cultural meanings: Placing traditional knowledge and archaeology in context in an Inuit landscape. *Journal of Archaeological Method and Theory* 11:183-211.

Stocks, B.J., Mason, J.A., Todd, J.B., Bosch, E.M., Wotton, B.M., Amiro, B.D., Flannigan, M.D., Hirsch, K.G., Logan, K.A., Martell, D.L. and Skinner, W.R. 2003. Large forest fires in Canada, 1959-1997. *Journal of Geophysical Research* 108:8149-8161.

Taillon, J., M. Festa-Bianchet, and S. D. Cote. 2012. Shifting targets in the tundra: protection of migratory caribou calving grounds must account for spatial changes over time. *Biological Conservation* 147:163-173.

Thomas, D.C., S.J. Barry, and G. Alaie. 1996. Fire-caribou-winter range relationships in northern Canada. *Rangifer* 16: 57-67.

Thorpe, N.L., S. Eyegetok, N. Hakongak, and Qitirmiut Elders. 2001. The Tuktu and Nogak Project: A Caribou Chronicle. Final Report to the West Kitikmeot Slave/Study Society. Ikaluktuuttiak, Nunavut. 2001.

Dedats'eetsa: Tłı̨chǫ Research and Training Institute. 2016. A summary report of Tłı̨chǫ traditional knowledge of Ekwó (barren-ground caribou) for the Bathurst Caribou Range Plan. Submitted by Petter Jacobsen. Submitted to the Government of the Northwest Territories. April 5, 2016. 66 pp.

Ungava Peninsula Caribou Aboriginal Round Table (UPCART). 2017. A Long Time Ago in the Future: Caribou and the People of Ungava (2017-2117). 45 pp. Online [URL]: <http://www.gcc.ca/pdf/UPCART-STRATEGY-October-17-2017.pdf>

Wekèezhii Renewable Resource Board (WRRB). 2010. Report on a Public Hearing held by the Wekèezhii Renewable Resources Board, 22-26 March 2010, 5-6 August 2010, Behchoko, NT. and Reasons for decisions related to a joint proposal for the management of the Bathurst caribou herd. Wek'eezhii Renewable Resources Board, Yellowknife, NT. 20 pp.

Wekèezhii Renewable Resource Board (WRRB). 2016a. Report on a Public Hearing Held by the Wek'eezhì Renewable Resources Board, 23-24 February 2016, Yellowknife, NT., & Reasons for Decisions

Related to a Joint Proposal for the Management of the Bathurst Ekwó (barren-ground caribou) herd - PART A. Wek'èezhìi Renewable Resources Board, Yellowknife, NT. 41 pp + Appendices.

Wekèezhii Renewable Resource Board (WRRB). 2016b. Reasons for Decisions Related to a Joint Proposal for the Management of the Bathurst Ekwó (barren-ground caribou) herd - PART B. Wek'èezhìi Renewable Resources Board, Yellowknife, NT. 41 pp + Appendices.

Wekèezhii Renewable Resource Board (WRRB). 2016c Bathurst Caribou Herd Public Hearing - Transcript February 23, 2016 (Day 1 of 2), pp. 115-118; pp. 141-144, and pp. 164-166. Online [URL]:
<http://www.wrrb.ca/sites/default/files/WRRB%20re%20BATHURST%20CARIBOU%20%2002-23-2016.pdf>

Wekèezhii Renewable Resource Board (WRRB). 2016d Bathurst Caribou Herd Public Hearing - Transcript February 24, 2016 (Day 2 of 2), pp. 58-63. Online [URL]:

<http://www.wrrb.ca/sites/default/files/WRRB%20re%20CARIBOU%20HERD%20%2002-24-2016.pdf>

White, R. G., D. E. Russell, and C. J. Daniel. 2014. Simulation of maintenance, growth and reproduction of caribou and reindeer as influenced by ecological aspects of nutrition, climate change and industrial development using an energy-protein model. *Rangifer* 34: Special Issue No. 22. 126 pp.

Williams, T.M. and A. Gunn. 1982. Descriptions of water crossings and their use by migratory barren-ground caribou in the districts of Keewatin and Mackenzie, NWT. NWT Wildlife Service File Report No. 27. Yellowknife, NWT.

Witter, L. A., C. J. Johnson, B. Croft, A. Gunn, and L. M. Poirier. 2012. Gauging climate change effects at local scales: weather-based indices to monitor insect harassment in caribou. *Ecological Applications* 22:1838-185.