Boreal Caribou (*Rangifer tarandus*) in British Columbia: 2017 Science Review

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EXECUTIVE SUMMARY

Boreal Caribou (*Rangifer tarandus*; Woodland Caribou - Boreal population) are listed as Threatened in Schedule 1 of Canada's *Species at Risk Act* and are on the Red list (indigenous species or subspecies that have/are candidates for Extirpated, Endangered, or Threatened status) in British Columbia (BC).

The *Implementation Plan for the Ongoing Management of Boreal Caribou (Rangifer tarandus caribou, pop 14) in British Columbia* (BCIP) has provided guidance for managing Boreal Caribou in the province since 2011 (Ministry of Environment 2011). The BC Boreal Caribou Research and Effectiveness Monitoring Board (REMB) was established to support the BCIP.

In 2010, the Ministry of Environment (MOE) completed the *Scientific Update for the Boreal Caribou (Rangifer tarandus caribou) in British Columbia* (MOE 2010). This 2017 Boreal Caribou Science Review summarizes results of research on BC's Boreal Caribou and their habitat between 2010 and 2016, and is intended to complement the 2010 Science Update.

Boreal Caribou recovery is a high priority for Treaty 8 First Nations, which are taking an increasingly active role in caribou stewardship and management. Recent projects gathered information on Boreal Caribou and their habitat from indigenous knowledge-holders in the Blueberry River First Nations, Doig River First Nation, and Métis Nation of British Columbia, and from First Nations in the Dehcho Region, Northwest Territories, and northern Alberta. Traditional ecological knowledge provided in these reports is integrated into this science review.

Since 2010, numerous scientific research projects have addressed questions of Boreal Caribou distribution, demographics, health, and habitat selection in northeastern BC. An intensive GPS/VHF radio-telemetry study (BCIP telemetry study) was initiated in December 2012. As of December 2016, the study had collected over 170,000 GPS locations from 239 adult female caribou, which have contributed to a greater understanding of BC's Boreal Caribou distribution and population dynamics and supported a variety of associated research projects. In February 2015, BCIP telemetry study results were used to refine the provincial Boreal Caribou Range and Core Area map.

Several projects have been or are currently being conducted in BC's Boreal Caribou Ranges that address various components of Boreal

Caribou predator/prey dynamics and relationships among those components, and include:

- calving habitat selection and spatial factors affecting predation risk to Boreal Caribou calves;
- associations between wolves (*Canis lupus*), industrial activity, and Boreal Caribou population growth rates;
- population growth rates of Boreal Caribou related to landscape attributes (e.g., degree of human disturbance, proportion of uplands vs. wetlands), ungulate abundance, and wolf abundance;
- Boreal Caribou survival in relation to the distribution and abundance of moose (*Alces americanus*) and wolves (in progress);
- Boreal Caribou behaviour and calving success in relation to oil and gas development;
- foraging trials using tame, adult female caribou to evaluate summer food habits and diet selection, and forage value in plant communities in boreal, montane, and alpine ecosystems;
- aerial surveys using the distance sampling method to estimate moose abundance in portions of BC's Boreal Caribou Ranges in 2010, 2013, and 2016;
- beaver (*Castor canadensis*) abundance in the Prophet, Parker, Maxhamish, Snake-Sahtaneh, Chinchaga, and Calendar Ranges;
- natural regeneration on low impact seismic lines;
- functional restoration of linear features; and,
- predicting population level response to seismic line restoration (not yet completed).

Results of the BCIP telemetry study reveal low adult and calf survival rates, which suggests BC's Boreal Caribou population is declining. While wolf predation is the primary source of mortality for adult caribou, information on the overall distribution and abundance of wolves in BC Boreal Caribou Ranges is still lacking. Although evidence of wolves preying on caribou calves was reported previously for the Snake-Sahtaneh Range, no formal studies of causes of calf mortality have been conducted in BC's Boreal Caribou Ranges. Based on resource selection models, calf survival is best explained by predation risk from black bears (*Ursus americanus*). For Ranges assessed, wolf densities were higher than what would be expected based on moose densities in those Ranges.

For all Ranges combined, Boreal Caribou selected treed bogs and poor fens and avoided deciduous swamps and upland habitats in all seasons.

Preliminary results suggest that human footprint positively affected wolf density, and negatively affected caribou population rate of change, and that there was an inverse relationship between wolf density and caribou population rate of change. Moose density on Boreal Caribou Ranges in BC is positively associated with the proportion of burns, but no relationship was found between moose density and anthropogenic disturbance metrics assessed (proportion of cutblocks, density of roads, density of seismic lines).

A three-year Boreal Caribou Health Research Program (BCHRP) was initiated in the fall of 2013 to assess the current health status of BC's Boreal Caribou population based on samples collected during the BCIP telemetry study. Samples were analysed to determine Boreal Caribou exposure to, or infection with, selected bacterial, viral, and parasitic diseases. Other indices of caribou health related to chronic physiological stress, immunity, nutrition, and toxicology were also examined. Preliminary results identified a number of potential threats to caribou health and fitness, including infection with the protozoan parasite *Neospora caninum* infection with the bacterial pathogen *Erysipelothrix rhusiopathiae*, significant hair loss related to infestation with winter ticks (*Dermacentor albipictus*); evidence of probable trace nutrient deficiencies; and, higher levels of cortisol (an indicator of chronic physiological stress) than in captive and free-ranging caribou and reindeer sampled in other study areas.

Researchers from the National Council for Air and Stream Improvement (NCASI) used a combination of ultrasound measures of rump fat and body condition score to assess body fat and nutritional condition of caribou in northeastern BC and the southern NT, including a subsample of animals radio-collared during the BCIP telemetry study. This ongoing work is providing insight into variations in body fat and condition within and between caribou populations.

Although an extensive body of information has been collected since 2010, knowledge gaps still exist, with some gaps identified by studies conducted during the last 5 years. Priority knowledge gaps include:

- wolf abundance and diet in Boreal Caribou Ranges;
- the primary cause of Boreal Caribou calf mortality;
- Range-specific seasonal habitat selection;
- the current condition (forage, habitat alteration) of Boreal Caribou Range in BC; and,
- the scale of habitat restoration required to result in desired functional and population responses by predators, alternate prey, and Boreal Caribou.

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1 INTRODUCTION

In May 2000, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated Boreal Caribou (*Rangifer tarandus*; Woodland Caribou - Boreal population) as nationally Threatened, which was reconfirmed in 2002 and 2014 (COSEWIC 2014). Boreal Caribou are currently listed as Threatened in Schedule 1 under the federal *Species at Risk Act* (SARA). In 2000, Boreal Caribou in British Columbia (BC) were ranked S3 (vulnerable) by the BC Conservation Data Centre (CDC) and placed on the provincial Blue list (any indigenous species or subspecies considered to be of Special Concern in BC). In 2006, Boreal Caribou were ranked S2 (imperilled) and upgraded to the Red list (any indigenous species or subspecies that have or are candidates for Extirpated, Endangered, or Threatened status in BC).

Environment Canada began assessing the status of Boreal Caribou in Canada in the mid-2000s (Environment Canada 2008, 2011), and completed a recovery strategy in 2012 (Environment Canada 2012). The goal of the recovery strategy is "to achieve self-sustaining local populations in all Boreal Caribou ranges throughout their current distribution in Canada, to the extent possible." Corresponding population and distribution objectives include: maintaining the current status of the 14 existing self-sustaining local populations, and, stabilizing and achieving self-sustaining status for the 37 not self-sustaining local populations. All BC Boreal Caribou populations were determined to be not self-sustaining.

The BC Ministry of Environment (MOE) began recovery planning for Boreal Caribou in BC in 2004 (Boreal Caribou Technical Advisory Committee 2004). At that time, information available on provincial Boreal Caribou distribution, habitat needs, and population status was limited to an ongoing radio-telemetry study of Boreal Caribou in the newly delineated Snake-Sahtaneh Range (Culling et al. 2004, Culling et al. 2006). In subsequent years, additional studies collected information on Boreal Caribou in the Maxhamish (Rowe 2006), Chinchaga (Rowe 2007), and Calendar (Culling and Culling 2017) Ranges, with a monitoring program established by MOE in 2008 (Thiessen 2009).

Since 2011, the *Implementation Plan for the Ongoing Management of Boreal Caribou (Rangifer tarandus caribou, pop 14) in British Columbia* (BCIP) has provided guidance for managing Boreal Caribou in the province (MOE 2011). The BCIP identified several objectives to allow long-term (50 years) recovery of Boreal Caribou populations including: protecting and restoring habitat, managing the industrial footprint, establishing industry standard management practices, mitigating effects of the industrial footprint by reducing predators, and managing habitat conditions (e.g. fire suppression). These objectives were designed to provide measurable targets for action and evaluation in order to ensure population and distribution goals are being achieved. The BCIP is currently under revision and an updated plan is expected to be completed in 2017.

In 2011, the BC Boreal Caribou Research and Effectiveness Monitoring Board (REMB) was established to support the BCIP. The REMB was established through a Memorandum of Understanding between BC Ministry of Forests, Lands and Natural Resource Operations (MFLNRO), BC MOE, BC Ministry of Energy, Mines and Natural Gas (now Ministry of Natural Gas Development), the Canadian Association of Petroleum Producers (CAPP), and the Explorers and Producers Association of Canada (EPAC). CAPP and EPAC supported implementation of the BCIP through a levy on all oil and gas activity authorizations, which provided up to a maximum of $2 million annually for 5 years. The Oil and Gas Commission (OGC) administers funding for REMB projects through the BC Oil and Gas Research and Innovation Society (OGRIS).

A Science Update was completed by MOE for Boreal Caribou in BC in 2010 (MOE 2010). Since 2010, a considerable amount of research and monitoring has been conducted on Boreal Caribou in BC. This 2017 Boreal Caribou Science Review summarizes results of research on BC's Boreal Caribou and their habitat between 2010 and 2016, and is intended to complement the 2010 Science Update. Relevant information from older research is included where appropriate. Knowledge gaps are identified at the end of each section, and are summarized in Section 10. A list of ongoing and completed technical reports and published articles on species and population management projects associated with BC's Boreal Caribou since 2010, and research on predator and alternate prey species, is included in Appendix 1. Additional information on the life history, ecology, and management of Boreal Caribou in BC can be found in the 2010 Science Update (MOE 2010).

2 TRADITIONAL ECOLOGICAL KNOWLEDGE

There is a growing appreciation for the role that First Nations' Traditional Ecological Knowledge (TEK)[1] can play in the stewardship and management of Boreal Caribou. Since 2000, radio-telemetry has been used to describe the distribution and population dynamics of Boreal Caribou in BC. Advances in Global Positioning System (GPS) technology have provided increasingly detailed information on how caribou move through their environment and interact with predators and other prey

[1] Also referred to as Indigenous Knowledge (IK)

species. However, because these studies began after the landscape within Boreal Caribou ranges had been dramatically altered by decades of industrial development, they are only capable of describing the current condition. Recent initiatives to collect information from First Nations' Elders and knowledge-holders on past caribou populations and habitat conditions provides context to better understand the historic landscape prior to habitat alteration. Boreal Caribou recovery is a high priority for Treaty 8 First Nations communities in BC, which are taking an increasingly active role in caribou stewardship and management.

Blueberry River First Nations (BRFN) historically relied on Boreal (Chinchaga herd) and Northern (Pink Mountain herd) ecotype caribou for both food and cultural practices. They commissioned a study to document community members' indigenous knowledge of caribou, including seasonal habitat use and reasons for population declines (Leech et al. 2016a). The project included: the compilation of earlier indigenous knowledge studies; an intensive field tour of important areas in BRFN territory with BRFN knowledge-holders, which was focused on identifying seasonally important habitat, landscape level habitat needs, and migration corridors for both ecotypes; the development of an indigenous knowledge-based habitat supply model (HSM) for the Chinchaga Range; and management recommendations for restoring caribou populations within BRFN territory.

BRFN community members report they no longer hunt caribou in their territory in response to declining populations (Leech et al. 2016a). Caribou hide is culturally important to the BRFN, including for drum-making. Knowledge-holders indicate that caribou drums sound different than those made from the hide of other species.

The Doig River First Nation (DRFN) conducted a Traditional Knowledge and Restoration Study for Boreal Caribou in the Chinchaga Range (Leech et al. 2016b). The study included: traditional knowledge derived from interviews and focus groups with DRFN knowledge-holders; and results of previous traditional use studies conducted from 2010-2015 (specific to proposed development projects) to describe cultural rules surrounding caribou hunting practices, seasonally important caribou habitat areas (e.g. movement corridors, calving grounds, rutting areas, and wintering sites), and observed impacts to important caribou habitat areas.

In 2010-2011, the Métis Nation of British Columbia (MNBC) and Environment Canada (Canadian Wildlife Service) collaborated on a project to collect Métis Traditional Knowledge (MTK) on Boreal Caribou populations in northeastern BC as part of a larger Environment Canada initiative to develop a Recovery Plan for Boreal Caribou populations. The MNBC Boreal Caribou Traditional Knowledge Project entailed identifying traditional knowledge holders, conducting interviews, and compiling data for entry into the MNBC Species at Risk database (Métis Nation British Columbia 2011).

In addition to TEK studies, a pilot project was conducted by the Prophet River First Nations, in cooperation with Wildlife Infometrics Inc., to test the effectiveness of using traditional hunting and trapping methods to reduce wolf (*Canis lupus*) populations within Boreal Caribou ranges (Sittler et al. 2016).

Information is also included from traditional knowledge studies from northern Alberta (Schramm et al. 2000) and the Dehcho Region of the Northwest Territories (NT; Dehcho First Nations 2011). The southern escarpment/central plateau of the Caribou Mountains in northern Alberta is important summer and winter habitat for Boreal Caribou. The area falls within the traditional lands of the Little Red River Cree Nation and Tallcree First Nation (LRR/TC; Schramm et al. 2002). There may be parallels drawn between that area and Boreal Caribou habitat along the western periphery of BC's Boreal Caribou Ranges, at the interface with BC's Northern ecotype ranges.

Traditional ecological knowledge provided in these reports is integrated into the sections below.

3 BOREAL CARIBOU DISTRIBUTION

Boreal Caribou Ranges and Core Areas were first delineated in 2004 based on information derived from an MOE aerial ungulate inventory (Backmeyer 2004), historical data, preliminary results of the Snake-Sahtaneh telemetry study (Culling et al. 2006), telemetry data and reports from Alberta and the NT, and local knowledge (Culling et al. 2004). Following compilation of this information, two reconnaissance fixed-wing flights were made in spring 2004 to verify potential Ranges by noting the presence of appropriate habitat and indications of caribou occupancy such as incised trail networks. Ducks Unlimited (DU) Earth Cover mapping, derived from Landsat TM 7 imagery (DU 2003), was used to further refine polygons based on the distribution of treed peatlands (Culling et al. 2004). Ranges were defined as broad areas of known historical or current use that supply the resources necessary to support Boreal Caribou. The intent was for Ranges to encompass adequate space to allow for periodic shifts in areas of activity due to local depletion of forage resources, disturbance, or stochastic events such as wildfire. Core Areas were defined as having high current capability and suitability based on general habitat requirements (treed peatlands, terrestrial and arboreal lichen forage base) and documented caribou occurrence. The boundaries of Ranges and Core

Areas were expected to be amended or refined based on results of future radio-telemetry studies (Culling et al. 2004).

The 2004 map identified 13 Core Areas within four major Ranges: Chinchaga, Snake-Sahtaneh, Calendar, and Milligan (Appendix 2). Two additional Core Areas, the Prophet and Parker, were delineated based on historical caribou occupancy and suitable habitat, but were not associated with a Range (Culling et al. 2004). Potential Boreal Caribou habitat centred on the Stanolind Creek area, northwest of Fort Nelson, was identified as an "area of interest, with current status unknown" (referred to as the Fort Nelson polygon). The status and boundaries of the Parker and Prophet Core Areas and Fort Nelson polygon were expected to be refined as more information became available.

BC's Range and Core Area boundaries were revised in 2010 to incorporate additional radio-telemetry and other information collected since 2004, including reclassifying the Prophet and Parker Core Areas to Ranges, and identifying an additional Core Area in the Snake-Sahtaneh Range (MOE 2010; Appendix 3).

An intensive GPS/VHF radio-telemetry study initiated in December 2012 as a component of the BCIP (*hereafter*, the BCIP telemetry study) helped to address these knowledge gaps. The BCIP study area encompassed the six established Boreal Caribou Ranges (Chinchaga, Snake-Sahtaneh, Calendar, Maxhamish, Prophet, Parker), the confirmed Core Areas delineated in 2010 (MOE 2010), and the status-pending Fort Nelson polygon (*hereafter*, the Fort Nelson Core Area). The BCIP study area also included four designated Resource Review Areas[2] (RRAs), including one each in the Chinchaga (RRA-A) and Prophet (RRA-B) Ranges, and two in the Calendar Range (RRA-C and RRA-D).

Between December 2012 and April 2016, 239 adult female caribou were fitted with a combination of GPS or VHF radio-collars as a component of the BCIP telemetry study (Culling and Culling 2013a, 2014, 2015, 2016). The collars were deployed with the objective of maintaining a sample of approximately 15% of the estimated population of the six individual Ranges. In the initial phase of the project, 164 individual Boreal Caribou

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[2]The provincial government established RRAs in June 2010 to support management of Boreal Caribou in areas within Boreal Caribou Ranges where there were no existing oil and gas, coal, mineral or placer tenures. A moratorium on new oil and gas tenures was implemented in the RRAs for a minimum of five years. The effectiveness of RRAs was scheduled to be reviewed after five years based on performance measures related to caribou population and range conditions (Cichowski *et al*. 2012).

were radio-collared between December 2012 and April 2013, with additional radio-collars deployed in subsequent winters to maintain the sample of active collars. Collars were deployed throughout all Core Areas to provide a balanced distribution to support associated late winter calf recruitment surveys. Emphasis was also placed on deploying collars in areas where little or no existing caribou use data were available, including the Shekelie watershed, which lies outside the area of current distribution.

As of December 2016, the BCIP telemetry study had collected over 170,000 GPS locations, which have contributed to a greater understanding of Boreal Caribou distribution within the province, and to supporting a variety of associated research projects. In February 2015, BCIP telemetry study results were used to refine the 2010 version of the Boreal Caribou Range and Core Area map. Updates to existing Core Areas included adjusting the boundaries of the Prophet Range polygon to better reflect caribou use, delineating a new Core Area in the northern portion of the Chinchaga Range (Chinchaga North), and formalizing the Fort Nelson polygon as the Fort Nelson Core Area (Wilson 2014, MFLNRO 2015). Updates to existing Ranges included: closing the gap between the adjacent Snake-Sahtaneh and Maxhamish Ranges; adjusting the southeast corner of the Calendar Range to align with the southwestern boundary of Alberta's Bistcho Range; incorporating the Parker, revised Prophet, and new Fort Nelson Core Area into one Range (Westside Range); and amalgamating the three original Core Areas surrounding Kotcho Lake into one large polygon (Kotcho Core Area). The 2015 boundary revisions, which were designed to follow existing landscape unit boundaries and capture matrix habitat, encompassed 91% and 99% of all telemetry points collected to the end of December 2014, for Core Areas and Ranges respectively (Wilson 2014, MFLNRO 2015; Figure 1).

Information from DRFN knowledge-holders suggests Boreal Caribou were formerly abundant to the north and east of the current DRFN Reserve, and likely ranged further south and west compared to their current distribution (Leech et al. 2016b). Recent recommendations from the DRFN TEK study include extending the southern boundary of the Chinchaga Range to include observed habitat areas just south of the DRFN Reserve.

Two of BC’s Boreal Caribou Ranges are contiguous with ranges in Alberta and the NT. The Chinchaga Range in BC is contiguous with Alberta’s Chinchaga Range. Environment Canada (2012) classifies both the Alberta and BC Chinchaga Ranges as one entity (AB1 Chinchaga). BC's Calendar Range is contiguous with northern Alberta’s Bistcho Range and with Boreal Caribou habitat in the Dehcho area of the southern NT.

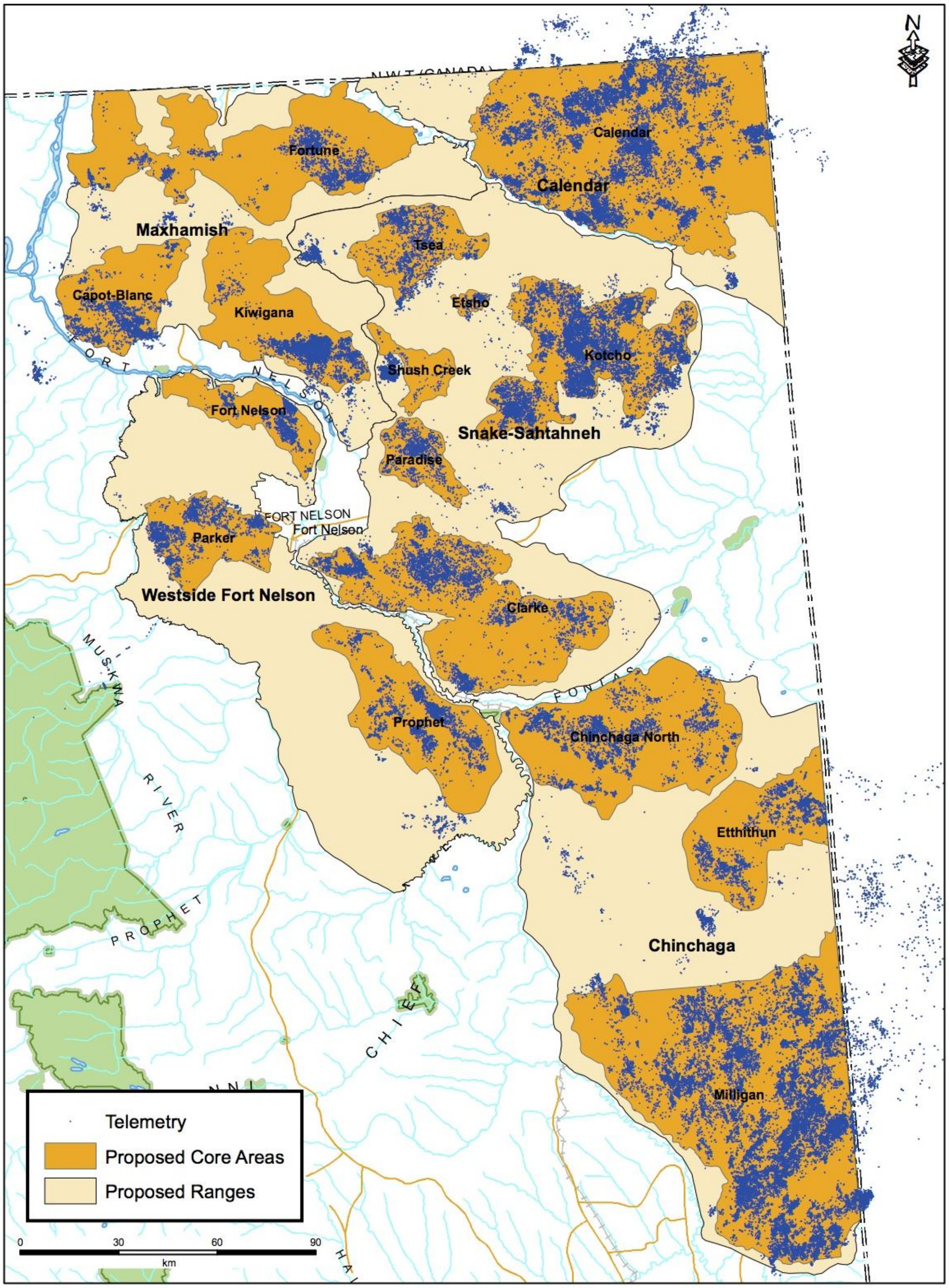

Figure 1. Proposed 2015 revisions to BC's Boreal Caribou Range and Core Area map showing radio-telemetry data to December 2014 (MFLNRO 2015).

Radio-telemetry and survey data collected in the past decade reveal that Boreal Caribou commonly move between the Calendar Range and these adjacent Ranges (Culling and Culling 2014, 2015, 2016, 2017; Johnson 2007; Larter and Allaire 2010, 2012). However, Environment Canada (2012) currently lists the Calendar population (BC2 Calendar) as distinct from the adjacent Alberta (AB2 - Bistcho) and NT (NT1) Ranges.

The BCIP telemetry study, coupled with previous telemetry projects within BC and adjacent jurisdictions and TEK studies, have provided a solid baseline of current Boreal Caribou distribution in northeastern BC. Continued collection of GPS telemetry data from the remaining active BCIP collars will augment this data set and contribute to further understanding of caribou movements, including:

- the extent of movement of individual caribou at the interface of Boreal and Northern ecotype Ranges:
  - Leech et al. (2016b) report traditional knowledge from the DRFN that suggests Boreal Caribou may have mixed during the winter with Northern ecotype caribou from the Pink Mountain area.
  - One adult female from the BCIP telemetry study made multiple calving season movements between the Parker (Boreal) and Muskwa (Northern) Ranges (Watters and DeMars 2016).
  - In the NT, Dehcho First Nations (2011) note that there is some interaction between the Boreal Caribou that inhabit the foothills and river valleys along the eastern edge of the Mackenzie Mountains and caribou that are resident in the mountains.
  - During the BCIP telemetry study, multiple attempts were made to deploy radio-collars within the area of suitable habitat encompassed by the original (2004) Prophet Core Area boundaries. While no caribou were located, evidence of limited caribou activity (e.g., older tracks and cratering from earlier in the winter) was found (D. Culling, pers. observ.). Local knowledge indicates caribou were routinely seen along the stretch of the Alaska Highway adjacent to the western edge of the 2004 Prophet Core Area boundary in the past. Métis Traditional Knowledge holders identified several areas where they believed caribou-vehicle collisions occurred with relative frequency, including in the vicinity of Prophet River (±50 km) and Buckinghorse (Métis Nation British Columbia 2011). However, the general consensus appears to be that caribou sightings in this area are far less common in recent years. Caribou activity in the 2004 Prophet Core Area boundary may be the result of Muskwa (Northern ecotype) animals making seasonal use of the area. The recent deployment of radio-collars on caribou in the Muskwa population may provide information that helps to address this question.

- the extent of movement of individual caribou between Ranges and jurisdictions:
  - Results of recent telemetry studies have revealed occasional movement of individuals between adjacent Ranges, including Calendar, Maxhamish and the Snake-Sahtaneh. Potential inter-Range movements that are not yet well-defined include between: a) the Chinchaga North (Chinchaga RRA) and Clarke Core Areas; b) the Prophet Range and the Chinchaga North Core Area, and c) within the Chinchaga Range (i.e., Milligan/Etthithun and the Chinchaga North Core Areas).
  - Telemetry studies conducted in the past decade are leading to a greater understanding of the transborder nature of Boreal Caribou within BC's Calendar Range (Culling and Culling 2014, 2015, 2016, 2017; Johnson 2007; Larter and Allaire 2010, 2012), and movement between Boreal Caribou Ranges within BC. During the March 2014 survey, Culling and Culling (2014) located 8 of 23 caribou originally radio-collared in BC's Calendar Range in the NT, including one animal that made multiple movements between Calendar and Trainor Lake, approximately 60 km north of the BC/NT border. In the March 2016 survey, nine of 20 Boreal Caribou collared in the Calendar Range between 2012 and 2016 were located in nine different groups in the NT (Culling and Culling 2016). Culling and Culling (2016) describe the locations of these individuals during previous years, including two caribou that were located in separate groups in the BC and Alberta portions of the upper Shekelie River drainage, respectively, in March 2015 (Culling and Culling 2015).

3.1 Knowledge gaps

The existing BCIP telemetry study and radio-collared caribou studies in surrounding areas are currently addressing transboundary Boreal Caribou Ranges, and potential overlaps between Boreal and Northern ecotypes.

A remaining knowledge gap with respect to Boreal Caribou distribution in BC concerns the adult male component of the population. Deploying GPS radio-collars on a sample of mature males would provide a more complete understanding of the extent of movement of adult males and the genetic connectivity between and within both BC Ranges and adjacent jurisdictions. Collecting GPS telemetry data on mature males would also provide information on potential travel corridors within and between Ranges.

4 BOREAL CARIBOU DEMOGRAPHICS

4.1 Historic population size and trend

In a review of caribou sightings in BC, Spalding (2000) found only three references to caribou in northeastern BC (in 1910, 1915, and 1925) and concluded that recorded historical sightings were insufficient to describe any changes in distribution or abundance.

Recently summarized traditional ecological knowledge indicates that BC's Boreal Caribou population has declined from historic levels (Métis Nation British Columbia 2011, Leech et al. 2016b). Leech et al. (2016b) describes the period between 1899 and 1950 as the beginning of great change in and adjacent to the area currently defined as the Chinchaga Range, including the arrival of the first agricultural settlers in the early 1900s, road building, and the first oil and gas exploration in the1920s. Between 1950 and 1990 there was continued expansion of agriculture[3], forest harvesting, and oil and gas exploration and development. DRFN knowledge-holders reported range contractions and decreases in caribou numbers in the Peejay, Milligan Creek, and Nancy Creek areas as early as the late 1970s, with many knowledge-holders having observed noticeable declines by the 1990s (Leech et al. 2016b). Results of interviews with 10 Métis Traditional Knowledge-holders, representing over 300 combined years of traditional knowledge and experience on the land in northeastern BC, support caribou population declines from historic levels (Métis Nation British Columbia 2011).

4.2 Current population size

During the original Range-delineation process in 2004 (Culling et al. 2004), coarse density estimates for individual Ranges were calculated by the BC Ministry of Water, Land and Air Protection (MWLAP) based on results of a 2004 winter ungulate inventory of Management Units (MU) 7-55 and 7-56 (Backmeyer 2004). A lower density limit was estimated using an overall average density of 3.1 caribou/100 km² (80% Confidence Interval [CI]) multiplied by the total area of all Ranges. An upper limit was calculated by applying separate overall density estimates to Core Areas (8.64 caribou/100 km²) and to matrix habitat (0.44 caribou/100 km²) within Ranges. Population estimates represented the average of upper and lower limits for each Range. The total population estimate for Boreal

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[3] While agricultural development may not have directly alienated high capability Boreal Caribou peatland habitat, indirect effects may have resulted from shifts in predator and prey populations, and habitat fragmentation.

Caribou in BC in 2004 using this method ranged from 1,201 to 1,823 animals with a midpoint of 1,512 (Table 1).

Table 1. Comparison of recent (2004-2016) population estimates of Boreal Caribou Ranges in BC.

Range ID[1]	**Population Estimate**			**Minimum Count 2013-2016 Recruitment Surveys**[4]			
	2004[2]	**MOE 2010**[3]	**EC 2012**[1]	**2013**	**2014**	**2015**	**2016**
BC1 (Maxhamish)	220-392 (306)	300	300	132	102	81	100
BC2 (Calendar)	154-429 (291)	290	290	135	79[5]	81[4]	107[4]
BC3 (Snake-Sahtaneh)	359-371 (365)	360	360	321	241	258	280
BC4 Parker	7-19 (13)	25	40-60	59	40	39	24
BC5 Prophet	28-79 (54)	54	50-100	35	37	21	16
BC Portion of Chinchaga (*formerly*, BC Chinchaga #1)[6]	433-533 (483)	250	n/a	256	214	189	194
AB1 Chinchaga (incl. BC portion)[7]	n/a	n/a	250	n/a	n/a	n/a	n/a
Fort Nelson Core Area[8]	n/a	n/a	n/a	14	10	9	7
Total All Ranges	1201-1823 (1512)	1279	1290-1360	952	723	678	728

[1] Range IDs and 2012 population estimate from Environment Canada (2012).

[2] Population estimates calculated by Ministry of Water, Land and Air Protection based on 2004 late winter ungulate inventory for MU 7-55 and MU7-56 (Backmeyer 2004).

[3] Population estimates from Ministry of Environment unpublished data (2008) except BC Parker Range estimate, which is from Thiessen (2009).

[4] From Culling and Culling 2013, 2014, 2015, 2016; minimum count represents the number of caribou observed during annual late winter (March) calf recruitment surveys of all groups containing collared female caribou, as well as uncollared groups incidentally observed.

[5] All groups located with caribou originally collared in the Calendar Range, including 8, 3, and 9 groups located north of the BC/NT border in 2014, 2015, and 2016, respectively.

[6] Portion of Chinchaga Range within British Columbia, previously referred to as "BC Chinchaga (#1) (Environment Canada 2008).

[7] Environment Canada (2012) currently defines the Chinchaga Range as "AB1 (includes BC portion)"as a transboundary Range that extends across the BC/AB provincial border.

[8] The "Fort Nelson Core Area" was initially identified as an "area of interest, but with current status unknown" pending more information (Culling et al. 2004). Preliminary results from the BCIP telemetry study supported its inclusion as a Core Area during the 2015 revision of Range and Core Area boundaries.

In 2010, BC's Boreal Caribou population was estimated at approximately 1,300 animals (MOE 2010), which incorporated results of more recent surveys (Rowe 2006, Thiessen 2009). MOE population estimates included only the BC portion of the Chinchaga Range. Environment Canada's 2012 estimate was largely based on MOE's 2010 estimate.

As a component of the BCIP telemetry study, annual late winter recruitment surveys conducted in March 2013 through 2016 provide the most recent minimum counts of BC's Boreal Caribou population (Culling and Culling 2013a, 2014, 2015, 2016). The highest number of caribou observed was 952 in 2013, with counts ranging from 678 to 728 between 2014 and 2016. Minimum counts derived from these surveys of radio-collared adult females do not represent population estimates as they do not accurately depict the proportion of adult males or the overall number of caribou. Observations of adult males were limited to those in groups containing one or more radio-collared females, or incidentally observed groups.

As noted in Section 3 (Boreal Caribou distribution), the transborder nature of Boreal Caribou within BC's Calendar Range, and movements between Boreal Caribou Ranges within BC, further confound estimating population size or comparing results over time.

4.3 Productivity, calf survival and recruitment

Two projects have evaluated calf production, survival, and recruitment of Boreal Caribou in northeastern BC since 2010. The BCIP telemetry study assessed calf production and survival between December 2012 and March 2016 (and is ongoing), based on pregnancy testing of captured female caribou, annual March calf recruitment surveys, and a fall calf survival survey conducted in November 2013 (Culling and Culling 2013a,b, 2014, 2015, 2016). DeMars and Boutin (2014) tracked calf survival to 4 weeks of age between 2011 and 2013, developed a method for predicting parturition and timing of calf mortality based on adult female caribou movement patterns, and assessed spatial factors affecting predation risk to Boreal Caribou calves.

Accurately estimating parturition and neonate survival rates is important to understanding ungulate population dynamics (DeMars et al. 2013). Precise identification of calving sites lays the foundation for describing both site-specific and landscape-level habitat requirements of parturient females, and ultimately supports management. Appendix 4 summarizes methods developed by DeMars et al. (2013) and Nagy (2011) for estimating parturition dates and survival.

Based on 252 adult female Boreal Caribou with conclusive serum progesterone level results from December 2012 to March 2016, the overall pregnancy rate for the BCIP telemetry study was 89% (Table 2, Culling and Culling 2016), which was lower than the pregnancy rate of 96% reported for the 2000-2004 Snake-Sahtaneh study (n=45; Culling et al. 2006). Pregnancy rates during the BCIP telemetry study ranged from 85% in 2013 to 100% in 2016 (Table 2). The low overall pregnancy rate was influenced by the bulk of the sample being collected during the harsh winter of 2012/13 (62% of the total sampled). Overall pregnancy rate from 2014 to 2016 was 95%. Pregnancy rates of female Boreal Caribou have typically ranged above 90% (Dzus 2001, Culling et al. 2006, Nagy 2011). However, a pregnancy rate of 82% was recently reported in the South Slave Region, NT (Kelly and Cox 2013), and of 77-80% for a subsample of females in northeastern BC (DeMars and Boutin 2014; Table 2). Poor body condition of adult females may result in reduced reproductive performance (Bergerud 1996), with factors such as timing of ovulation, pregnancy rates, age at first breeding, calf survival and juvenile growth, directly or indirectly influenced by nutritional condition (Cook and Cook 2015). Preliminary results from an ongoing study on Boreal Caribou body condition indicate that Boreal Caribou females that raised a calf the previous summer generally had lower ingesta-free body fat (IFBF), and that pregnancy among individuals was positively related to IFBF (Cook and Cook 2015; see Section 5: Boreal Caribou health and condition).

Table 2. Percent of adult female caribou pregnant based on serum progesterone levels for Boreal Caribou in northeastern BC from 2011 to 2015 [(N)= sample size].

	2011	**2012**	**2013**	**2014**	**2015**	**2016**
Calf survival study[1]	80 (25)	-	77 (30)	n/a	n/a	n/a
BCIP[2]	n/a	n/a	85 (155)[3]	90 (40)	97 (36)	100 (21)

[1] From DeMars and Boutin (2014)
[2] From Culling and Culling (2014, 2015, 2016) and BCIP unpublished data
[3] Pregnancy status of 9 of 164 adult females captured was unknown or inconclusive

Recent information from the Dehcho region of the southwestern NT is shedding light on the longevity and lifetime productivity of female Boreal Caribou (Larter and Allaire 2016). One caribou was determined to be 22 years old at the time of death, with an additional six animals aged between 13–17 years old. This was only the second of over 42,000 caribou teeth aged at the commercial laboratory found to have reached 22 years. All but one of those seven female caribou had calved at least once during the period they were radio-collared and monitored. The oldest caribou, which had been monitored for 27 months before her death, successfully produced a calf at age 20 and 21 years. Her 2013 calf did not survive to the following March, but she did successfully raise her 2014 calf to 10 months. Larter and Allaire (2016) suggest that this apparent high lifetime productivity of Dehcho caribou may result in greater population-level resilience to disturbance and change.

In 2011 and 2012, peak of calving in northeastern BC was estimated at May 15 (DeMars and Boutin 2014), consistent with findings from earlier studies in the Snake-Sahtaneh (Culling et al. 2006; peak May 14 [n=66]) and Chinchaga (Rowe 2007; peak May 14 [n=7]), but was one week later on May 22 in 2013 (Table 3, DeMars and Boutin 2014). Severe late winter conditions in 2012/2013 likely contributed to the delay in the peak of calving that year (DeMars and Boutin 2014). Consistency in calving dates among individual caribou has also been documented in NT. In the Dehcho area, of 13 females that each calved for four consecutive years, two had three of four calves born on the same date and another two had all of their calves born within a three-day period each year (Larter and Allaire 2013).

Table 3. Calf survival from parturition to four weeks for Boreal Caribou in northeastern BC from 2011 to 2013 (from DeMars and Boutin 2014).

	2011	**2012**	**2013**
Pregnancy rate based on progesterone (%)	80 (25)[1]	-	77 (30)[1]
Predicted parturition rate (%)	80	74	60-77
Calves/100 cows at 4 weeks	52[2]	26	27
Calf survival rate to 4 weeks (% of calves born)	65	35	35-44
Calving date (mean)	May 15	May 13	May 22
Calving date (range)	Apr 29 – Jun 1	Apr 22 – Jun 21	May 9 – Jun 15

[1] (N) = number of adult female caribou
[2] 28 calves/100 cows at 6 weeks

In northeastern BC, calf survival was less than 30 calves/100 cows by four weeks after parturition in 2012 and 2013, and by six weeks after parturition in 2011 (Table 3, DeMars and Boutin 2014). A similar pattern was observed during the Snake-Sahtaneh study in 2004, where 41 calves/100 cows and 29 calves/100 cows were observed four weeks and six weeks, respectively, following the peak of calving (Culling et al. 2006). Culling et al. (2006) observed that the period of highest calf mortality on the Snake-Sahtaneh Range occurred between seven and 21 days of age, and that calf survival continued to decline from mid-summer through mid-winter. By March (i.e., 10 months after parturition), calf survival ranged between 12 and 21 calves/100 cows from 2013 to 2016 (Table 4, Culling and Culling 2016). This was higher than that observed during the earlier Snake-Sahtaneh study, which was 5 and 9 calves/100 cows for March 2003 and 2004, respectively (Culling et al. 2006, Appendix 5).

Table 4. Comparison of annual calf recruitment to 10 months (calves/100 cows) in all Boreal Caribou Ranges based on March 2013 through March 2016 late winter BCIP surveys, northeastern BC (from Culling and Culling 2016).

Range	Recruitment to 10 Months (calves/100 cows)			
	March 2013	March 2014	March 2015	March 2016
Chinchaga[1]	14 (189)[2]	10 (166)	9 (142)	18 (150)
Snake-Sahtaneh	24 (190)	11 (177)	18 (157)	18 (196)
Calendar[3]	35 (78)	13 (60)	22 (55)	26 (72)
Maxhamish	28 (79)	10 (80)	21 (47)	29 (58)
Prophet	19 (26)	10 (29)	0 (21)	15 (13)
Parker	4 (45)	32 (25)	8 (25)	15(20)
Fort Nelson	0 (10)	0 (9)	n/a[4]	n/a[4]
Annual Recruitment - All Ranges	21 (617)	12 (546)	15 (447)	20 (509)

[1] Including the Milligan and Etthithun Core Areas and the Chinchaga Resource Review Area (RRA).
[2] (N) = number of adult females
[3] All groups with BCIP-collared caribou (including groups located in NT or AB).
[4] Ranges with less than 10 caribou in total observed excluded.

A BCIP telemetry study fall calf survey was conducted in November 2013 to determine the portion of radio-collared females with a calf at the onset of winter 2013-14, following the particularly harsh winter the previous year. Recruitment to six months in all Boreal Caribou Ranges combined was 14 calves/100 females (Culling and Culling 2013b).

Based on resource selection function (RSF) models, DeMars and Boutin (2014) found Boreal Caribou neonate survival was best explained by predation risk from black bears (*Ursus americanus*), however, actual causes of calf mortality were not investigated. Black bears contribute significant predation pressure on Boreal Caribou populations in Québec (Pinard et al. 2012). DeMars and Boutin (2014) suggest further investigation is required on the role of bear predation on calf survival in Boreal Caribou population declines. While no formal studies on causes of calf mortality have been conducted in BC's Boreal Caribou Ranges, Culling et al. (2006) reported evidence of wolves preying on caribou calves.

In comparing factors influencing survival to six months of 1,241 radio-collared caribou calves in Newfoundland over three decades (1979-2012), Mahoney et al. (2015) found daily survival rates varied between phases of population growth and decline. Predation was the dominant source of mortality throughout, but the mean percentage of calves killed by predators was 30% higher during the decline compared to the growth phase. During the population growth phase, the major predators were black bears and lynx (*Lynx canadensis*), shifting to black bears and coyotes (*Canis latrans*) during the decline.

The relationship between low birth weight and neonate mortality has been documented among *Rangifer* populations (Boertje et al. 1996, Bergerud et al. 2008, Nieminen et al. 2013), with smaller calves more vulnerable to predation.

4.4 Boreal Caribou adult survival

During the BCIP telemetry study, the standardized annual finite survival rate for adult females in all BC's Boreal Caribou Ranges combined varied from 0.73 ± 0.03 SE between May 2013 and April 2014, following the unusually long, harsh winter of 2012/2013, to 0.87 ± 0.03 SE between May 2015 and April 2016 (Table 5, Culling and Culling 2016). The standardized annual adult survival for 57 females during the 58-month Snake-Sahtaneh study was estimated at 0.94 (95% CI: 0.89 to 0.99; Culling et al. 2006). In comparison, the standardized annual survival for 82 Snake-Sahtaneh adult female caribou monitored between January 2013 and April 30, 2016 was 0.84 (95% CI: 0.78 to 0.89; BCIP telemetry study, unpubl. data). The standardized annual survival of adult female caribou for both the Snake-Sahtaneh Range, and all BC Boreal Caribou from 2013 to 2016 was lower than during the Snake-Sahtaneh study from 2000 to 2004.

Table 5. Standardized adult female survival rates of radio-collared adult female Boreal Caribou in northeastern BC from May 1, 2013 to April 30, 2016 (from Culling and Culling 2016).

Year[1]	**Number of adult female caribou**[2]	**Finite Survival rate**[3]	**95% Confidence Interval**
2013/14	209	0.73 ± 0.03 SE	0.67 – 0.80
2014/15	180	0.86 ± 0.03 SE	0.81 – 0.91
2015/16	168	0.87 ± 0.03 SE	0.84 – 0.93

[1] Period runs from May 1 to April 30
[2] Number of adult female caribou in the entire time period
[3] Finite survival rate based on the Kaplan-Meier staggered entry design

Larter and Allaire (2013) reported 79% mean adult female survival for the Dehcho region between 2005 and 2013. Animals collared in the north Dehcho (north of the Mackenzie River), where there are fewer seismic lines, and more abundant and larger patches of unburned habitat, had a somewhat higher estimated survival (82%) than those collared in the south Dehcho (78%)[4].

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[4] No confidence intervals provided.

4.4.1 Adult mortality factors

Wolves are the primary predator of Boreal Caribou across their range in Canada (Stuart-Smith et al. 1997, Rettie and Messier 1998, Schaefer et al. 1999); however, black bears have also been implicated in Boreal Caribou mortalities (Schaefer et al. 1999, Pinard et al. 2012).

Between the start of the BCIP telemetry study in December 2012 and the end of April 2016, a total of 104[5] Boreal Caribou mortalities were investigated, including 95 radio-collared animals and nine uncollared animals encountered incidentally in mid to late winter of the first year of the project (February to April 2013; Culling and Culling 2016). Thirty-seven percent of all mortalities detected occurred between March and July 2013, following an unusually hard winter in 2012/2013. Annually, the lowest number of Boreal Caribou mortalities occurred in late fall-early winter (November through January), with the highest between March and July (Figure 2; Culling and Culling 2016). A similar seasonal pattern of mortality was observed during the 2000-2004 Snake-Sahtaneh study with all five mortalities occurring between April and October (Culling et al. 2006).

The cause of adult Boreal Caribou deaths as determined from mortality site investigations conducted during the BCIP telemetry study between December 2012 and April 30, 2016, included 72 confirmed and seven suspected incidents of wolf predation, three cases of confirmed wolverine (*Gulo gulo*) predation, one accidental death, five deaths confirmed to be the result of poor condition or disease, and two animals that were shot (Culling and Culling 2016). While the cause of death for the remaining 14 animals could not be determined in the field, health and condition related factors were suspected in several cases. Four of the five caribou deaths confirmed to be due to poor condition or disease occurred in the first year of the study, including three radio-collared caribou and one incidental observation of an uncollared animal. All mortalities due to wolverine predation occurred in late winter (February – March). Wolf predation was typically highest in late winter and spring (Figure 3). During the Snake-Sahtaneh study, five mortalities were investigated with two confirmed as wolf predation, one suspected as black bear predation, and two undetermined (Culling et al. 2006).

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[5] A total of 104 Boreal Caribou mortalities were investigated between the start of BCIP monitoring in December 2012 and the end of April 2016, including 9 uncollared animals encountered incidentally in mid to late winter of the first year of the project (February to April 2013) and one caribou (BC1006) that was fitted with a VHF collar in March 2008 by MFLNRO and died on an unknown date prior to December 2012. Month of death was determined for 103 mortalities investigated (Culling and Culling 2016).

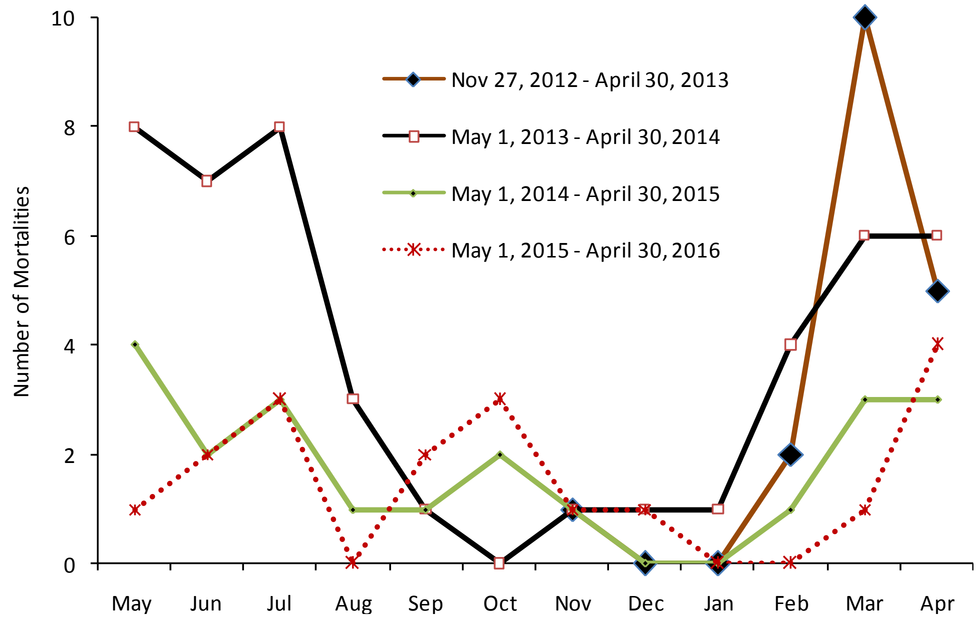

Figure 2. Incidence of adult Boreal Caribou mortalities by month, northeastern BC, November 27, 2012 to April 30, 2016 (n=103; from Culling and Culling 2016.).

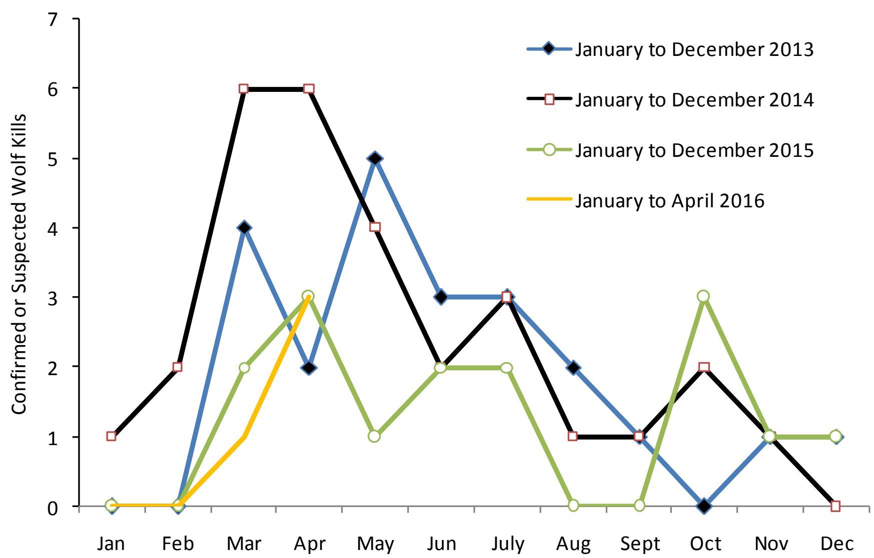

Figure 3. Incidence of adult Boreal Caribou mortalities attributed to wolves by month, northeastern BC, December 17, 2012 to April 30, 2016 (n=104; from Culling and Culling 2016).

Rapid freeze-thaw cycles witnessed throughout recent winters frequently created hard crusting conditions in mid to late winter in BC's Boreal Caribou Ranges during the BCIP telemetry study. During the March recruitment surveys, daytime temperatures frequency rose to the mid to high teens (C), then fell below freezing each night, creating conditions that could impede caribou movement but allow wolves to readily travel on top of the crust (Culling and Culling 2016).

4.4.1.1 Human-caused mortality

Humans have hunted woodland caribou for thousands of years, primarily for food and clothing, but also for other purposes (Ministry of Environment, Lands and Parks 1997; Leech et al. 2016a,b).

Leech et al. (2016b) reports that Boreal Caribou were an important and predictable food source for the DRFN in recent history, and were harvested for sustenance in the winter and spring at an average of two animals per family per year in the 1950s and 1960s. Caribou were particularly important when moose (*Alces americanus*) and other food sources were scarce.

DRFN trappers often hunted caribou in winter, which helped sustain trapping practices that were critical to many families' livelihoods. DFRN community members also used caribou for non-food purposes, including using the processed hides for bedding, moccasins, vests, gloves, and beadwork (Leech et al. 2016b).

In 2010, information on past and current harvest of Boreal Caribou was gathered from Dehcho First Nations community harvesters (Dehcho First Nations 2011). While Fort Liard is in the Dehcho Region, the community did not participate in the project. Community members from Fort Liard are believed to harvest Boreal Caribou from the Fortune Core Area (Maxhamish Range). General patterns of Boreal Caribou harvest in the Dehcho Region include:

- although Boreal Caribou continue to be harvested, there appears to be a decline in the rate of harvesting by Dehcho First Nation members throughout the Dehcho, and this decline is attributed to several factors including:
    - harvesters currently spend less time on the land than in previous generations;
    - Boreal Caribou are shy animals and sensitive to sensory disturbance, therefore the use of skidoos rather than dog teams reduces incidental contact;
    - decreased use of dog teams results in decreased need for harvested meat for dogs;

- there is reduced demand for Boreal Caribou hide, which stretches less than moose hide, for making snowshoe lacing and dog harnesses;
- most harvesters prefer moose to Boreal Caribou (moose provide more meat and are a preferred taste) so Boreal Caribou are generally harvested on an opportunistic basis while doing other land use activities, such as trapping or moose hunting; and,
- some harvesters are aware that Boreal Caribou are at risk, and therefore have cut back on their harvesting of the animals.

In the Dehcho Region, harvesting of Boreal Caribou generally takes place in the fall and winter months when the animals are moving around more, or in mid to late winter/early spring when caribou are in larger groups in more concentrated areas. This is consistent with past practice.

Results of the MTK survey indicate that while seven of 10 interviewee's traditionally harvested Boreal Caribou, only two continued to do so, with all respondents indicating they preferred to hunt moose and elk (*Cervus elaphus*; Métis Nation British Columbia 2011). Most interviewees had stopped or limited harvesting Boreal Caribou in an effort to conserve populations. The two individuals that did continue to harvest caribou stated that the animals were much harder to find now.

Boreal Caribou were closed to non-indigenous hunting in the province between 1978/79 and 1987/88, and again since 2001. It is unknown whether previous hunting pressure had an effect on the population. Thomas and Gray (2002) report that large legal harvests of caribou in the late 1960s and early 1970s in BC, Alberta, and Saskatchewan, combined with recovering wolf populations and adverse weather, appear to have caused population declines in the 1970s. The authors note that "caribou population highs in the 1960s probably were atypical and should not be considered management objectives."

Poor access prior to the advent of oil and gas development likely contributed to limited non-indigenous hunting pressure on Boreal Caribou in BC. While the extent of illegal harvest (i.e., poaching) is unknown, Environment Canada (2012) suggests that improved access into caribou range due to an expanding network of linear corridors could potentially lead to increased illegal hunting of caribou.

The two radio-collared caribou that were shot during BCIP telemetry study occurred in separate events, in September 2015 and April 2016, along the Coles Lake Road, which bisects peatland habitat in the Fortune Core Area. It is believed that in both cases the animals were legally harvested by First Nations community members of nearby Fort Liard, NT

(Culling and Culling 2016; N. Larter pers. comm.). Fort Liard harvesters access cabins at Maxhamish Lake and at Sandy Creek on the Liard River by ATV, vehicle, and snowmobile from the Maxhamish Road (D. Allaire, pers. comm.). Approximately 15 Boreal Caribou are harvested each year by the SambaaK'e Dene Band (formerly the Trout Lake Band), of the Dehcho political region (N. Larter, pers. comm.).

Less is known about mortalities due to vehicle collisions. MTK-holders identified the vicinity of Prophet River (±50 km) and Buckinghorse as areas where caribou-vehicle collisions may have occurred relatively frequently (Métis Nation British Columbia 2011).

4.5 Current population trend

Since 2010, indicators of current population trend include the Environment Canada critical habitat scientific assessment (Environment Canada 2011), caribou counted during March calf recruitment surveys (Culling and Culling 2013a, 2014, 2015, 2016), calf recruitment (Culling and Culling 2013a, 2014, 2015, 2016), and lambda (λ) based on calf recruitment and radio-collared adult female caribou survival (Culling and Culling 2014, 2015, 2016).

Environment Canada (2011) assessed the Snake-Sahtaneh and Alberta/BC Chinchaga populations as being in decline, with the status of the other BC populations unknown.

As mentioned previously, minimum counts derived from March calf recruitment surveys of radio-collared adult females do not represent population estimates. However, assuming that a comparable sample size of collared animals is relocated over time, and that survey conditions (snow cover, days since fresh snow, light) are comparable, the minimum counts can provide information on the general population trend (see Table 1). The decrease in the minimum number of caribou counted between 2013 and 2014 corresponds to lower adult female survival observed in 2013/14 following the atypically long winter of 2012/13 (see Section 4.4: Boreal Caribou adult survival) and may indicate a decline in that year. Minimum counts from 2014 to 2016 suggest that the population may have stabilized at a lower level.

Overall recruitment rate for Boreal Caribou in BC (all Ranges combined) for all four years from 2012 to 2016 (Table 6, see also Section 4.3: Productivity, calf survival and recruitment) was lower than Environment Canada's (2008) suggested minimum recruitment rate of 28.9 calves/100 cows for population stability.

Based on overall recruitment (all Ranges combined) and standardized finite adult female survival rate, the estimated annual population rate of increase, or lambda (λ), ranged from 0.78 to 0.97 (Table 6), which suggests the current overall status of BC's Boreal Caribou population is declining (Culling and Culling 2014, 2015, 2016).

Table 6. Standardized adult female survival rates of radio-collared adult female, March calf recruitment, and population rate of increase (λ) of Boreal Caribou in northeastern BC from March 2013 to April 2016 (from Culling and Culling 2014, 2015, 2016).

Year (May 1 to April 30)	Adult female survival (%)[1]	March calf recruitment (Calves/100 cows)[2]	Lambda (λ)
2012/13	n/a	21	n/a
2013/14	0.73	12	0.78
2014/15	0.87	15	0.94
2015/16	0.87	20	0.97

[1] Based on Kaplan-Meier staggered entry design survival – see Table 5
[2] March calf recruitment surveys – see Table 4

4.6 Knowledge gaps

Since 2010, considerable effort has been put into monitoring Boreal Caribou calf recruitment, adult female mortality rates, and causes of adult female mortality in BC. The BCIP telemetry study has provided valuable information on the status of Boreal Caribou populations and an understanding of how difficult winters (i.e. the winter of 2012/13) affect caribou. Continued monitoring of calf recruitment, and adult mortality rates and causes (by maintaining a sample of GPS radio-collared adult females) is needed to understand Boreal Caribou dynamics under varying and changing environmental conditions, and to continue to track population status, which currently appears to be declining.

Knowledge gaps on Boreal Caribou demographics include:

- adult male Boreal Caribou demographics (based on a sample of GPS collared mature adult male caribou); this information would aid in determining more precise minimum population counts and sex ratios during annual recruitment surveys, and genetic exchange between Ranges;
- causes of Boreal Caribou calf mortality, including the role of black bear predation on calf survival;
- the role of alternate predators, including wolverine and lynx, in Boreal Caribou adult and calf survival; and,
- the effects of climate change, including changes to snowpack, frequent mid-winter freeze/thaw cycles, and atypical winter temperature fluctuations, on Boreal Caribou productivity and predation risk.

5 BOREAL CARIBOU HEALTH AND CONDITION

Little historical information is available on the health and condition, including diseases and pathogens, of BC's Boreal Caribou population.

While viral, parasitic, and bacterial diseases can affect individual caribou and may have effects at the population level, Environment Canada (2012) suggests they do not constitute a major threat at the national level. However, Boreal Caribou populations in western Canada are generally relatively small, which increases the risk that health related factors may have serious effects at both the local (herd) and regional level (Schwantje et al. 2014). The incidence of health-related effects is expected to increase with increasing habitat loss, degradation, and fragmentation, and with the effects of climate warming (e.g. greater frequency of forest fires, periods of thermal stress for ungulates, and the northward expansion of both white-tailed deer [*Odocoileus virginianus*] and arthropod vectors of disease and other pathogens; Schwantje et al. 2014).

Disease and pathogens may contribute directly to diminished adult survival and reproductive success (e.g. abortions) or indirectly by leading to calf morbidity and an increased risk of neonatal mortality due to predation, decreased resistance to environmental stressors, or failure to thrive (Schwantje et al. 2014). Chronic disease or infestations may put individuals at greater risk of predation and reduce their ability to cope with other stressors, such as nutritional deficits, random weather events, other infections (e.g. wounds), and anthropogenic disturbances (e.g. industrial development or recreational land use).

A three-year Boreal Caribou Health Research Program (BCHRP; Schwantje et al. 2014, 2016) was initiated in the fall of 2013 to assess current health status of Boreal Caribou in BC. Samples were collected from Boreal Caribou captured during the BCIP telemetry study between December 2012 and March 2016, and from mortality site investigations of radio-collared and incidentally-encountered uncollared caribou conducted during the same period (Culling and Culling 2013a, 2014, 2015, 2016). In Year 1 of the BCHRP study, caribou samples were evaluated for exposure to, or infection with, selected bacterial, viral, and parasitic diseases. Other indices of health related to chronic physiological stress, immunity, nutrition, and toxicology were also examined.

Preliminary results identified a number of potential threats to caribou health and fitness, including:

- infection with the protozoan parasite *Neospora caninum*;
- infection with the bacterial pathogen *Erysipelothrix rhusiopathiae,* which was identified in the tissues of five caribou that died during

a period of higher than expected mortality in the spring and summer of 2013;

- significant hair loss related to infestation with winter ticks (*Dermacentor albipictus*);
- evidence of probable trace nutrient deficiencies; and,
- higher levels of cortisol (an indicator of chronic physiological stress) than in captive and free-ranging caribou and reindeer sampled in other study areas.

A summary of results to date from the BCHRP is presented in Appendix 6.

E. rhusiopathiae is a concern because it has been implicated in mortalities in other ungulates and potentially in semi-domesticated and domesticated reindeer (Schwantje et al. 2016). Samples collected during the original Snake-Sahtaneh telemetry study (Culling et al. 2006) and the 2008-2010 Nexen study, which focused on the Calendar Range and the Tsea Core Area of the Snake-Sahtaneh Range (Culling and Culling 2017), were analysed by the BCHRP to assess historic exposure to *E. rhusiopathiae*. Results revealed historical exposure in the Snake-Sahtaneh Range but not in the Calendar Range (B. Macbeth, pers. comm.).

The winter tick is a well-known ectoparasite of moose, but also infects other ungulates in northeastern BC (Wood et al. 2010). The species appears to be undergoing a northward range expansion that may be the result of climate change (Kutz et al. 2009, Vervest 2011, Kashivakura 2013, Kelly and Cox 2013). Hair loss resulting from rubbing to relieve tick-related irritation may lead to thermal stress and increased metabolic demand, particularly during extended periods of cold weather in late winter. Time and energy spent grooming over foraging may potentially affect Boreal Caribou condition. Also, winter ticks can carry and likely transmit microorganisms (e.g. *Anaplasma* sp.) that have the potential to cause severe/fatal disease in cervids (Schwantje et al. 2016). Based on over 15 years of capturing and handling Boreal Caribou in northeastern BC and the Dehcho and South Slave regions of the NT, increased incidence of mild to extreme hair loss has been observed on caribou (D./B. Culling, pers. observ.). Although greater effort has been made to search for evidence of winter tick infestations in recent years, increasingly common observations of tick larvae, nymphs, and adults are believed to reflect an actual increase in infestations rather than a result of increased search effort. In 262 individual capture events of Boreal Caribou in northeastern BC between 2012 and 2016, 207 (79%) animals had some degree of hair loss or breakage, 36 of which showed extensive areas of hair loss/breakage with areas of exposed skin (Culling and Culling 2016).

While Chronic Wasting Disease (CWD) and meningeal worm (*Parelaphostrongylus tenuis*) are not currently present in Boreal Caribou in northeastern BC, both are potential future threats. Recent studies have found that increased summer precipitation is a factor in increased prevalence of meningeal worm in white-tailed deer (Jacques et al. 2015, Maskey et al. 2015). Range expansion of white-tailed deer, coupled with warmer winters and wetter summers (Spittlehouse 2008) and the presence of an appropriate intermediate gastropod host, could result in the meningeal worm becoming a potential pathogen in BC's Boreal Caribou Ranges over the long term.

The BCHRP is further examining factors that may directly and indirectly affect the health status, including survival and reproduction, of Boreal Caribou in BC (Bondo et al. in prep). Current research goals include:

- investigating caribou health temporally and spatially on a landscape level;
- investigating whether caribou health is associated with a variety of abiotic and biotic factors; and,
- evaluating whether hair cortisol concentration, haptoglobin, and serum amyloid A can be used as physiological bio-indicators of caribou health.

Recommendations from Schwantje et al. (2016) include:

- continued monitoring for *E. rhusiopathiae, N. caninum*, and winter tick in at least some herds;
- continued biological sampling of caribou captured or found dead; and,
- monitoring of key caribou pathogens (e.g. *E. rhusiopathiae*) in moose and other significant species that inhabit Boreal Caribou Ranges, including community-based monitoring programs for harvested species.

Cook and Cook (2015) suggest that adult female nutrition in summer and early autumn may strongly influence breeding probability and timing (particularly of lactating females), recovery of maternal energy reserves, and overwinter body fat levels, which ultimately affect the likely probability of adult female survival. As well, maternal nutrition affects calf growth and development.

In the winters of 2012 through 2015[6], researchers from the National Council for Air and Stream Improvement (NCASI) used a combination of ultrasound measures of rump fat and body condition score (BCS) to estimate body fat (expressed as a percent of ingesta-free body fat [IFBF]) and nutritional condition of caribou in northeastern BC and the southern

[6] Data collection is ongoing, with additional Boreal Caribou sampled in BC and the NT in February 2016 and in the NT in December 2016 and February 2017.

NT (Cook and Cook 2015). The caribou, which were sampled in conjunction with radio-collar deployment, included BC Boreal Caribou captured as part of the BCIP telemetry study, Boreal Caribou in the Dehcho and South Slave regions of the NT, and Northern Caribou from the South Peace region on BC.

Cook and Cook (2015) found marked variation in levels of IFBF both among and within herds. Among Boreal Caribou herds, IFBF increased on a west to east gradient and was strongly related to longitude. Body fat levels were moderate in BC Boreal Caribou (7.6% IFBF; 66% with measurable rump fat) and higher in animals from the NT (9.7%; 90% with measurable rump fat). Northern Caribou had the lowest IFBF levels (5.8%) with only 25% of animals having measurable rump fat. Cook and Cook (2015) suggest the observed longitudinal correlation could be associated with factors such as anthropogenic activity, predation pressure, or underlying ecological influences on forage quality and quantity.

Results from body condition data collected in early winter (mid-December) suggest that mid-winter (late January through February) IFBF levels are largely determined by body fat levels acquired the previous summer through mid-autumn. Preliminary results from this analysis indicate: Boreal Caribou females that raised a calf the previous summer generally had lower IFBF; pregnancy among individuals was positively related to IFBF; and IFBF levels in late winter were similar to those in mid-December, which suggests that much of the variation in IFBF was set by conditions caribou experienced in the previous summer and autumn (Cook et al. 2016).

The NCASI study is also evaluating relative influences of summer versus winter environmental conditions on body condition of caribou in southern NT. A repeated sampling protocol on individual caribou captured first in early winter (December 2016) and then again in late winter/early spring (February and March 2017) is being used to evaluate the separate influences of environmental conditions in summer versus those in winter on levels of body condition.

Schwantje et al. (2014) notes that much can be learned about the health status of caribou populations, including uncollared adult females, adult males, and calves, through non-invasive, community-based sampling techniques, such as fecal sample collection. Fecal surveys can provide data on the sex, age class, reproductive status, genetic background, diet, and stress levels of individual caribou as well as the structure, size, and trends of caribou herds (Hettinga et al. 2012).

5.1 Knowledge gaps

Since 2012, the REMB has supported a number of projects that have provided valuable information on the health status of BC's Boreal Caribou population, including the BCIP telemetry study, the BCHRP, and research on caribou nutritional condition by NCASI. Ongoing BCHRP research to investigate temporal and spatial factors that affect caribou health on a landscape level and abiotic and biotic factors that affect caribou health will further support BC's Boreal Caribou recovery efforts. Deploying GPS radio-collars on a sample of mature males would support the collection of additional information on caribou health, including the potential for the transfer of disease and parasites between Ranges and populations. Employing non-invasive, community-based sampling techniques, such as fecal surveys, would provide an additional spatial component to the assessment of disease and parasites of BC's Boreal Caribou.

Broad knowledge gaps associated with Boreal Caribou health in BC are currently being addressed and include:

- how does the loss, degradation, and fragmentation of habitat affect the incidence of health-related effects on Boreal Caribou;
- how will climate change affect the health of Boreal Caribou, including:
    - potential physiological stress; and,
    - the northward expansion of species, such as white-tailed deer and winter ticks, that may contribute to apparent competition and the transmission of diseases and pathogens;
- whether ungulate and predator species present in Boreal Caribou Ranges are potential vectors of pathogens that could ultimately threaten Boreal Caribou; and,
- whether the observed correlation between longitude and IFBF reported by Cook and Cook (2015) is associated with factors such as anthropogenic activity, predation pressure, or underlying ecological influences on forage quality and quantity.

6 BOREAL CARIBOU HABITAT USE

6.1 Seasonal movements and range fidelity

BC's Boreal Caribou generally occupy overlapping seasonal ranges and do not undertake predictable spring and fall migrations between discrete winter and summer ranges. However, some individuals have been found to display sporadic migratory behaviour (BCIP telemetry study unpubl. data; Culling and Culling 2014, 2016; Watters and DeMars 2016). Females display fidelity to general calving areas (i.e., areas used by females with neonate calves), however, the behaviour varies both among animals and between consecutive years for individuals (Culling et al. 2006, Rowe 2007, DeMars et al. 2011, DeMars and Boutin 2014, Culling and Culling 2017). Pregnant females make pre-calving movements of varying lengths in early April to mid May (Culling et al. 2006, Rowe 2007, DeMars et al. 2011, Culling and Culling 2017), including movements up to 120 km in the Snake-Sahtaneh Range (Culling et al. 2006) and 85 km in the Maxhamish Range (DeMars et al. 2011). These findings are consistent with information from BRFN and DRFN knowledge holders (Leech et al 2016a,b), and from research in the NT (Nagy 2011, Kelly and Cox 2013, Larter and Allaire 2016). DRFN knowledge-holders emphasized that while Boreal Caribou may be considered non-migratory, both seasonal and daily movements for caribou can be large, and habitat areas identified by DRFN knowledge-holders must remain connected (Leech et al. 2016b).

Snake-Sahtaneh caribou showed strong calving fidelity to individual Core Areas; caribou with multi-year GPS data sets made pre-calving movements of up to 90 km to return to a previous general location within a maternal core. One female wintered in Clarke Core Area and travelled to the Paradise Core Area to calve for five consecutive years (Culling et al. 2006).

Culling et al. (2006) found individual Snake-Sahtaneh caribou also made sporadic, irregular movements, including one female that made a 74-km loop through the West Kotcho and Paradise Core Areas, returning to within 700 m of her starting point in four days. While the reason for such movements is unknown, they may be in response to an immediate predation threat. Other atypical movements appeared to be associated with accessing seasonally available resources. One Snake-Sahtaneh female made an early December movement from her typical area of activity to the shoreline of Kotcho Lake, where she remained for roughly three weeks before returning (Culling et al. 2006). Based on field observations during the study, it was suspected she may have been foraging on wintergreen vascular plants on the lake margin.

Home ranges were relatively stable between years in the Snake-Sahtaneh Range based on seven females with multi-annual data sets (Culling et al. 2006). In Québec, Faille et al. (2010) found home-range fidelity varied between seasons, with forest-dwelling caribou displaying higher fidelity during calving and summer, and lower fidelity during winter. Caribou displayed reduced fidelity following disturbances, with anthropogenic changes (primarily forest harvesting) producing stronger negative responses than natural ones. However, despite this negative influence on fidelity, caribou tended to demonstrate range fidelity even in study sites most highly impacted by human activities. Faille et al. (2010) suggest that reduced home-range fidelity in female caribou could result in lower survival for both the female and her calf due to reduced familiarity with food distribution, escape cover, and predation risk. Conversely, females that maintain range fidelity even in a dramatically modified landscape could risk falling into an ecological trap.

Boreal Caribou group size varies throughout the year, but typically includes less than 10 adults (Culling et al. 2006; BCIP telemetry study unpubl. data). During calving and summer, caribou space out across the landscape, with females typically found alone or with their neonate calf. Group size increases through the late summer and fall, prior to the rut. The largest groups are found in mid to late winter, when caribou are in fluid aggregations with low group fidelity (Culling et al. 2006; BCIP telemetry study unpubl. data).

6.2 Seasonal activity periods

Data from GPS or ARGOS satellite collars has been used to identify seasonal activity periods based on changes in movement rates of individual radio-collared Boreal Caribou in the Snake-Sahtaneh Range (Culling et al. 2006), the southern NT (Nagy 2011), and the Alberta portion of the combined AB-BC Chinchaga Range (MacNearney et al. 2016). The number of activity periods varied from four broad seasons identified based on weekly movement rates of Snake-Sahtaneh caribou (Culling et al. 2006) to eight activity periods for Boreal Caribou in the Dehcho-North, Dehcho-South, South Slave, and Cameron Hills sub-populations (*hereafter*, NT Boreal Southern sub-population; Nagy 2011). Despite varying methods and inter-location intervals, broad activity periods were fairly comparable (Table 7). Accurately identifying biologically significant seasonal activity periods based on changes in caribou movement rates will better inform future management guidelines.

6.3 Seasonal habitat use

The distribution of Boreal Caribou in Canada spans seven ecozones and numerous ecoregions, with caribou displaying variable local adaptations to a wide variety of ecological conditions (Environment Canada 2011). Within BC, Boreal Caribou distribution falls within the Boreal Plains and Taiga Plains ecozones (which correspond to the Boreal Plains and Taiga Plains ecoprovinces); three ecoregions (Central Alberta Upland, Hay River Lowland, and Northern Alberta Upland), and six ecosections (Clear Hills, Fort Nelson Lowland, Etsho Plateau, Petitot Plain, Trout Lake Plain, and Maxhamish Upland; Figure 4).

The Chinchaga Range lies mostly in the Clear Hills ecosection of the Boreal Plains ecozone. All other Ranges lie within the Taiga Plains ecozone, which is characterized by large lowland areas to the east that

Table 7. Comparison of seasonal activity periods defined by recent studies based on changes in movement rates of radio-collared Boreal Caribou.

Seasonal Period	**Snake-Sahtaneh**	**AB Chinchaga**[2]	**NT Boreal Southern Subpopulation**[1]
Spring	Apr 9 - Sep 16 (Spring/Late Summer)	Apr 9 – Apr 24	Apr 5 - Jun 6 (Pre-to Post-calving)
Summer		Jul 2 – Sep 24	Jun 7 - Aug 12 (Early/Mid Summer) Aug 13 - Sep 12 (Mid/Late Summer)
Early Fall/ Breeding	Sep 17 - Dec 16 (Fall-Early Winter)	Sep 25 – Nov 6	Sep 13 - Oct 20 (Breeding)
Late Fall			Oct 21 - Nov 30
Early Winter		Nov 7 – Jan 28	Dec 1 - Jan 25
Mid Winter	Dec 17 - Feb 11	-	Jan 26 - Mar 15
Late Winter	Feb 12 - Apr 8	Jan 29 – Apr 8	Mar 16 - Apr 4
Calving/ Post-calving	May 1 - Jun 30 (Neonate)	Apr 25 –Jul 1	Apr 30 - Jun 6 (Calving)
Comment	Four seasonal use periods defined based on weekly movement rates stratified using hierarchal cluster analysis. Included broad Spring-Late Summer (SLS) and Fall-Early Winter (FEW) activity periods and an additional Neonate period nested within SLS.	Five seasonal use periods defined based on inflection points in movement rates; an additional calving/post calving season based on earliest and latest estimated parturition dates of female caribou plus the 4 weeks following the last calving date.	Eight activity periods defined by 1) changes in daily movement rates based on satellite location data and hierarchical and fuzzy cluster analyses, and 2) first/last known estimated parturition (calving season) and conception (breeding season) dates.
Source	Culling et al. 2006	MacNearney et al. 2016	Nagy 2011

[1] Dehcho-North, Dehcho-South, South Slave, and Cameron Hills sub-populations
[2] Alberta portion of the combined AB-BC population (AB1 Chinchaga)

Figure 4. Ecosections of Boreal Caribou Ranges (2010 boundaries) in BC.

have been dissected below the plateau surface by the Liard, Fort Nelson and Petitot rivers, and by higher uplands adjacent to the Rocky Mountain Foothills. Within this ecozone, the landscape varies from the more heterogenous peatland/upland mosaic of the Maxhamish Uplands ecosection, west of the Fort Nelson and Liard rivers, to the more broadly uniform Petitot Plain ecosection, which is characterized by many small lakes, wetlands, black spruce and tamarack (*Larix laricina*) muskeg, and slow-moving streams. The Clear Hills ecosection in the Chinchaga Range contains more extensive rolling upland habitat, including drier lodgepole pine (*Pinus contorta*) stands. However, the Chinchaga RRA lies primarily in the Fort Nelson Lowland and therefore is more similar to other Ranges in that ecosection than to the rest of the Chinchaga Range (http://www.env.gov.bc.ca/ecology/ecoregions/polareco.html).

A summary of biophysical attributes for Boreal Caribou habitat in the Boreal Plain and Taiga Plain ecozones are found in Appendices 7 and 8, respectively (Environment Canada 2012). Biophysical attributes are defined as the habitat characteristics required by caribou to carry out life processes necessary for survival and reproduction (Environment Canada 2012).

At the landscape scale, Boreal Caribou require a perpetual supply of large, contiguous areas of suitable summer and winter habitat with minimal anthropogenic disturbance to allow them to space out at low densities and avoid predators. At the finer scale, caribou select peatland complexes dominated by black spruce (*Picea mariana*) bog throughout the year, with wetlands (fens), mature black spruce and lodgepole pine stands, and lakes used seasonally. Wilson and DeMars (2015) found that Boreal Caribou in BC selected treed bogs and poor fens and avoided upland habitat and deciduous swamps in all seasons. Appendix 9 summarizes general knowledge of Boreal Caribou habitat use based on First Nations TEK (Leech et al 2016a,b; Dehcho First Nations 2011, Schramm et al. 2002) and past and recent research (Culling et al. 2006, DeMars and Boutin 2014) from northeastern BC and adjacent areas. Some common themes include:

- treed bogs and poor fens are important habitats during all seasons;
- lodgepole pine and spruce (*Picea* spp.) forests are important during winter;
- deep and hard-crusted snow in late winter influences habitat selection;
- terrestrial lichens are the most important forage in all seasons, especially winter, although arboreal lichens are also used;
- vascular plants including deciduous shrubs, forbs, grasses and sedges are seasonally important;
- lakes/areas near water are seasonally important, including for predator avoidance or relief from insect harassment in the snow free season and for foraging for sedges and cattails in winter (along lake margins/fens);
- mineral licks are important habitat features; and,
- caribou may travel predictable routes.

Leech et al. (2016a) used information from BRFN knowledge-holders, combined with ecological data collected on-site to describe habitats important to Boreal Caribou in a manner consistent with scientific ecological classification systems. Important seasonal habitats identified by BRFN knowledge holders include: bogs, poor fens, and treed fens (calving); mature coniferous stands (spruce/pine) with abundant terrestrial lichens (winter); and south facing slopes with early green-up (late winter/early spring).

The DRFN TEK study identified seasonally important Boreal Caribou habitat areas, including movement corridors, calving grounds, rutting areas and wintering sites, as well as observed impacts to these areas (Leech et al. 2016b). DRFN knowledge-holders identified peatlands, the margins of waterbodies, and areas of early green-up (e.g., south-facing slopes) as important sources of spring forage (Appendix 9).

6.3.1 Closed-canopy conifer habitat

Boreal Caribou have been reported to use mature coniferous habitat in late winter (Darby and Pruitt 1984). Closed-canopy conifer forests may be associated with: more efficient foraging for terrestrial lichens during periods of high snow accumulations; access to the more abundant arboreal lichen loads associated with older forests; greater mobility; and, thermal cover. Forest canopy influences snow pack characteristics (i.e., snow depth and crust hardness), with dense conifer cover providing increased snow interception and limiting the effects of wind and sun exposure (Schaefer 1996). The energetic costs of cratering through light, uncrusted snow is less than in denser, crusted snow (Fancy and White 1985). Based on field observations, caribou are frequently reluctant to leave patches of mature conifer (lodgepole pine/spruce) when snow is > 1 m deep and crusted (D. Culling, pers. observ.[7]).

RSF models indicated Snake-Sahtaneh caribou use of the Closed Needleleaf[8] class (DU 2003) throughout the year was lower than expected based on availability (Culling et al. 2006). However, due to spectral similarities between conifer types and other mapping issues, closed spruce and closed pine classes were mapped together with Closed Mixed Needleleaf as the "Closed Needleleaf" class (DU 2003). This inability to distinguish between conifer types in the Earth Cover imagery likely affected seasonal model results.

During the 2000-2004 Snake-Sahtaneh study, caribou did not appear to be constrained by deep snow, with snow depths typically 25-50 cm (Culling

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[7] Based on personal observations during capture/radio-collar deployment of over 800 Boreal and Northern caribou in BC, Alberta, and the NT.

[8] At least 61% of the cover is trees and at least 75% of the trees are needleleaf species; Needleleaf classes included black spruce, white spruce, lodgepole pine, tamarack, and balsam fir (*Abies balsamea*; DU 2003)

et al. 2006). In contrast, snow depth was measured at >100 cm in the Tsea Core of the Snake-Sahtaneh Range in February 2013. Snow depths of 75-100 cm were measured in the Snake-Sahtaneh, Maxhamish, and Calendar Ranges in the late winters of 2013, 2014, and 2015 (BCIP telemetry study, unpubl. data). Mature closed-canopy lodgepole pine and black spruce stands within and adjacent to peatland complexes in BC's Boreal Caribou Ranges may offer respite from deep, crusted snow in late winter in some years. During periods of higher than average snow accumulations these sites may represent important fine-scale habitat features. The value of these sites may increase over time if climate change results in increased snow accumulations and/or increased ice/crusting conditions (see Section 8.2: Climate change).

6.3.2 Calving habitat

Earlier studies of Boreal Caribou calving seasonal movements and habitat selection in northeastern BC report:

- variable fidelity to calving sites both among animals and between consecutive years for individual Snake-Sahtaneh female caribou, with fidelity typically to a general area rather than a specific feature (Culling et al. 2006);
- strong fidelity to individual Core Areas during the calving season by female caribou in the Snake-Sahtaneh Range (Culling et al. 2006);
- fidelity to local areas for calving in the Chinchaga Range (Rowe 2007);
- variable habitat characteristics at calving/neonatal sites (Culling et al. 2006): during May-June calf surveys, females were located in small islands of mature black spruce forest or mixedwood habitat within surrounding peatlands, in old burns on the edge of wetlands, in alder thickets with abundant standing water, and along lakeshores; the majority of calving sites were in coniferous habitats; VRI mapping indicated 58 of 66 sites (88%) were leading black spruce, with 56 sites (85%) in less than 45% crown closure; and, all 66 calving sites were characterized by very low gradients;
- strong selection for swamps (low-lying peatland and bogs) during the calving period (Rowe 2007); and,
- significant avoidance of streams from spring through late summer (April 9 - Sept 16) by female caribou in the Snake-Sahtaneh Range, including during the nested neonate period (May 1 - June 30), with probability of caribou use increasing with increasing distance to streams (Culling et al. 2006).

Calving habitat selection was the focus of a three-year study across multiple Boreal Caribou Ranges in northeastern BC (DeMars et al. 2011, 2012, DeMars and Boutin 2013, 2014, 2015; DeMars 2015). Information from this study was also used to develop a predictive map of calving habitat suitability (DeMars and Boutin 2015, DeMars and Wilson 2016). While calving site selection varied among individuals, DeMars and Boutin (2015) found Boreal Caribou adult females with neonate calves (≤ 4 weeks old) tended to select landscapes with a high proportion of nutrient-poor fen (Figure 5) and treed bog (Figure 6) habitats with selection for fens that were likely transitional between nutrient-poor and nutrient-rich. They suggest this fine-scale selection may represent a trade-off between forage quality/quantity and predation risk, with calving females selecting fens that have adequate forage to meet lactation demands, but not so productive as to be attractive to alternate prey species and their predators.

Boreal Caribou select calving habitat at multiple spatial scales. Within landscapes dominated by nutrient-poor fen and treed bog, DeMars and Boutin (2014) found female caribou selected calving areas away from well sites, early seral vegetation, rivers, and lakes, and avoided areas with high densities of linear features. In contrast to adult female caribou selecting calving sites in more open habitats in eastern ranges, DeMars and Boutin (2014) found that female caribou in BC's boreal forests selected calving sites with relatively high concealment cover. Appendices 10 and 11 provide land cover types and GIS data sources that DeMars and Boutin (2014) used to model resource selection functions.

DeMars and Boutin (2014) report that forage quantity and/or quality appears to play a limited role in Boreal Caribou calving area selection, suggesting that females instead select habitats to reduce predation risk. They found lower lichen abundance at calving sites versus winter sites, with no difference between the two in shrub, forb, and graminoid cover. While acknowledging small sample sizes and other sampling limitations, composition analyses of pellets indicated similar diets at calving and wintering sites (see Section 6.4 Caribou forage and nutrition). DeMars and Boutin (2014) suggest that in northeastern BC, as the peak of calving (approximately May 15) occurs prior to spring green-up (approximately June 1), the role of forage quality or quantity in habitat selection may become evident later in the neonate period as new plant growth emerges and lactation demands increase.

Variability in calving site selection reported by DeMars and Boutin (2014) is consistent with results of the earlier Snake-Sahtaneh study (Culling et al. 2006). DeMars and Boutin (2015) suggest this variability may be associated with the spacing out strategy.

Parturient female caribou avoidance of streams during the calving period was consistent between Culling et al. (2006) and DeMars and Boutin (2014).

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Figure 5. Bedding depression left by a female Boreal Caribou and her neonate calf during May 2011 at calving site located within a nutrient-poor fen in the Maxhamish Range of northeastern BC. Nutrient-poor fens occur in areas with slow flowing groundwater that is low in minerals. Key indicator species include tamarack and bog birch (*Betula glandulosa*) (Photo Craig DeMars).

Figure 6. Bedding depression left by a female Boreal Caribou and her neonate calf during May 2011 at calving site located within a treed bog in the Prophet Range of northeastern BC. Treed bogs are characterized by *Sphagnum* moss, lichens, and Labrador tea *(Ledum groenlandicum*) with black spruce (*Picea mariana*) being the dominant tree species. (Photo Craig DeMars).

First Nations knowledge-holders report that Boreal Caribou use wetlands and waterbodies for predator avoidance during the spring/calving period (Leech et al 2016a,b; Dehcho First Nations 2011, Schramm et al. 2002). Caribou use of lakes during calving season is discussed further in the Section 6.3.3.1 (Use of lakes in calving season).

6.3.3 Seasonal use of lakes

Wetlands and lakes are abundant in BC's Boreal Caribou Ranges, however, there are very few large lakes with islands, and the majority of lakes are small and lack shoreline complexity (e.g. peninsulas).

In investigating whether lakes were seasonally important to Boreal Caribou in the Snake-Sahtaneh Range, Culling et al. (2006) found caribou displayed:

- avoidance of individual lakes from spring through late summer (April 9 - September 16), including during the nested Neonate period (May 1 - June 30);
- no evidence of selection in the fall-early winter (September17-December 16) and late winter (February 12 - April 8);
- significant selection for individual lakes in mid-winter (December 17-February 11); and,
- significant selection for lake clusters (defined as two or more lakes greater than two hectares each, with overlapping 250 m buffers) in all seasons.

Mid-winter was the only season in which Snake-Sahtaneh caribou showed significant selection for both individual lakes and lake clusters. Culling et al. (2006) frequently observed Boreal Caribou on lakes and along lake margins from November through January. Site inspections revealed caribou were foraging for wintergreen vascular plants, as well as pawing apart muskrat (*Ondatra zibethicus*) “push-ups” (i.e., domes of frozen aquatic vegetation covering breathing holes in the ice). On several lakes, caribou disturbance was evident at all push-ups on a given lake. While mid winter was the only season that Snake-Sahtaneh caribou showed significant selection, use of lakes has been commonly observed throughout field activities associated with the 2000-2004 study, the 2008-2010 Nexen telemetry study (Culling and Culling 2017), and during field work associated with the 2012-2016 BCIP telemetry study (D. Culling, pers. observ.; Figure 7).

Figure 7. Abundant Boreal Caribou tracks on a small lake in late winter; Clarke Core Area, Snake-Sahtaneh Range; March 2, 2013. (Photo Diane & Brad Culling).

Wilson and DeMars (2015) examined selection across multiple Boreal Caribou Ranges with a range of ecological conditions, including Calendar, Maxhamish, Snake-Sahtaneh, Parker and Prophet. They found Boreal Caribou home ranges were more likely to be located at greater distances from both rivers and lakes than random among all seasons. Wilson and DeMars (2015) suggest that caribou may locate their home ranges away from rivers and lakes in response to predation risk from wolves, which use those types of features for travelling and hunting.

6.3.3.1 Use of lakes in calving season

As mentioned in Section 6.3.2 (Calving habitat), First Nations knowledge-holders described Boreal Caribou use of waterbodies during the spring/ calving period. In the Chinchaga Range, DRFN knowledge-holders report that lakes provide relief from insects and heat, and escape from wolves and bears in summer (Leech et al 2016b). Summer use of lakes for predator avoidance by females with calves was also reported by the LRR/TC First Nation (Schramm et al. 2002). Knowledge-holders indicate an association with lakes and waterbodies for caribou in the fall and early winter in the Dehcho (Dehcho First Nations 2011) and northern Alberta (Schramm et al. 2002).

Across their Canadian distribution, Boreal Caribou have been reported to use lakes and islands to reduce predation risk during calving (Shoesmith and Storey 1977, Fuller and Keith 1981, Bergerud 1985, Cumming and Beange 1987, Edmonds 1988, Racey et al. 1991, Carr et al. 2007, Carr et al. 2011), however, the pattern is not consistent (Hirai 1998, DeMars and Boutin 2014).

In assessing characteristics of habitat used by caribou during the calving and nursery period in two provincial parks in northern Ontario, Carr et al. (2011) found the majority of caribou nursery areas occurred on islands rather than the mainland shoreline of lakes. Selecting for clusters of islands appeared to be an important anti-predator strategy. Carr et al. (2011) report that parturient caribou selected for larger lakes with larger than average sized islands configured within shorter than average distances to other islands or landforms (e.g., peninsulas) that might allow escape from predators. The nearest landform for escape from these nursery sites on islands was typically another island, and most often 2-3 islands.

When all lakes in the Snake-Sahtaneh study area were included, adult female Boreal Caribou showed avoidance of individual lakes from spring through summer, including the May-June neonate period, however, when only those lakes falling within clusters were considered, Snake-Sahtaneh females showed significant selection in the neonate period (Culling et al. 2006).

Results of RSF modeling of calving season habitat selection in a study area that encompassed the Calendar, Maxhamish, Snake-Sahtaneh, Prophet, and Parker Ranges, DeMars and Boutin (2014, 2015) found Boreal Caribou females showed avoidance of lakes. They suggest this avoidance may be due to the hydrogeomorphology of lakes in BC's Boreal Caribou Ranges, which provides limited escape terrain, and that risk of predation may be higher in those areas.

6.4 Caribou forage and nutrition

BRFN knowledge-holders described terrestrial (ground) lichen as the most important food source for Boreal Caribou, with arboreal (tree) lichens also used. Consistent with results of past scientific research on woodland caribou food habits, BRFN knowledge-holders understood lichen to be particularly important in winter, with caribou feeding more generally from available vascular plants (greens) in other seasons. The use of cattail (k'aazuudle; *Typha latifolia*) was identified as an important winter food source for Boreal Caribou by a DRFN community member.

Caribou are frequently observed foraging and lounging on petroleum leases throughout BC's Boreal Caribou Ranges (D. Culling, pers. observ.; Figure 8). In the Chinchaga Range, Rowe (2007) assessed caribou plant selection at disturbed sites based on fecal fragment analysis. Winter pellet samples (n=25) were collected from disturbed sites, including leases or pipelines that had been replanted with agronomic species (n=20) and agricultural fields (n=2), and from control sites in peatland (n=2) and mature forest (n=1). Terrestrial and arboreal lichens comprised the majority of winter pellet samples analyzed (Table 8). Dominant forbs included *Equisetum* spp., followed by a group of non-native agronomic species (*Trifolium* sp./*Medicago* sp./*Melilotus* sp. [clover/alfalfa/sweet clover]), and *Carex* spp. On average, pellet samples collected on replanted leases and pipelines contained slightly higher proportions of forbs and fewer tree species than those collected at forested sites.

Figure 8. Boreal Caribou on petroleum lease, Milligan Core Area, Chinchaga Range, November 2013. (Photo Diane & Brad Culling).

Table 8. Percent of plant groups in Boreal Caribou winter fecal pellet samples (n=25) collected in the Chinchaga Range in 2004 and 2005 (from Rowe 2007).

Plant Group	Percent of fecal sample ± SE
Trees	1.92% ± 0.63%
Shrubs	7.15% ± 0.73%
Forbs	8.32% ± 1.25%
Lichens	66.45% ± 1.73%
Grasses	5.50% ± 1.03%
Sedge/Rushes	3.88% ± 0.65%
Mosses	6.74% ± 1.13%
Insect Matter	0.05% ± 0.04%

DeMars and Boutin (2014) analyzed a small sample of Boreal Caribou fecal pellets collected during winter and at calving sites. Lichen and moss were the dominant items identified, comprising roughly 55% and 22% of pellets analyzed, respectively (Table 9). While variation in digestibility between plant groups may result in some species being over-represented in fecal fragment analysis, the presence of a significant portion of moss in fecal samples may also indicate low availability of preferred forage species and declining winter range condition (Ihl and Barboza 2007, DeMars and Boutin 2014). Although the reason for the high proportion of moss in caribou winter pellet samples is not known, DeMars and Boutin (2014) recommend investigating whether the condition of available winter habitat within BC's Boreal Caribou Ranges is declining.

Table 9. Mean proportion (%) of major plant groups found in fecal pellets collected from female Boreal Caribou during the winter and at calving sites in northeast BC (from DeMars and Boutin 2014).

Season	**Lichens**	**Moss**	**Grass**	**Sedge/ Rush**	**Equisetum**	**Shrubs**	**Conifer**
Calving (n=7)	55.8	21.2	1.1	7.6	9.1	4.5	0.6
Winter (n=7)	55.0	23.5	1.2	9.2	4.5	5.1	1.5

In northeastern BC, Denryter et al. (2017) conducted foraging trials using tame, adult female caribou to evaluate summer food habits and diet selection, and forage value in plant communities in boreal, montane, and alpine ecosystems. They compared diet composition to forage abundance in potential natural vegetation (PNV) communities available to free-ranging caribou in Boreal and Northern ecotype Ranges to determine forage selection and to quantify forage availability. Within the Boreal White and Black Spruce (BWBS) biogeoclimatic zone, plant communities sampled included: boreal black spruce bogs and fens, boreal black spruce uplands, boreal tree-rich fens, and boreal white spruce (*Picea glauca*). A a few wetlands types were also sampled opportunistically. Findings from the three-year study include:

- caribou were highly selective foragers (28 of 282 species encountered within sample plots comprised 78% of diets overall) and individual caribou were remarkably consistent in the species and the proportions of each species consumed;
- selection patterns were generally consistent across the summer/early autumn (late June to early October) season and among PNV communities;
- 234 of 282 forage species encountered were assessed for selection: caribou selected for 28 species, displayed neutral use of 91 species,

and avoided 115 species, with the strongest selection for deciduous shrubs, forbs, lichens, and mushrooms;

- summer/early autumn diets were dominated by deciduous shrubs (primarily leaves and berries) in all plant communities sampled, with the proportion of deciduous shrubs consumed averaging two times the percentage of their available biomass;
- caribou avoided ≥ 50% of understory vegetation in all plant communities; conifers, evergreen shrubs, mosses, clubmosses, and two genera of terrestrial lichens (*Stereocaulon paschale*; *Peltigera* spp.) accounted for <1% of all recorded intake despite high abundance in many enclosures and mosses were strongly avoided despite being abundant in most enclosures (comprising <0.05% of all caribou diets); and,
- the proportion of terrestrial and arboreal lichen in caribou diets varied with productivity of the plant community, with the highest consumption occurring in unproductive boreal black spruce communities (bogs and tree-poor fens) and the lowest consumption in more productive boreal communities (tree-rich fens, boreal white spruce), and lichen consumption declined with higher abundance of accepted vascular plants; caribou selected only five of 14 species of terrestrial lichens encountered, with 97% of all terrestrial lichen intake comprised of species of the genera *Cetraria*, *Flavocetraria*, *Cladina*, and *Cladonia*.

Based on these foraging trials, Denryter et al. (2017) suggest optimal summer foraging habitat for caribou includes an abundance of palatable deciduous shrubs and a diverse understory of selected forbs, lichens, and mushrooms. Denryter et al. (2017) note the importance of using biologically sensitive indicators capable of discriminating between accepted and avoided plant forage species in evaluating habitat suitability. The use of tame caribou to determine selection of plant species provides information on the forage value of caribou summer habitats that are not captured by traditional methods of assessing habitat quality. Their study highlights seasonal differences in diet composition for caribou in northeastern BC. While lichens are the predominant winter forage, female caribou require a broader selection of forage species to satisfy nutritional requirements during the growing season.

Beginning in winter 2015, nutritional evaluations conducted by NCASI scientists jointly with scientists and caribou biologists at NT Department of Environment and Natural Resources, BC MFLNRO, and BC MOE were extended from northeastern BC into southern NT. The ongoing study includes sampling forage quality and quantity in boreal habitats of NT as a preliminary indication of nutritional adequacy of vegetation communities there (J. Cook, pers. comm.). Extensive sampling of plant communities common in southern NT was conducted in summer 2016.

These data will be combined with similarly-collected data in northeastern BC to provide a regional perspective of forage quality and quantity for the common and important habitats used by caribou across the ranges where wild caribou were sampled for body condition. Analysis may provide insights linking regional variation in forage quality and quantity on variation in body condition of wild caribou.

A decline in forage availability and/or quality on calving and summer ranges may lead to an increase in foraging-related activities and/or a reduction in the daily dry matter intake, which will result in caribou relying upon body reserves to compensate (Bergerud et al. 2008). The current research collaboration between Cook and Cook (NCASI) and the BC and NT governments will contribute to a greater understanding of Boreal Caribou habitat condition in BC. To complement information on range/forage condition, information on forage accessibility is also needed.

Consistent with the DRFN observation of cattail as an important winter food in the Chinchaga Range (Leech et al 2016b), Snake-Sahtaneh caribou foraged on cattail rhizomes and sedges (*Carex* sp.) in early winter (Culling et al. 2006). As noted in Section 6.3.3 (Seasonal use of lakes), Snake-Sahtaneh caribou were frequently seen cratering on the margins of small lakes and wetlands in winter. In the Lower Mackenzie Valley, NT, Nagy et al. (2003) reported Boreal Caribou cratering through hard-crusted snow to feed on cured stalks of horsetail (*Equisetum* spp.) on lake margins and venturing out onto frozen lakes to lick small mounds of mineral soil. Caribou have been reported to supplement their winter diet of lichens with "winter-green" vascular plants, which supply higher concentrations of protein, nitrogen, and phosphorus (Klein 1982).

6.5 Knowledge gaps

GPS location data collected by the BCIP telemetry study provides an unprecedented opportunity to investigate and compare habitat use and movements across the distribution of Boreal Caribou in BC. The data have already been used to revise Boreal Caribou Range and Core Area boundaries and a subset of the data has been used to investigate seasonal and calving habitat selection, but additional analyses can be undertaken.

Knowledge gaps on Boreal Caribou habitat use in BC include:

- are there differences in habitat selection and movements among Boreal Caribou Ranges given the variation in ecological conditions between Ranges (use existing BCIP telemetry study caribou GPS data);
- how does deep, crusted snow affect caribou habitat selection, movements, access to terrestrial lichens, and vulnerability to predation (use existing BCIP telemetry study caribou GPS data for

an analysis of Boreal Caribou habitat selection during the deep snow winter of 2012/13);

- are there stands of mature coniferous forest that are seasonally important (late winter) to Boreal Caribou; how do these areas compare between individual Range and Core Areas;
- are there fine-scale habitat features (mineral licks, etc.) that are seasonally important to Boreal Caribou; how do these areas compare between individual Ranges and Core Area;
- are there identifiable movement corridors within and between Boreal Caribou Ranges, including calving season travel corridors; if so, what are the habitat attributes of these areas; and,
- what is the current condition of Boreal Caribou Range, including:
  - the quantity, quality and accessibility of forage necessary to meet both winter and summer requirements;
  - are there specific areas of high lichen biomass that are important on a seasonal basis;
  - are there any factors affecting availability of forage;
  - what are the effects of climate-induced habitat changes on the distribution, abundance, and quality of terrestrial lichen (DeMars and Boutin 2014); and,
  - what are the effects of long-term fire-suppression on the distribution, abundance, and quality of terrestrial lichen (DeMars and Boutin 2014)?

A number of studies have developed, or are currently developing resource selection functions for Boreal Caribou and other species in Boreal Caribou Ranges in northeastern BC. Developing a standardized habitat class map layer that could be applied to all studies would be useful for comparing habitat selection between studies and between species.

7 PREDATORS AND ALTERNATE PREY

Boreal Caribou exist in a dynamic, multiple predator-prey system in the boreal region of Canada. Wolves are typically their primary predator (MOE 2010, Environment Canada 2012), with black bears, wolverine, lynx, and coyotes exerting variable predation pressure on adult and juvenile caribou across the national distribution (MOE 2010). Grizzly bears (*Ursus arctos*) and golden eagles (*Aquila chrysaetos*) prey on adults and calves of other ecotypes of woodland caribou (Young and McCabe 1997, Gustine 2005) and may be potential occasional predators of adults or calves along the western periphery of Boreal Caribou distribution in BC (Culling et al. 2006).

Moose are the primary prey for wolves, with Boreal Caribou, and beaver (*Castor canadensis*) important alternate prey (MOE 2010, Culling and Culling 2016). Other regional ungulate species that occur at variable densities adjacent to, and occasionally within, BC's Boreal Caribou Ranges include elk, white-tailed deer, plains bison (*Bison bison bison*), and wood bison (*B. b. athabascae*).

Successful recovery of Boreal Caribou in BC requires accurate information on the relative density of predators and primary and alternate prey species, and an understanding of how these species interact. Since 2010, a number of studies have collected information on predator and prey populations in western Canadian Boreal Caribou Ranges.

The following subsections provide information on the abundance and habitat use of individual predator and prey species in BC's Boreal Caribou Ranges. Information on predator-prey interactions is addressed in Section 8.3 (Predator/prey dynamics).

7.1 Wolves

7.1.1 Wolf inventory methods

Traditional aerial inventory methods are not well-suited to describing wolf densities in the boreal forest. Estimating population size is hindered because wolves range over large areas, live primarily in forested habitats, and are secretive by nature (MFLNRO 2014). Serrouya et al. (2015, 2016) are attempting to develop a cost-effective, accurate method of censusing wolves in boreal forest habitat, which would provide an important tool for assessing the degree to which anthropogenic habitat disturbance affects predator-prey relationships. They carried out a multi-year pilot project, which consisted of three components:

- conducting simulation analyses to determine wolf survey intensity;
- applying results of power analyses to aerial wolf surveys in the field in the winters of 2014/2015 and 2015/2016; and,
- performing post-hoc assessments of the survey methodology (Serrouya et al. 2015, 2016).

While the study design included validating survey methods using data from GPS and VHF radio-collared wolves located within delineated wolf survey units (WSUs; Serrouya et al. 2015), a lack of active wolf collars within survey areas limited their ability to do so.

Following Year 1 of the pilot project (2014/2015), Serrouya et al. (2015) recommended that:

- future surveys attempt to capture the natural variation in ungulate densities and variation in the footprint of human disturbance;
- surveys should be conducted in areas where there is a sufficient number of active wolf collars to allow validation of the estimate of the census method being used; and,

- the simulation exercise should be repeated with more precise wolf tracking data (e.g., with hourly fix rate data instead of daily fix rates).

In Year 2 (2015/2016), they conducted additional surveys and attempted to validate their survey methods using data from wolves fitted with GPS collars that recorded locations every five minutes during winter (Serrouya et al. 2016).

Findings on wolf census techniques from the pilot project (Serrouya et al. 2015, 2016) include:

- the survey method, which consisted of flying belt transects and deviating from the transect line when wolf tracks were encountered to locate the pack and assess pack size, was logistically feasible for surveying wolves in large, remote areas using a fixed-wing aircraft;
- transect spacing affects detection rates and, therefore, transects should be no greater than 3 km apart;
- survey timing was found to be very important, with the highest success in detecting and tracking wolves roughly three days after a large snowfall;
- to avoid double counting wolf packs, each new set of tracks encountered should be backtracked to ensure they are not connected to other sets of tracks previously documented;
- identifying sources of counting errors during surveys is important; potential counting errors can result from: edge effects, pack-count false negatives, pack-count false positives, and pack size enumeration errors; and,
- potential edge effects during wolf surveys can be minimized by: avoiding wolf corridors (rivers) when delineating survey boundaries, delineating relatively similar shaped and sized survey units, and being consistent in the timing of surveys following snowfall.

7.1.2 Wolf abundance in Boreal Caribou Ranges

Wolf control measures, including bounties and poisoning, were common and widespread in BC throughout the first half of the 20th century and resulted in reduced wolf populations by the late 1950s (MFLNRO 2014). However, provincial populations have increased since active control ended with the removal of bounties in 1955 and the end of large-scale poisoning in wilderness areas in 1961. Current provincial wolf management plan mapping indicates BC's Boreal Caribou Ranges fall within the low-density area (average density estimate of 2-5 wolves/1,000 km^2) based on wolf density extrapolations and relative densities of ungulate prey (MFLNRO

2014). In contrast, high wolf density areas have estimated densities between 5-15 wolves/1,000 km^2 (MFLNRO 2014).

Prior to 2010, two wolf telemetry projects were conducted in BC's Boreal Caribou Ranges. Between November 2002 and March 2004, Culling et al. (2006) fitted 31 individual wolves with GPS (19) or VHF radio-collars (12), including 15 females and 16 males. Results of the study include:

- six packs, comprising an estimated 60 wolves, were identified;
- four packs had a minimum of 12-15 wolves/pack;
- there were an estimated 6.3 wolves/1,000 km^2 within the Snake-Sahtaneh Range, which represented a minimum density, and GPS data revealed incomplete coverage (i.e., a gap between territories) of radio-marked packs across the study area;
- mean pack territory size was 2,190 ± 549 km^2, with a mean intra-territory density of 164 ± 31 km/wolf;
- the largest groups were observed in winter, and in spring and summer individual radio-collared and uncollared wolves were often seen hunting alone;
- all five wolf packs for which GPS data was acquired encompassed significant portions of one or more Boreal Caribou Core Areas; and,
- some Core Areas fell within zones of overlap between multiple adjacent pack territories.

Between March 2005 and March 2007, Rowe (2007) tracked eleven wolves (8 females, 3 males) with GPS or VHF radio-collars to determine seasonal movements, home range size, and habitat use in the Chinchaga Range. Results of the study include:

- pack size ranged from three to 10 wolves; and,
- average individual annual home range (MCP) size was 2,286 ± 550 (SE) km^2 (n=8, range 1,022 - 5,663).

In response to a question on whether there are more predators (wolves, bears, and lynx) in Boreal Caribou habitat than there were in the past, Métis Traditional Knowledge holders suggest wolf populations are increasing due to a decrease in trapping, and that wolves are being sustained through the winter months by road killed ungulates (Métis Nation British Columbia 2011).

In the winters of 2014/15 and 2015/16, Serrouya et al. (2015, 2016) surveyed six WSUs to estimate wolf densities, including four in northeastern BC, two in the NT, and one in Alberta. Wolf densities ranged from 1.6/1,000 km^2 in the Hay River Lowlands, NT, to 15.6/1,000 km^2 in the Chinchaga WSU in northeast BC (Table 10).

The density of wolves in the Calendar and Clarke WSUs reported by Serrouya et al. (2015) is consistent with results from the earlier Snake-Sahtaneh study, where Culling et al. (2006) estimated a minimum density of 6.3 wolves/1,000 km^2, with four of six packs identified containing a minimum of 12 to 15 wolves each. As the distribution of GPS data from radio-collared wolves indicated a vacant area between pack territories, Culling et al. (2006) suspected an additional, unidentified pack was operating in the Clarke Core Area. If this was the case, the wolf density estimate would have been even higher. At the time of the Snake-Sahtaneh study, a 2004 moose inventory estimated a density of 0.08 moose/km^2 for wildlife management units encompassing the Snake-Sahtaneh Range (Culling et al. 2006).

7.1.3 Wolf habitat selection in Boreal Caribou Ranges

Culling et al. (2006) found radio-collared wolves denned both within and adjacent to the Snake-Sahtaneh Range, including multiple den sites within Core Areas. Wolves were closely associated with beaver activity from spring through fall, with several dens located in abandoned beaver lodges. While beaver represented the majority of items in wolf scat samples collected at den sites (n=27), scat samples also included waterfowl and ungulate calf (moose and caribou) remains. Seasonal RSF models indicated wolves selected for the Wetlands/Waterbodies habitat class over all others between April and September, with use during the May-June neonate period roughly five times greater than expected based on availability (Culling et al. 2006). The Low Vegetation class, which included fens, was also heavily used by wolves during calving season. Riparian and peatland habitats within Core Areas provided wolves access to open water and beaver prey during the denning period.

Radio-collared wolves in the Chinchaga Range showed highest selection for habitats with moderate (10-49%) proportions of wetlands (Rowe 2007).

Results of a recent multi-scale analysis of wolf habitat selection in BC's Boreal Caribou Ranges (DeMars and Boutin 2014) include:

- pack territories were tightly spaced and overlapped significantly with Caribou Ranges and Core Areas;
- wolves were not confined to specific areas within Caribou Ranges during the calving season;
- wolves were closely associated with aquatic areas, showing selection for nutrient-rich fens and being closer to rivers and lakes than expected;
- early seral vegetation and areas of high linear feature density were generally avoided; and,

Table 10. Habitat conditions and wolf densities of five[1] wolf survey units (WSU) surveyed by Serrouya et al. (2015, 2016).

WSU	Area (km^2)	% Dominant Habitat Types	Level of Habitat Disturbance	Survey Date	Wolf Density (Wolves/ 1,000 km^2)	Comments
Calendar (BC)	4,974	coniferous forests (64%); wetlands (18%)	Moderate (1.3 %)	Jan - Feb 2015	7.0	Petitot River forms southwest boundary; recent forest fires over large parts of WSU (especially in the north); disturbance mainly seismic lines with some pipelines and unploughed and unploughed roads; human activity mainly O&G development; few cabins or snow-mobile routes
Clarke (BC)	5,161	upland coniferous or broadleaf forest (60%); wetlands (25%)	Moderate (2.7 %)	Dec 2015	7.4	WSU encompasses HWY 97, Fort Nelson (pop < 4000), and sections of Fort Nelson and Fontas rivers; oil and gas activity includes many seismic lines, roads, pipelines and some production plants, snow- mobile activity observed
Chinchaga (BC)	3,414	upland coniferous or broadleaf forest (51%); wetlands (43%)	Moderate (1.7 %)	Feb 2015	15.6	WSU encompassed Chinchaga RRA and Fontas River, Sikanni Chief River is western boundary; oil and gas tenuring suspended in RRA; recent forest fires in parts; disturbance mainly oil and gas (seismic lines, pipelines, roads) and some logging; snow-mobile activity relatively rare
Hay River Lowlands (NT)	5,571	upland coniferous forests (23 %); wetlands (66%)	Minimal (0.07%)	Nov 2015 and Feb 2016[2]	1.6	Most northerly WSU, encompassed Kakisa Lake community (pop < 50); disturbance was primarily old linear features (seismic) generally in advanced stages of natural regeneration; snowmobile activity minimal to non-existent during surveys
Fort Liard (NT)	4,382	upland coniferous forests (64 %); wetlands (7 %)	Low (0.6 %)	Jan 2016	5.3	Northern WSU; located immediately east of Fort Liard (pop< 600) and the Liard River; cabins and snowmobile activity in southern part of WSU near the Muskeg River and near some of the southern lakes
Cold Lake (AB)	7,271	coniferous forests (41 %); broadleaf forest (16 %); wetlands (24 %)	High (7.5 %),	Feb 2016	9.9	Most southerly and easterly WSU; immediately north of Cold Lake Air Weapons Range; highest level of human disturbance including on-going human activity observed during survey

[1] Parker WSU was surveyed in 2015 (Serrouya et al. 2015), but excluded from the 2016 analysis as it was too small (752 km^2) for estimating wolf density; one wolf pack (six wolves) was estimated during 2015 survey.
[2] The November 2015 survey was interrupted due to weather, but was completed in February 2016.

- wolves selected lines that increased movement efficiency and sightability.

Results of DeMars and Boutin (2014) are consistent with those of Culling et al. (2006) indicating that beaver are an important prey species for wolves in BC's Boreal Caribou Ranges during spring and summer, and that wetlands and waterbodies are important to wolves during the denning period.

7.2 Black bears

Prior to 2010, information about black bears in Boreal Caribou Ranges in northeastern BC was based on a study of nine GPS-collared bears (5 female, 4 male) in the Snake-Sahtaneh Range in 2003-2004 (Culling et al. 2006). Although black bear activity was strongly associated with deciduous-dominated upland and riparian habitats within the upland-peatland mosaic, five bears made significant use of Boreal Caribou Core Areas during the May-June caribou neonatal period. Within Core Areas, bear use was concentrated in upland patches dominated by trembling aspen (*Populus tremuloides*) and along upland riparian zones, linear corridors (roads and pipelines), and in cutblocks. Individual bears were commonly located near areas of beaver activity. During the 2000-2004 study, one of five radio-collared adult female Boreal Caribou mortalities was due to black bear predation (Culling et al. 2006).

In spring 2012 and 2013, DeMars and Boutin (2014) deployed 19 GPS collars on black bears (4 female, 15 male) within or adjacent to the Snake-Sahtaneh, Maxhamish, and Prophet Boreal Caribou Ranges and the Fort Nelson Core Area. Findings of the study include:

- at larger spatial scales, black bears favoured landscapes dominated by upland deciduous forest;
- within Boreal Caribou Ranges, bears were closer to aquatic features than expected and showed strong selection for rich fens across all scales;
- selection patterns suggested a preference for habitats associated with higher grass and forb abundance, which are important food sources for bears in the early spring;
- at a second-order scale, bears selected for upland deciduous forest, deciduous swamp, and poor fen while upland conifer, rich fen, and conifer swamp were avoided compared to treed bog;
- within Caribou Ranges, bears strongly selected for upland deciduous forests and rich fens;
- bears generally selected areas with high linear feature density, weakly selected for areas with increasing slope, and were closer to water sources, particularly lakes, relative to random locations; and,

- black bears were also closer to early seral vegetation with this effect strongest at the second-order scale.

Using remote cameras in several Boreal Caribou Ranges in BC, Alberta and NT, Tigner et al. (2014) found that black bears used upland forests more than lowland forests.

All three studies found black bear preference for upland forests, and both BC-focussed studies showed black bear preference for riparian/water features and early seral/cutblocks. In northeastern Alberta, Latham et al. (2011a) found that overall, black bears selected upland forests and avoided bogs and fens. However, at the individual level, habitat selection was highly variable with some bears selecting bogs and fens.

There have been no research or monitoring projects conducted on black bear abundance or densities in Boreal Caribou Ranges in BC.

7.3 Other predators

Little is known about the relative densities of medium-sized terrestrial predators within BC's Boreal Caribou Ranges, including wolverine, lynx, and coyotes. Scrafford and Boyce (2015) note that lack of data prevents making accurate assessments of wolverine populations at both the national and provincial scale. The northward expansion of cougar (*Puma concolor*) represents a potential long-term threat to Boreal Caribou, particularly if white-tailed deer move into Boreal Caribou Ranges.

In addition to wolves and black bears, a number of other potential caribou predators have been observed in Boreal Caribou Core Areas during BCIP telemetry study field activities, including three wolverines, five lynx, and one golden eagle in the initial radio-collar deployment phase (December 2012-April 2013; Culling and Culling 2013). In early March 2013, a wolverine was found in the middle of a group of 15 caribou in the Calendar Range. A second wolverine was observed excavating two adjacent beaver lodges in the Clarke Core Area in March (Figure 9), and a third was seen on top of a beaver lodge in the Calendar Range in the first week of April. During the Horn River Basin moose survey, Thiessen (2010) reported seeing wolverine in the Kiwigana and Paradise Core Areas. Both animals seen were actively excavating beaver lodges and evidence of wolverine attempting to access beaver lodges was noted at another two sites.

Figure 9. Wolverine excavating one of two adjacent beaver lodges within the Clark Core Area, Snake-Sahtaneh Range, March 2013. (Photo Diane and Brad Culling).

GPS telemetry is being used to study wolverine ecology in lowland boreal forests of north-central and northwestern Alberta (Scrafford and Boyce 2015). Preliminary results include:

- overall, lowland wolverine habitat is comprised of bogs, wetlands, and coniferous forests;
- based on seasonal RSF models, wolverine show strong selection for bogs in summer;
- wolverine in lowland boreal habitat concentrate winter foraging on beaver, snowshoe hare (*Lepus americanus*), and moose; and,
- confirmed prey items collected at wolverine GPS clusters included 27% moose remains, 24% beaver, 19% snowshoe hare, and 5% Boreal Caribou (Table 11), with ungulate remains typically scavenged.

Table 11. Percent occurrence of identifiable prey items at wolverine GPS radio-telemetry clusters in northern Alberta (n=62; from Scrafford and Boyce 2015).

Prey Item	**Occurrence**	**Prey Item**	**Occurrence**
Moose	27 %	Boreal Caribou	5 %
Beaver	24 %	Trapper Bait Pile	3 %
Snowshoe Hare	19 %	Black Bear	2 %
Unidentified Ungulate	10 %	Marten	2 %
Grouse	6 %	Red Squirrel	2 %

While historic and provincial trapping harvest records may provide information on the relative abundance of some predators (wolverine, lynx, coyotes, wolves) and beaver over time, a summary of that information is beyond the scope of this review. Because trapping effort, and therefore harvest, tend to be linked to fur prices, trapping harvest may not accurately depict trends in abundance of those species and should be interpreted with caution.

7.4 Moose

Two moose inventories were conducted in Boreal Caribou Ranges prior to 2010. In 2004, a stratified random block moose inventory was conducted in Management Units (MU) 7-55 and 7-56, which encompassed the entirety of the Snake-Sahtaneh, Calendar, and Maxhamish Ranges (Backmeyer 2004; Table 12). The overall moose density was estimated at 0.087 moose/km^2, with a population estimate of 2,998 ± 752 (90% Confidence Interval [CI]). Calf recruitment was estimated at 32 and 42 calves/100 cows in MU 7-55 and MU 7-56, respectively. In 2005, a stratified random block moose inventory was conducted in MU 7-47, which encompassed the Chinchaga Range. The moose density was estimated at 0.044 moose/km^2 for a population estimate of 435 moose ± 25% (90% CI), and calf recruitment was estimated at 9 calves/100 cows ± 75% (90% CI; Rowe 2005).

In 2010, Thiessen (2010) conducted the first survey using the distance sampling method (Buckland et al. 2001, 2004) for moose in the Horn River Basin of northeastern BC. In comparison to standard stratified random block counts, the distance sampling method allowed a larger area to be surveyed at a lower cost, and provided density estimates for a series of survey units and geo-referenced locations for mapping the distribution of moose across the study area. The eight survey units encompassed all or portions of seven Boreal Caribou Core Areas, including Parker, Paradise, Kiwigana, Tsea, Fortune West, Fortune East, Calendar, and Capot-Blanc. The density estimate for moose for the entire survey area was 0.116 moose/km^2 (Table 12). In general, moose densities were highest in the southern units. The ratio of calves/100 cows ranged from 22 in Capot-Blanc to 42 in the Fortune West unit. Bergerud (1992) indicates that calf recruitment (at 6-9 months of age) of 25-26 calves/100 females is required for moose population stability.

Since 2010, two additional surveys were conducted using the distance sampling method to estimate moose densities within Boreal Caribou Ranges. In January 2013, McNay et al. (2013) surveyed seven Boreal Caribou Core Areas and the Chinchaga RRA, estimating an overall density of 0.095 moose/km^2. Estimated densities varied across the survey

Table 12. Moose inventories conducted in and adjacent to BC's Boreal Caribou Ranges, 2004-2016.

Survey Type[1]	Year	Survey Area	Population Estimate	Population % Confidence Interval	Density (moose/km²)	Density % Confidence Interval	Source
SRB	2004	MU 7-55 and MU 7-56[2]	2,998	2,245 - 3,750 (90% CI)	0.087	Not provided	Backmeyer 2004
SRB	2005	MU 7-47	435	326-544 (90% CI)	0.044	0.033-0.055 (90%CI)	Rowe 2005
DS	2010	Overall[3]	2,685	2,224 - 3,243 (95% CI)	0.116	0.096 – 0.140 (95% CI)	Thiessen 2010
DS	2010	Parker (MU 7-49)	749	611 - 918 (95% CI)	0.246	0.201 – 0.302 (95% CI)	Thiessen 2010
DS	2010	MU 7-55 Units	1,272	972 - 1,664 (95% CI)	0.082	0.063 - 0.107 (95% CI)	Thiessen 2010
DS	2010	Horn River Basin Units			0.151	0.125 - 0.183 (95% CI)	Thiessen 2010
DS	2010	Paradise (MU 7-56)	581	389 - 867 (95% CI)	0.124	0.083 – 0.186 (95% CI)	Thiessen 2010
DS	2010	Kiwigana	407	287 - 577 (95% CI)	0.159	0.112 – 0.225 (95% CI)	Thiessen 2010
DS	2010	Tsea	293	181 - 474 (95% CI)	0.172	0.106 – 0.278 (95% CI)	Thiessen 2010
DS	2010	Fortune West	100	57 - 177 (95% CI)	0.049	0.028 - 0.087 (95% CI)	Thiessen 2010
DS	2010	Fortune - East	114	69 - 188 (95% CI)	0.043	0.026 - 0.071 (95% CI)	Thiessen 2010
DS	2010	Calendar	85	37 - 195 (95% CI)	0.018	0.008 - 0.040 (95% CI)	Thiessen 2010
DS	2010	Capot- Blanc	129	80 - 209 (95% CI)	0.076	0.047 - 0.123 (95% CI)	Thiessen 2010
DS	2013	Overall[4]	1,379	1,103 - 1,742 (95% CI)	0.095	0.076 - 0.120 (95% CI)	McNay et al. 2013
DS	2013	Overall (no Etthithun)	1,423	1,253 - 1,592	0.098	0.088 - 0.114 (95% CI)	McNay et al. 2013
DS	2013	Overall (no Etthithun/Prophet)	1,466	1,281 - 1,651	0.101	0.088 - 0.114 (95% CI) (sic)	McNay et al. 2013
DS	2013	Chinchaga	363	216 - 591 (95% CI)	0.151	0.090 - 0.246 (95% CI)	McNay et al. 2013
DS	2013	Clarke	322	209 - 500(95% CI)	0.145	0.094 - 0.225 (95% CI)	McNay et al. 2013
DS	2013	Etsho/Kotcho	345	128 - 932 (95% CI)	0.127	0.047 - 0.343 (95% CI)	McNay et al. 2013
DS	2013	Etthithun	34	10 - 209	0.044	0.013 - 0.147	McNay et al. 2013
DS	2013	Milligan	587	348 - 987	0.113	0.067 - 0.190	McNay et al. 2013
DS	2013	Prophet	144	31 - 657	0.121	0.026 - 0.551	McNay et al. 2013
DS	2016	Overall[5]	1,453	1,119 - 1,888	0.104	0.080 - 0.136	Webster and Lavallée 2016
DS	2016	Clarke/ Chinchaga Combined	1,198	860 - 1,669	0.125	0.090 - 0.174 (95% CI)	Webster and Lavallée 2016
DS	2016	Clarke Core Area	395	269 - 510 (95% CI)	0.074	0.051 - 0.109 (95% CI)	Webster and Lavallée 2016
DS	2016	Chinchaga RRA	670	419 - 1,072 (95% CI)	0.157	0.098 - 0.251 (95% CI)	Webster and Lavallée 2016
DS	2016	Fortune Core Area	331	210 - 520 (95% CI)	0.076	0.049 - 0.120 (95% CI)	Webster and Lavallée 2016

[1] SRB = stratified random block; DS = distance sampling
[2] Study area encompassed the Snake-Sahtaneh, Calendar, and Maxhamish Ranges.
[3] Study area roughly corresponded to the Parker, Paradise, Kiwigana, Tsea, Fortune West, Fortune East, Calendar, and Capot-Blanc Core Areas.
[4] Study area roughly corresponded to the Chinchaga RRA and the Clarke, Etscho/Kotcho (combined), Etthithun, Milligan, and Prophet Core Areas.
[5] Study area roughly corresponded to the Clarke and Fortune Core Areas and the Chinchaga RRA.

area, with the highest in Chinchaga RRA and lowest in the Etthithun Core Area (Table 12). For the combined study area, the overall population was estimated at 1,379 moose, with an estimated 51 calves/100 cows (95% CI:41 – 60) overall. Based on the relative change in calf ratios from previous surveys, McNay et al. (2013) suggested moose populations were likely increasing in the survey area.

Webster and Lavallée (2016) used distance sampling to determine the abundance of moose in and around the Clarke and Fortune Core Areas and the Chinchaga RRA. The overall density estimate for all areas combined was 0.104 moose/km^2 with a corresponding population estimate of 1,453 moose (Table 12). There were 45 calves/100 cows overall, with 45, 44, and 38 calves/100 cows in the Clarke and Fortune Core Areas and the Chinchaga RRA, respectively.

Direct comparison between recent distance sampling surveys is limited by the varying size and habitat composition of individual study areas (Webster and Lavallée 2016). The 2010 inventory was based more broadly on MUs, the 2013 survey was based on Boreal Caribou Core Areas, and the 2016 survey was based on Core Areas with a surrounding buffer. In comparing calf ratios between the 2013 and 2016 surveys, Webster and Lavallée (2016) suggest that juvenile recruitment was still positive ($\lambda > 1$) in the latest survey, but slightly less so.

Moose density estimates derived from distance sampling surveys conducted since 2010 were higher than estimates from the 2004 random block inventory. It is not known whether these differences represent a genuine increase in the local moose population or result from the varying methods used. Backmeyer (2004) noted that the 2004 results indicated little change in the overall moose population estimate for MU 7-55 and MU 7-56 over the previous 15 years based on a 1988 moose survey of the same general area, which reported a density estimate of 0.09 moose/km^2 (Ministry of Water, Land and Air Protection, unpubl. data)[9].

Of 13 GPS-collared moose mortalities investigated from January 2015 to September 2016, two were not predator related (one unknown, one obstructed labour), and 11 were suspected or confirmed to be due to wolf predation (Figure 10, BC OGRIS unpubl. data). All 11 suspected or confirmed wolf predation mortalities occurred between January and April and the two mortalities that were not due to predation occurred in May.

[9] No Confidence Intervals provided.

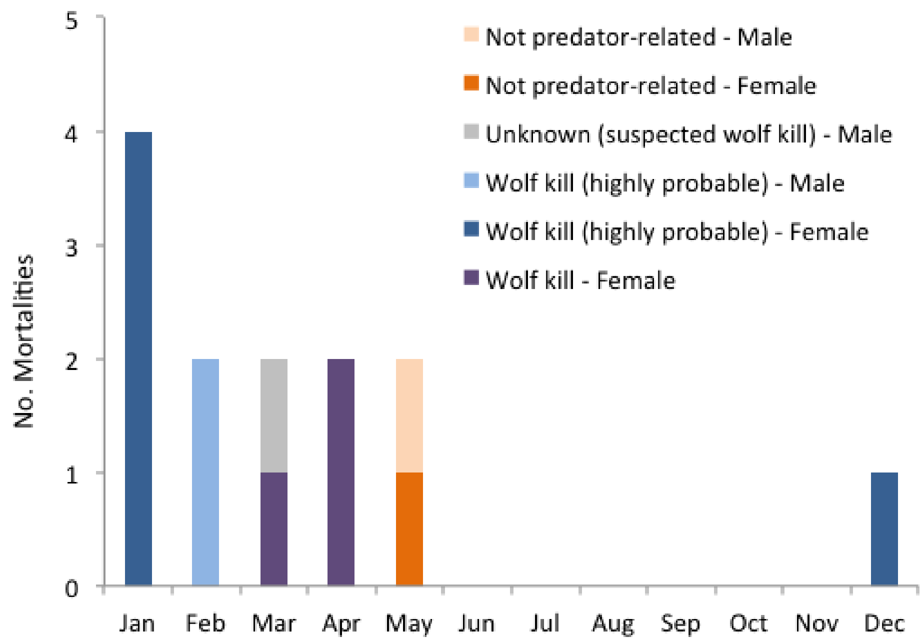

Figure 10. Cause and timing of radio-collared adult moose mortalities in Boreal Caribou Ranges in northeastern BC, January 2015 to January 2017.

Determining what supports moose densities and distribution within and adjacent to BC's Boreal Caribou Ranges is an important step in understanding apparent competition between moose and caribou. Mumma and Gillingham (2016a,b) analyzed fine-scale GPS telemetry data from female and male moose in the Clarke and Fortune Core Areas and the Chinchaga RRA to build seasonal resource selection models. Based on data collected to July 2016, results indicate that while there is variability by season and sex, moose generally selected both coniferous and deciduous uplands, hardwood swamps, and rich fens (Mumma and Gillingham 2016b). More information on results of the study are found in Section 8.1.3 (Anthropogenic habitat alteration).

7.5 Other ungulates

Other ungulate species found in and adjacent to BC's Boreal Caribou Ranges include elk, white-tailed deer, and bison. Mule deer (*Odocoileus hemionus*) occur to the south and west of the Chinchaga Range, and in the foothills and eastern slopes of the Rocky Mountains. While mule deer are found around Toad River, they are not present in the vicinity of Fort Nelson (Z. Dancevik, pers. comm.)

Elk are common in the grasslands and foothills of the Rocky Mountains of the Peace Region, including in the Prophet and Muskwa river valleys. The lower portion of the Muskwa River bisects the Parker Range. Elk occur at lower densities in agricultural lands adjacent to the Chinchaga Range and in the Fort Nelson area. Roughly 50-100 elk are found in the vicinity of the community of Fort Nelson. These animals congregate in large herds in cultivated fields during winter, dispersing short distances to mixedwood forests in summer (Z. Dancevik, pers. comm.).

White-tailed deer are distributed throughout the forests and agricultural lands of the Boreal Plains ecoprovince and are gradually expanding their range northward into the Taiga Plains. Individuals have been observed on multiple occasions in the South Slave Region of the NT (Karl Cox, pers. comm.), with sightings reported as far north as Norman Wells (N 65° latitude), and to N 64° latitude in Yukon (Dawe 2011 *citing* Veitch 2001).

While no inventories have been conducted specifically for elk or white-tailed deer in or adjacent to BC's Boreal Caribou Ranges, densities are very low for both species. No elk or white-tailed deer were observed incidentally during the 2013 moose survey, with almost 4,000 km of transect flown within a combined area of over 14,500 km² (McNay et al. 2013). Only one elk was observed incidentally in the Chinchaga RRA during the January-February 2016 moose survey (Webster and Lavallée 2016). Table 13 lists incidental observations of elk, white-tailed deer, and bison within and adjacent to BC's Boreal Caribou Ranges between 2010 and 2016.

Wood bison were historically present in northeastern BC, but were extirpated in the early 1900s (Harper et al. 2000). A herd of wood bison was reintroduced to the Etthithun Lake area of the Chinchaga Range in 2002 (Rowe and Backmeyer 2006). Since then, the Etthithun wood bison herd has expanded in both distribution and numbers. During an aerial bison inventory in March 2006, 124 bison were counted in eight discrete groups ranging from two to 36 animals (Rowe and Backmeyer 2006). All bison observed during the inventory were within a 20-km radius of their original release site, with habitat use concentrated within sedge meadow complexes and along pipeline right of ways. In March 2009, Thiessen (2009) counted 156 bison between the Fontas River and Cautley Creek in the Chinchaga Range, including two groups (40 animals) on the Alberta side of the border. Thiessen (2009) notes that survey effort was focussed in areas of presumed high quality bison winter range, therefore this count represents the minimum number of wood bison known to be alive in the area and is not an estimate of the total population. Wood bison are now frequently observed in and adjacent to the Milligan and Etthithun Core Areas (D. Culling, pers. observ.).

Table 13. Incidental observations of elk, white-tailed deer, and bison within and adjacent to Boreal Caribou Ranges in BC, 2010-2016.

Range	Species[1]	No.	Observation Type	Source
Parker	ELK	52	2010 Moose Survey Horn River Basin	Thiessen 2010
Parker	WTD	6	As above	Thiessen 2010
Capot-Blanc	WB[2]	2	As above	Thiessen 2010
Parker	WTD	1	2011 beaver lodge survey	Thiessen and DeMars 2012
Chinchaga	WB	49	2013 Moose survey	McNay et al. 2013
Parker	WTD	5	Remote cameras	Matrix Solutions Inc. pers. comm.
Parker	ELK	70	Remote cameras	As above
Parker	BP	71	Remote cameras	As above
Chinchaga RRA	Elk	1	2016 moose survey	Webster and Lavallée 2016
Chinchaga	WB	n/a	Numerous observations of individuals and large groups during BCIP telemetry study field activities and surveys	Culling and Culling (2013, 2014, 2015, 2016) and unpubl. data

[1] ELK = Elk; PB = Plains bison; WB = Wood bison; WTD = White-tailed deer
[2] Two male wood bison from the Nahanni herd were sighted on an island in the Liard River roughly 7 km downstream of the confluence with the Fort Nelson River in the Capot-Blanc Core Area (54.64096°/123.9591°)

In November 2015, motion-sensing cameras were deployed in the Parker Range to monitor large mammal use. Interim results, based on 77 cameras installed across a variety of environmental conditions (i.e., linear features versus game trails) between November 2015 and July 2016, include observations of 232 moose, 506 caribou, 70 elk, 71 plains bison, five white-tailed deer, and no mule deer (J. Fitzpatrick, pers. comm.[10]; Table 13). Observations of plains bison (Figure 11) are assumed to be the result of animals that have escaped from local bison ranches located within 20 km of the Parker Range. The extent and distribution of plains bison in this area is not currently known.

[10] For more information in the project, see: http://www.bcogris.ca/sites/default/files/bcip-2016-17-project-profile-phase-2.pdfhttp://www.bcogris.ca/sites/default/files/remb-webinar-series-2017-02-01.mp4

Figure 11. Image of plains bison in the Parker Range captured by remote cameras, February 2, 2016. (Photo courtesy of Matrix Solutions Inc. and BC OGRIS).

7.6 Beaver

While historic beaver populations were reduced in the early 20th century due to over-harvesting, their distribution has returned to approximately that of pre-settlement times (RIC 1998). Beaver are among the diversity of wildlife species that First Nations relied on in muskeg habitats of northeastern BC (Leech et al. 2016a). That Europeans historically referred to the Dane-Zaa people as the "Beaver" speaks to the regional importance of the species. Densities of bear appear to have been relatively high in northeastern BC in past decades.

Beaver represent an abundant seasonal food source during the wolf denning period that may contribute to increased pup survival and higher densities of wolves than would be expected given the relatively low ungulate biomass found in peatland habitats (Fuller and Keith 1981, Page 1989, Potvin et al. 1991, Hayes 1995, Culling et al. 2006, Latham 2009, Latham et al. 2013). As noted in Section 7.1.3 (Wolf habitat selection in Boreal Caribou Ranges), beaver remains accounted for the majority of items in scat samples collected at wolf den sites in the Snake-Sahtaneh Range (Culling et al. 2006).

As mentioned in Section 7.3 (Other predators), wolverine are known to prey on beaver in peatland habitats in northeastern BC and northwestern Alberta.

In October 2011, Thiessen and DeMars (2012) conducted a stratified random block count to determine beaver lodge densities and to model beaver resource selection in the Parker and Prophet Ranges. Thiessen and DeMars (2012) estimated 157 and 395 active beaver lodges in the Parker and Prophet survey areas, respectively (Table 14). Based on an active colony containing an average of six beavers, Thiessen and DeMars (2012) estimated 942 and 2,370 beavers for the Parker and Prophet survey areas, respectively.

Table 14. Results of October 2011 stratified random block count of beaver lodges in the Parker and Prophet survey areas, northeastern BC.

Survey Area	Estimated No. Active Beaver Lodges	Estimated Density of Active Beaver Lodges	Estimated No. Beaver in Survey Area	Estimated Density of Beaver in Survey Area
Parker	157	0.21 lodges/km^2	942	1.25 beaver/km^2
Prophet	395	0.33 lodges/km^2	2,370	1.98 beaver/km^2

At the fine scale, resource selection functions indicated that beaver selected aquatic habitats and avoided upland deciduous, upland mixedwood, and bog habitats (Thiessen and DeMars 2012). At the landscape scale, beaver habitat selection was best explained by the proportion of bogs, rich fens, and upland conifer forests within 400 m of lodges.

Thiessen and DeMars (2012) also estimated the relative contribution of beaver to overall prey biomass. Moose was the largest contributor to total prey biomass, followed by beaver, caribou and then deer for both Ranges. Beaver densities and the relative contribution of beaver to the overall prey biomass were higher in the Prophet than the Parker Range. Caribou made up less than 10% of available prey biomass in both Parker and Prophet Ranges. Thiessen and DeMars (2012) suggest the role beaver plays as a prey item for wolves may vary across Boreal Caribou Ranges, with a higher proportion of beaver expected in the summer diet of wolves in the Prophet than in the Parker Range.

A second helicopter stratified random block count was conducted by MFLNRO in October 2012 to estimate the relative abundance of beaver in the Prophet, Parker, Maxhamish, Snake-Sahtaneh, Chinchaga, and Calendar Ranges. The data have not yet been analyzed, therefore, density estimates have not yet been calculated (MFLNRO, unpubl. data).

During March 2013 BCIP telemetry study field activities, Culling and Culling (2013) observed fresh beaver activity outside lodges at several sites throughout Core Areas despite over 100 cm of accumulated snow.

While Thiessen and DeMars (2012) found the density of active beaver lodges in the Parker and Prophet survey areas was within the range of densities reported elsewhere in Canada, a survey of the Klua Lake area reported a density of only 0.11 active lodges/km^2 (Poole 1998). As Klua Lake is less than 20 km from the Prophet survey area, Thiessen and DeMars (2012) suggest this difference may be the result of changes in beaver densities over time or variable habitat suitability between study areas. In the Sahtu region, NT, Popko et al. (2002) reported beaver densities of 480 active lodges and 400 inactive (less than 5-yr- old) lodges per 1,000 km^2, respectively.

7.7 Knowledge gaps

Knowledge gaps associated with the interaction of predator and prey species within BC's Boreal Caribou Ranges are discussed in Section 8 (Ecosystems Dynamics).

Since 2010, one multi-species study (DeMars and Boutin 2014), two wolf surveys (Serrouya et al. 2015, 2016), and three moose surveys (Thiessen 2010, McNay et al. 2013, Webster and Lavallée 2016) have provided new information on predator and alternate prey populations in BC's Boreal Caribou Ranges.

Having current and reliable estimates of the abundance of wolves and moose in Boreal Caribou Ranges will support assessment of the efficacy of measures directed at caribou recovery. The development of effective wolf survey methods for the boreal forest (Serrouya et al. 2015, 2016) and application of new methods for surveying ungulates in large landscapes (Thiessen 2010, McNay et al. 2013, Webster and Lavallée 2016) provides opportunities for conducting periodic cost-effective inventories of these species. However, the varying size and habitat composition of individual survey areas can hinder direct comparison between surveys. Establishing standard survey areas for moose and wolves within the BC distribution of Boreal Caribou would allow spatial and temporal comparisons to be made between surveys, and would support parallel research.

Despite the issues associated with trapping harvest data (see Section 7.3: Other predators), it may be useful to explore long-term trapping harvest data for trends in predator and beaver abundance.

8 ECOSYSTEM DYNAMICS

Boreal Caribou population dynamics in BC are driven by a number of interacting factors (Figure 12). While predation is recognized as the proximate cause of Boreal Caribou declines, landscape level habitat alterations, which can disrupt anti-predator strategies, increase predator efficiency and/or abundance, and support higher primary prey densities, are considered the ultimate cause (Seip 1991, Vistnes and Nellemann 2001, McLoughlin et al. 2003, Festa-Bianchet et al. 2011).

The following sections address key dynamics of Boreal Caribou ecosystems in BC.

8.1 Habitat alteration

Habitat alteration on Boreal Caribou Ranges has been linked to population declines (Schaefer 2003, Vors et al. 2007), reduced adult caribou survival (Dunford 2003, Courtois et al. 2007), reduced spatial separation between caribou and other prey or predators (Latham 2009), and reduced range occupancy (Rettie and Messier 1998, Schaefer 2003, Vors et al. 2007, Courtois et al. 2008, Arsenault and Manseau 2011). Boreal Caribou generally exist at low densities, which is likely a consequence of using low productivity environments. Habitat alteration potentially reduces the ability of Boreal Caribou to avoid predators, and to shift areas of use in response to changes in forage supply or natural disturbance.

Both natural and anthropogenic disturbances contribute to habitat alteration on Boreal Caribou Ranges in BC (see Figure 12). While both types of disturbance generally convert areas to early seral habitats, most anthropogenic disturbances also include increased access resulting from roads and other linear features.

Environment Canada (2012) identified critical habitat for Boreal Caribou as: i) the area within the boundary of each Boreal Caribou range that provides an overall ecological condition that will allow for an ongoing recruitment and retirement cycle of habitat, which maintains a perpetual state of a minimum of 65% of the area as undisturbed habitat; and ii) biophysical attributes required by Boreal Caribou to carry out life processes.

In the NT, Nagy (2011) defined secure habitat for Boreal Caribou as unburned areas >400 m from anthropogenic linear features, with population growth rates higher in areas where animals had access to large patches (>500 km²) of secure, unburned habitat.

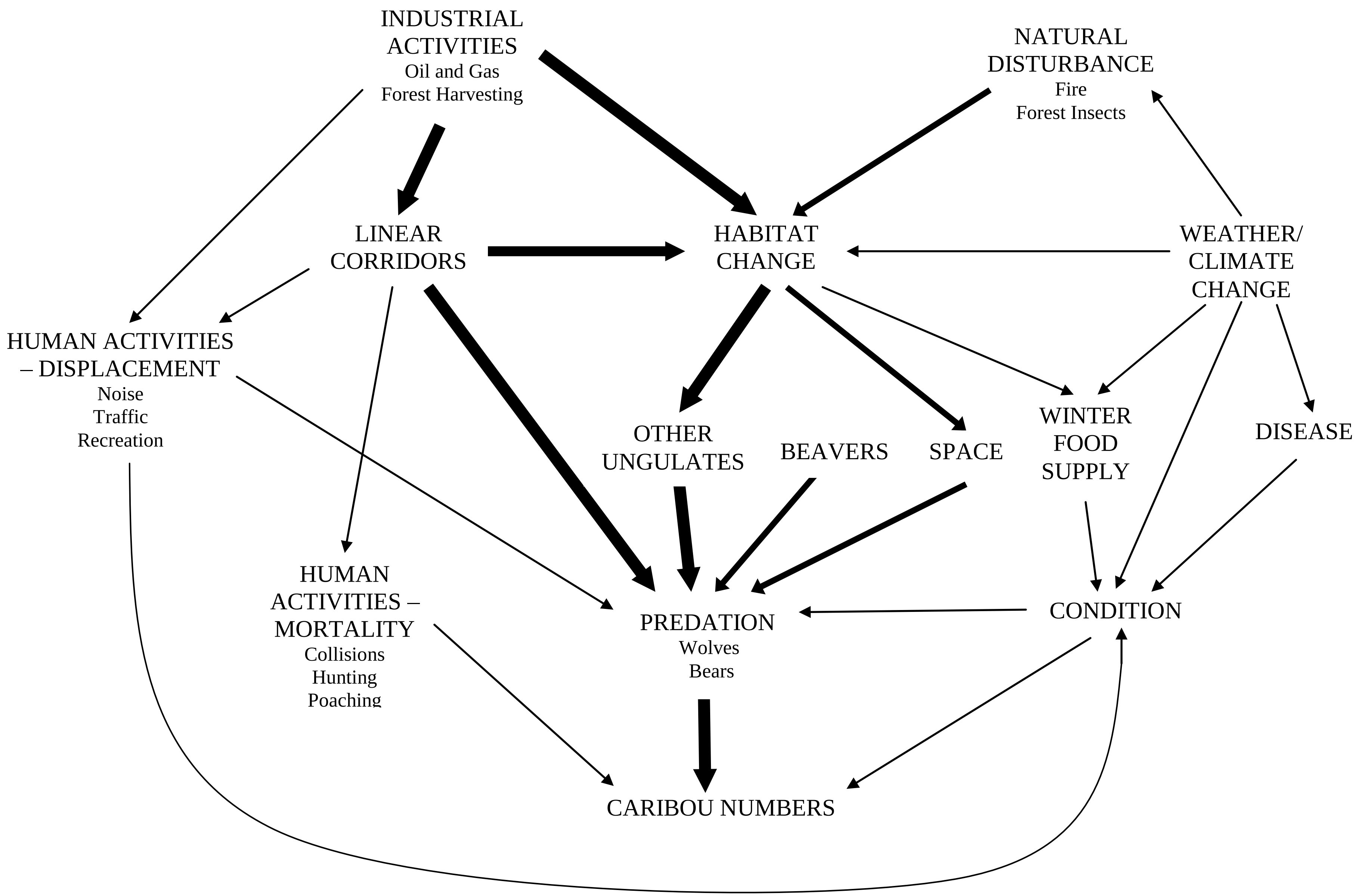

Figure 12. Linkages between factors affecting Boreal Caribou numbers in northeastern BC.
(Thickness of arrows indicates relative contribution)

8.1.1 Habitat alteration levels

Environment Canada's (2012) assessment of habitat alteration levels on Boreal Caribou Ranges across Canada indicated that habitat alteration on all of BC's Boreal Caribou Ranges exceeded the 35% undisturbed threshold identified for critical habitat (Table 15).

Table 15. Percent of BC Boreal Caribou Ranges disturbed by fire and anthropogenic features (from Environment Canada 2012).

Range ID[1]	Percent of Range Disturbed		
	Fire[2]	Anthropogenic[3]	Total[4]
BC1 (Maxhamish)	0.5	57	58
BC2 (Calendar)	8	58	61
BC3 (Snake-Sahtaneh)	6	86	87
BC4 Parker	1	57	58
BC5 Prophet	1	77	77
BC Portion of Chinchaga	n/a	n/a	n/a
AB1 Chinchaga (incl. BC portion)[5]	8	74	76
Fort Nelson Core Area[6]	n/a	n/a	n/a

[1] Range IDs from Environment Canada (2012)
[2] Based on area of fires <40 years
[3] Anthropogenic features were defined as any human-caused disturbance to the natural landscape that could be identified visually from Landsat imagery at a scale of 1:50,000, and included a 500 m buffer
[4] Total disturbance includes the combined area of fire and anthropogenic disturbance; areas where the two types of disturbance overlap are only counted once, and therefore total disturbance in some cases will be less than what would be expected by adding the areas of the two types of disturbance
[5] Environment Canada (2012) currently defines the Chinchaga Range as "AB1 (includes BC portion)" as a transboundary Range that extends across the BC/AB provincial border
[6] The "Fort Nelson Core Area" was initially identified as an "area of interest, but with current status unknown" pending more information (Culling et al. 2004). Preliminary results from the BCIP telemetry study supported its inclusion as a Core Area during the 2015 revision of Range and Core Area boundaries

Environment Canada's (2012) anthropogenic disturbance levels were similar to those calculated by Thiessen (2009) for most of BC's Boreal Caribou Ranges except for Calendar and Parker, which had higher levels of disturbance in Thiessen's (2009) analysis (71% and 68% respectively). Thiessen's (2009) methods differed from Environment Canada's in that Thiessen (2009) used digital data sources and buffered anthropogenic features with a 250 m buffer, whereas Environment Canada (2012) included only those anthropogenic features visible on 1:50,000 scale Landsat imagery and buffered them with a 500 m buffer.

Disturbance levels in Environment Canada's (2012) analysis and in Thiessen's (2009) analysis were based on the landscape prior to 2010 and 2008 respectively, and do not include new disturbances, or recruitment of disturbances into the undisturbed category since then. Environment Canada's (2012) disturbance mapping likely incorporated some recruitment of previously disturbed areas (prior to 2010) into the undisturbed category because it was based on a visual assessment of anthropogenic features rather than digital spatial information. However, it does not provide disturbance dates and therefore is time-consuming to update (requiring a reassessment of each range using updated Landsat images) and difficult to use for projecting habitat recruitment into the future using time-since-disturbance estimates.

Caslys Consulting Ltd. (2015) assessed the use of SPOT imagery to attribute existing anthropogenic features with activity class and to identify and map any unmapped features, and concluded that SPOT imagery could be used for those two purposes.

Currently, there is no consolidated database for habitat alterations in Boreal Caribou Ranges in BC.

8.1.2 Natural disturbance

Boreal forest ecosystems experience frequent large-scale, stand-initiating events such as wildfire and forest insect/disease infestations (MOF and MELP 1997). BC's Boreal Caribou Ranges encompass a diverse array of ecosystems, from the extensive treed peatlands found in the central portion of the Calendar Range and the Fortune Core Area of the Maxhamish Range (Petitot Plain ecosection) and the more heterogenous upland mixedwood and coniferous-dominated forests with pockets of treed peatlands in the Capot-Blanc Core Area (Maxhamish Uplands ecosection) to large patches of lodgepole pine along the south slopes of the Milligan Hills of the Chinchaga Range (Clear Hills ecosection; see Figure 4). If not limited by topographic features, wildfires in the BWBS can be massive, however they typically contain residual patches of unburned mature forest (MOF and MELP 1997). The varying surface forms, accumulation of organic materials, and susceptibility to drought also influence the effects of wildfire on these upland and peatland landscapes (Rowe and Scotter 1973). Given this diversity, the effects of wildfire on Boreal Caribou habitat can vary within and between Ranges.

While considerable research has focused on understanding the effects of wildfire on the structure and function of boreal forests, the effects of burning on boreal peatlands are less well understood (Flannigan et al. 2008). Differences in hydrology and vegetation structure within peatland bog and fen complexes results in variable moisture conditions, fuel structure, rates of fuel consumption, and fire return intervals (Flannigan et al. 2008). Fuel loads vary in peatland bogs due to differences in decomposition and peat accumulation between high, dry hummocks and low, wet hollows (Benscoter et al. 2002). Severe peatland fires may result in the combustion of deep peat layers that can burn for several months and may even burn throughout the winter under snow cover (Flannigan et al. 2008).

Plant community response following wildfire is variable between and within ecosystems. While fire destroys lichens, resulting in short to mid-term impacts on caribou forage lichen supply (Joly et al. 2003), periodic burning rejuvenates older forests on transitional sites where lichen abundance is declining due to increases in competing vegetation such as mosses. However, on sites where mosses are absent or scarce, periodic fires may not be required to reduce competition. In northern Alberta, Dunford et al. (2006) found terrestrial lichen abundance in peatlands recovered after 40 years following wildfire. In contrast to long-term impacts to terrestrial lichen supply, wildfire on more well-drained sites can result in short- to long-term changes to vascular plant communities, including species composition, forage biomass, and forage quality (Lyon et al. 2000, Sittler 2013).

MTK holders observed that while Boreal Caribou generally avoided burned areas for some time, response varied depending on the level of burn and type of fire (Métis Nation British Columbia 2011). For example, some fast-moving crown fires may not include a surface fire component, leaving understory vegetation, including lichens, intact. Wilson and DeMars (2015) found that Boreal Caribou in BC selected for areas close to early seral/immature forest habitats (<50 years), but caution that congregating near edges may be an artefact of mapping or analysis and requires further investigation. In the Snake-Sahtaneh Range, Culling et al. (2006) found Boreal Caribou showed selection for burned habitats (< 50 years) during the snow-free months, with highest use during fall and early winter (mid-September to mid-December). Snake-Sahtaneh caribou were also observed within the perimeter of older fires, both in burned patches and in remnant unburned areas in the late spring and early summer months. Figure 13 shows residual patches of unburned vegetation within the boundary of a large 2014 burn in the Kotcho Core Area.

While Boreal Caribou use of burned areas within 60 years of fire appears to be low (Schaefer and Pruitt 1991, Dalerum et al. 2007), use of burns has been reported in southeastern Manitoba (Darby and Pruitt 1984), northern Alberta (Dunford 2003), and the Mackenzie Valley, NT (Nagy et al. 2005). In Saskatchewan, Boreal Caribou avoided young to mid-successional conifer forests (e.g. jack pine [*Pinus banksiana*] and black spruce ≤40 years) at a coarse spatial scale, but selected young to mid-successional jack pine forests during autumn rut, mid winter and late winter/spring at a fine scale (Stewart 2016). Use of burned areas may vary depending on the amount of area burned, with use of post-fire habitat increasing with greater abundance of wildfire (Dunford 2003) or with greater patchiness of the area within the burn perimeter (Culling et al. 2006). In northern Alberta, Boreal Caribou did not shift home ranges or change home range size in response to fire, presumably as home ranges were sufficiently large to provide adequate habitat and space even with fire disturbance (Dalerum et al. 2007). Knowledge-holders from the Little Red River Cree observed that caribou will leave the area affected by a fire, but return the following year to see if some of the caribou lichen patches survived (Schramm et al. 2002). If a fire is severe, caribou lichen habitat is lost for decades (Schramm et al. 2002).

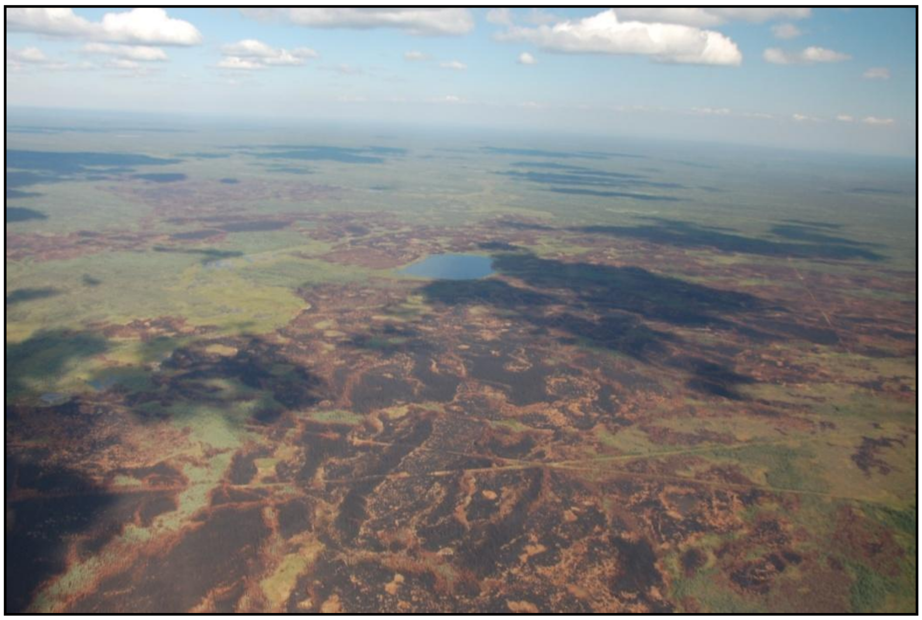

Figure 13. New wildfire with residual undisturbed patches within the burn perimeter, Kotcho Core Area, Snake-Sahtaneh Range, August 2014. (Photo Diane and Brad Culling).

Stewart (2016) suggests that fine-scale selection of post-fire pine forests (<40 years) in Saskatchewan, which make up 39% of the landscape, may be an artefact of caribou having to traverse through these forests as they move between forage sites or forage habitats. For Boreal Caribou Ranges in BC, sites were defined as early seral for up to 50 years post-fire (Culling et al. 2006, Wilson and DeMars 2015). Wilson and DeMars (2015) also included cutblocks in the early seral category. Selection for early seral/burns in those studies could have potentially been for older portions of the early seral category where terrestrial lichens and other stand attributes may have started recovering. Mapping accuracy (e.g. difficulty in identifying spectral signature of cover classes) where poor fens or treed bogs may have been misidentified as early seral could have also potentially contributed.

Natural disturbances also contribute to alternate prey numbers. Moose density on Boreal Caribou Ranges in BC is positively associated with the proportion of burns (Mumma and Gillingham 2016b).

Historically, forest insects have likely played a minor role in disturbance in BC's Boreal Caribou Ranges; however, with increased average winter temperatures and fewer cold weather extremes predicted, forest insect activity is expected to increase as winter temperatures become insufficient to maintain populations at endemic levels (MOE 2015). In addition to the mountain pine beetle (*Dendroctonus ponderosae*; MPB), the eastern spruce budworm (*Choristoneura fumiferana*) may be a concern where mature patches of spruce are found.

The MPB has affected significant portions of some Northern Caribou winter ranges in both BC and Alberta. In recent years, the MPB epidemic has spread from the interior of the province to attack lodgepole pine stands in the northeast. The MPB was first detected on Boreal Caribou Ranges in BC in the Chinchaga Range in 2007, and then spread northward and was detected in most Boreal Caribou Ranges by 2015 (Westfall and Ebata 2007, 2015). Mature lodgepole pine stands within the larger peatland complexes in BC's Boreal Caribou Ranges offer respite from deep snow in late winter (see Section 6.3.1: Closed canopy conifer habitat). Studies on Northern Caribou ranges indicate that initially, dwarf shrub abundance increases and terrestrial lichen abundance decreases following MPB attack (Cichowski and Haeussler 2013, Seip and Jones 2010, Cichowski et al. 2009) but that terrestrial lichen abundance appears to stabilize or increase and dwarf shrub abundance decreases about 10 years following attack (Cichowski and Haeussler 2013). Caribou continued to forage for terrestrial lichens in MPB killed stands following needle loss, up to eight years following attack (Seip and Jones 2010, Cichowski 2010).

8.1.3 Anthropogenic habitat alteration

In the past century, anthropogenic habitat alteration and alienation resulting from agriculture, forestry, and petroleum industry development have dramatically altered the landscape of northeastern BC (Leech et al. 2016b).

Geophysical (seismic) exploration and oil and gas exploration and production are the primary habitat disturbances in Boreal Caribou Ranges in northeastern BC, with linear corridor development associated with seismic line clearing the dominant petroleum industry footprint (Environment Canada 2011). Additional disturbance results from production activities, including lease site construction and development of additional access (all-season and winter roads) and supporting infrastructure. Linear disturbances associated with exploration and production (seismic lines, pipelines, and temporary and permanent access roads) affect significant areas. Linear disturbances have created a legacy footprint that is continually augmented by new development (Figure 14). Until the late 1990s, most seismic lines were cleared using bulldozers and were between 6 and 8 m wide, but by the late 1990s, narrower lines cut using specialized equipment (low impact seismic; LIS) started to become more common (Golder Associates and Explor 2016). Intensive 3-D seismic programs have become increasingly common in recent years. While industry has made important improvements in operational practices and methods over the past few decades, this has been offset by a corresponding increase in the level and intensity of development.

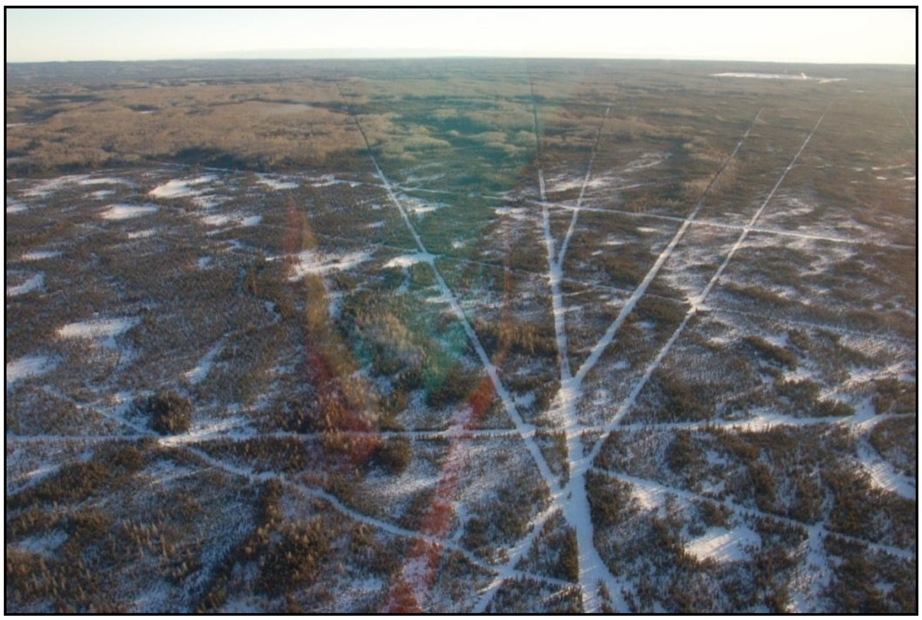

Figure 14. Example of legacy, "cat-cut" seismic lines overlain by recent 3-D seismic grid lines, Kiwigana Core Area, Maxhamish Range, February 2013. (Photo Diane and Brad Culling).

Although harvesting of white spruce, trembling aspen and lodgepole pine stands is the primary forestry activity within BC's Boreal Caribou Ranges (Goddard 2009), relatively little forestry occurs within Core Areas (i.e., peatland habitats).

Industrial activities can affect Boreal Caribou habitat and population dynamics in northeastern BC indirectly through:

- facilitating increased access and search efficiency for predators, particularly wolves, along linear corridors;

- habitat alteration (e.g. loss of mature forests, impacts on lichens, increased forage for other ungulates resulting in higher ungulate densities);
- displacement from preferred or low risk habitats;
- increased energy expenditure; and,
- human-caused mortality including vehicle collisions, poaching, and First Nations' subsistence harvesting (see Figure 12).

Indigenous knowledge-holders attribute caribou population declines to the cumulative impacts of industrial development, particularly loss of intact calving habitat and winter foraging areas, increased access, and increases in wolf populations (Leech et al. 2016a,b; Métis Nation of British Columbia 2011).

Previous studies on anthropogenic disturbances in Boreal Caribou ranges have shown that:

- Boreal Caribou generally avoid roads and other linear features (e.g. seismic lines) where they are able to (James and Stuart-Smith 2000, Dyer et al. 2001, Antoniuk et al. 2007, Fortin et al. 2008, Courbin et al. 2009, Leblond et al. 2011, Nagy 2011, Pinard et al. 2012) often despite availability of preferred habitat (e.g. lichen producing habitat) near those features (Schindler et al. 2007);
- Boreal Caribou use of areas adjacent to linear corridors varied with season and type and age of disturbance (Dyer et al. 2001, Nagy 2011);
- Boreal Caribou avoidance of well sites was greatest during late winter and calving (Dyer et al. 2001);
- physical disturbance from petroleum industry exploration, including roads, drilling sites, and seismic lines, can result in avoidance of habitats well beyond the actual development footprint (Dyer et al. 2001);
- at the landscape level, Boreal Caribou are less abundant in and avoid areas affected by forest harvesting (Rettie and Messier 2000, Courtois et al. 2008, Courbin et al. 2009);
- areas with high levels of disturbance limit the ability of Boreal Caribou to avoid those features (Tracz et al. 2010, Leblond et al. 2011);
- Boreal Caribou demonstrate fidelity to ranges despite high levels of development within them (Faille et al. 2010, Tracz et al. 2010), although caribou displayed reduced fidelity following disturbances, with anthropogenic disturbances (primarily forest harvesting) producing stronger negative responses than natural ones (Faille et al. 2010);
- Boreal Caribou habitat selection appears to be based primarily on habitat, regardless of land use intensity, such that areas selected by

caribou contain suitable habitat but elevated predation risk (Antoniuk et al. 2007);

- log hauling has resulted in displacement of Boreal Caribou (Cumming and Hyer 1998);
- simulated petroleum exploration noise resulted in higher mean movement rates and displacement of Boreal Caribou (Bradshaw et al. 1997);
- linear corridors provide easier access for predators to travel into Boreal Caribou habitat and to prey on Boreal Caribou by increasing connectivity between peatland complexes and predator-rich upland areas (James and Stuart-Smith 2000, Latham et al. 2011b);
- during winter, wolves travelled farther and faster on packed (snow machine trails or ploughed) linear corridors and unpacked linear corridors than in forests (James 1999);
- there was no difference in distance travelled by wolves on packed or unpacked linear corridors, suggesting that ease of movement was not the sole influence on wolf use of linear corridors, but also possibly the longer sight-lines (James 1999);
- wolf locations were closer to linear corridors than random points, and wolves used linear features as travel routes (James 1999; James and Stuart-Smith 2000; Neufeld 2006);
- wolves selected roads and cutblocks (Courbin et al. 2009);
- predation risk was higher for Boreal Caribou found close to linear corridors than for Boreal Caribou found farther away (James and Stuart-Smith 2000);
- the combined land use footprint, rather than specific features, has the greatest influence on mortality of adult Boreal Caribou (Antoniuk et al. 2007);
- revegetation rates on seismic lines are slow (Golder Associates 2012), with recovery of conventional lines (i.e., 5–8 m width, cut using bulldozers using low-blading) varying greatly due to factors such as: forest type, degree of root damage at the initial disturbance, soil compaction, competition from introduced species, drainage, and repeated disturbance from humans (i.e., ATVs, re-entry into industrial sites) or wildlife through the creation of game trails (Lee and Boutin 2006, Golder Associates 2012); and,
- there is poor or no recovery on conventional seismic lines in wet lowland areas even after 30 years (Seccombe-Hett and Walker-Larsen 2004, Lee and Boutin 2006).

There are no summaries of mortalities due to vehicle collisions, hunting, and poaching available for Boreal Caribou in BC, but caribou-vehicle collisions have been reported in other areas of the province (Simpson et al. 1994).

Table 16 outlines recent or current projects conducted on the effects of anthropogenic disturbances on Boreal Caribou Ranges in BC. A number of projects are ongoing and results from those projects may be preliminary or pending. Most studies are assessing functional response of Boreal Caribou and/or predators and/or other prey to anthropogenic features but some are also addressing numerical responses.

Results on anthropogenic disturbances from the study assessing predation risk to Boreal Caribou calves (DeMars and Boutin 2014) are addressed in Section 6.3.2 (Calving habitat).

The ongoing BCHRP is currently exploring linkages between caribou health and condition and habitat alteration (Schwantje et al. 2016). BRFN knowledge holders suggest that the loss of suitable winter habitat increases the susceptibility of caribou to predation as they lack the energy and fat reserves to outrun wolves (Leech et al. 2016a).

With respect to numerical responses to anthropogenic disturbances, based on preliminary results, Serrouya et al. (2016) found that human footprint positively affected wolf density, and negatively affected caribou population rate of change, and that there was an inverse relationship between wolf density and caribou population rate of change. Serrouya et al. (2016) indicate that data are showing potential for statistical significance. Mumma and Gillingham (2016b) did not find a relationship between moose density and anthropogenic disturbance metrics assessed (proportion of cutblocks, density of roads, density of seismic lines) and sample sizes were insufficient to assess interactions between factors. A study has recently been initiated to assess the relative contributions of human development and climate change on Boreal Caribou dynamics, which will include alternate prey and predator distribution and abundance, weather-related impacts on forage and nutrition, and natural disturbances (Serrouya 2015).

With respect to functional responses to anthropogenic features, Wilson and DeMars (2015) found that Boreal Caribou in northeastern BC selected home ranges with low densities of linear features, but that selection of areas relative to linear feature density varied among seasons. During late winter, Boreal Caribou selected their preferred habitats, treed bogs and poor fens, when linear feature densities were as high as 4-8 and 2-4 km/km^2 respectively, but selected rich fens and conifer swamps up to densities of 0-2 and 2-4 km/km^2 respectively. They found no trend with distance to well sites during any season. In the earlier Snake-Sahtaneh study, Antoniuk et al. (2007) found reduced use of areas within 1,000 m of hydrocarbon facilities and consistent avoidance of comparatively active or large land use features, such as roads, wells, and cutblocks. However, response to seismic lines was inconsistent. Caribou in the Chinchaga

Table 16. Recent projects assessing effects of anthropogenic habitat alteration on Boreal Caribou Ranges in northeastern BC.

Project	**Activities completed**	**Current and Planned Activities**
BCIP-2011-01 Assessing spatial factors affecting predation risk to boreal caribou calves (DeMars and Boutin 2014)	• Identified key attributes of calving habitat • Evaluated spatial factors influencing survival of neonate calves (included an assessment of space use by wolves and black bears)	•
BCIP-2014-05 BC Boreal Caribou Health Research Program (Schwantje et al. 2016)	• Conducted assessments on live-captured and dead caribou	• Continue ongoing analysis of boreal caribou health dataset • Test utility of selected stress and immune biomarkers as simplified health assessment and monitoring tools • Undertake a broader evaluation of temporal and spatial relationships between larger-scale (landscape level) factors and caribou health, reproduction and survival.
BCIP-2015-08 Censusing wolves to determine associations between industrial activity and caribou population growth rates (Serrouya et al. 2016)	• Examined how population growth rates of boreal caribou relate to landscape attributes (e.g., degree of human disturbance, proportion of uplands vs. wetlands), ungulate abundance, and wolf abundance.	•
BCIP-2015-09 Assessing caribou survival in relation to distribution and abundance of moose and wolves (Mumma and Gillingham 2016b)	• Built preliminary moose resource selection models using data collected as of July 2016 • Evaluated influence of anthropogenic disturbances on moose densities in NE BC using previously collected moose density data • Finalized analyses exploring the influence of linear features on the probability of a caribou encountering a wolf and the probability of a caribou being killed given an encounter • Evaluated caribou responses to risk of encounter and risk of being killed using resource selection functions	• Add additional new data and re-run resource selection models • Use moose resource selection, wolf risk models, and landscape attributes to model caribou survival at the core and individual level
BCIP-2016-13 Adaptive management of woodland caribou under current and future change to climate and human footprint (Serrouya 2015)	•	• Year 1: develop a 20-year record of winter severity index, icing events, and fire history and forest succession across western Canada • Future years: empirically test multiple mechanisms through which climate and industrialization jointly impact caribou demographics using structured equation models (SEMs) to text relationships among variables.
BCIP-2016-15 Caribou and wolf behaviours in	• Assessed behaviour and calving success of boreal caribou in relation to oil and gas development (MacNearney et al.	• Assess caribou and wolf response to well sites and pipelines at different stages of activity

Project	Activities completed	Current and Planned Activities
relation to oil and gas development (Foothills Research Institute 2015)[1]	2016)	
BCIP-2015-04 Analysis and improvement of linear features to increase caribou functional habitat in west-central and northwestern Alberta (Pigeon et al. 2016)[1]	• Determined how caribou, predators and humans respond to seismic lines at different stages of regeneration • Evaluated whether the zone of influence of linear features changed in relation to the level of regeneration • Assessed how human activity on linear features was affected by landscape attributes and regeneration • Produced spatially explicit models to aid in the prioritization of areas for restoration	•
A Bayesian approach to characterizing habitat use by, and impacts of anthropogenic features on, woodland caribou (Rangifer tarandus caribou) in northeast British Columbia (Wilson and DeMars 2015)	• Used a non-parametric Bayesian analysis to model selection of habitats in their current condition	•
Black bear use of seismic lines in northern Canada (Tigner et al. 2014)	• Used remote wildlife cameras to assess black bear use of seismic lines	•

[1] Project conducted in Alberta portion of Chinchaga Range

Range demonstrated some level of avoidance of areas with >50% disturbance, while wolves did not appear to select habitats based on disturbance levels (Rowe 2007). In the NT, Boreal Caribou avoided areas ≤ 400 m from seismic lines where possible (i.e., where the density of linear corridors was sufficiently low), crossed fewer seismic lines and travelled faster when they crossed them than expected, and, avoided lines during periods when females and calves were most vulnerable to predators or hunters (Nagy 2011).

In the Alberta portion of the Chinchaga Range, MacNearney et al. (2016) found a significant interaction between the phase of development and distance to nearest well site on caribou response, with relative probability of selection decreasing with increased activity at well sites in all seasons. Caribou avoided well sites in the high (development) and moderate (operation) activity phases up to a distance of 3 km. However, MacNearney et al. (2016) were unable to identify a distance at which caribou stopped responding to well sites, which they suggest may be due to the limited availability of undisturbed habitat in the study area. In contrast, Boreal Caribou selected for areas closer to low activity well sites (i.e., abandoned or reclaimed leases) in late winter. While this may provide foraging opportunities, it may increase risk of predation. MTK holders have also observed Boreal Caribou feeding within anthropogenic disturbances, such as reseeded pipelines and reclaimed areas, and bedding down in abandoned lease pads (Métis Nation British Columbia 2011).

In the Alberta portion of the Chinchaga Range, where regeneration height of seismic lines was low (70% <1 m) and 93% of the range is within 500 m of seismic lines, Pigeon et al. (2016) were unable to detect clear regeneration thresholds to identify when caribou and wolf habitat selection patterns were no longer affected by presence of seismic lines. In the Chinchaga Range, Boreal Caribou avoided all types of anthropogenic features, consistently selected for areas further from seismic lines, and used areas closer to seismic lines when they were in areas of high seismic line densities (Pigeon et al. 2016). When Boreal Caribou were using areas closer to seismic lines, they selected for seismic lines with high vegetation height during spring, summer, and early winter and for seismic lines with low vegetation height during fall and late winter (Pigeon et al. 2016). During the snow-free rendezvous season, wolves using areas <62.5 m from seismic lines selected areas near seismic lines with low vegetation height.

In eastern Alberta/western Saskatchewan, wolves travelled twice as fast on conventional seismic lines and pipelines than they did in forests in both summer and winter, but travelled slower on low-impact-seismic lines than in forests (Dickie et al. 2016). In summer, compared to linear features with vegetation <1 m in height, wolf travelling speed was reduced by 23%

by vegetation 1-2 m high, 13% by vegetation 2-5 m high, and 27% by vegetation >5 m high (Dickie 2015). In winter, wolves moved faster when vegetation height was 1-2 m and 2-5 m and did not start moving slower until vegetation was >5 m, at which point they moved 44% slower (Dickie 2015). DeMars and Boutin (2014) found that although wolves generally avoided early seral vegetation and areas of high linear feature density, when using seismic lines, selection depended more on increased movement efficiency, and secondarily on sightability.

In their preliminary resource selection models, Mumma and Gillingham (2016b) found moose response to roads and seismic lines, which are the most widespread anthropogenic disturbance features in northeast BC, varied seasonally and by sex. Resource selection functions will be updated and rerun as more data become available (Mumma and Gillingham 2016b).

In investigating the relationship between linear features and the probability of caribou and wolf encounters and the probability of caribou being killed given an encounter, Mumma and Gillingham (2016b) found:

- the probability of caribou-wolf encounters increased near or in areas with higher densities of roads and seismic lines, in areas with more hardwood swamps and treed bogs, and at lower elevations;
- the probability of a caribou being killed increased in areas with more conifer and hardwood swamps;
- in winter, the probability of being killed decreased in areas with more treed bogs and rich and poor fens;
- in summer, the probability of being killed given an encounter increased in areas with higher amounts of terrain roughness but decreased in areas with more edges between vegetation classes; and,
- there was no relationship between linear features and the probability of being killed in a given encounter.

Tigner et al. (2014) found that black bears in Boreal Caribou Ranges in BC, Alberta and NT used most types of seismic lines more frequently than undisturbed forest interior, but did not appear to use seismic lines ≤2 m wide more often than the forest interior. Black bears used upland forest more than lowland forest, but there was no evidence that black bear use of lowland forests increased as seismic line density increased. DeMars and Boutin (2014) found that black bears generally selected areas with high linear feature density and were closer to early seral vegetation. Tigner et al. (2014) suggest that black bear use of seismic lines could alter their ability to hunt for caribou and other prey, even though seismic lines did not increase black bear use of lowland forests.

Assessing the impact of habitat alteration based on simply quantifying the overall disturbance footprint may underestimate impacts to Boreal

Caribou. Latham (2009) suggests that a few key linear features in a wolf pack's territory may be more important than overall linear feature density. The intelligence and capacity of wolves to learn allows them to effectively take advantage of anthropogenic changes to their environment. Culling et al. (2006) routinely observed wolf use of linear corridors in the Snake-Sahtaneh Range. On one occasion, a pack was tracked visually from the air (i.e., by helicopter) shortly after a fresh snowfall. The fresh tracks revealed that the pack had been systematically hunting a ploughed network of source and receiver lines in an active 3D seismic program in upland mixedwood forest. As the pack moved throughout the area, repeatedly splitting and re-joining at intersecting lines, it effectively created a dragnet, with no ungulate more than 250 m from a potential encounter.

In Alaska, Nellemann and Cameron (1998) found that the greatest incremental impacts to Barren-ground Caribou (*R. t. groenlandicus*) were attributed to initial construction of roads and related facilities. Females and calves were far more sensitive to displacement from surface development than adult males and yearlings, and oil and gas facilities also appeared to displace calving caribou to other areas, which may have led to lower fecundity (Nellemann and Cameron 1998).

8.2 Climate change

Climate change models for northern BC predict increasing average annual temperatures, increasing average winter temperatures, increasing summer precipitation, and a slightly longer summer season extended in both spring and fall (Spittlehouse 2008). Although precipitation is generally predicted to increase, increased evaporation due to increased temperatures could lead to drought conditions in boreal forests in western Canada and drying of peatlands (Price et al. 2013). Sudden, extreme, and intense weather events are also expected.

Impacts of climate change on caribou may include changes in vegetation species composition, increased frequency and severity of natural disturbances, altered species' distributions, increased incidence of diseases and parasites, altered plant phenology, and increased incidence of icing (Vors and Boyce 2009). Over the next 80 years, the majority of BC's Boreal Caribou habitat is predicted to shift from the Boreal White and Black Spruce biogeoclimatic zone to the Interior Douglas-Fir and Ponderosa Pine zones (Hamann and Wang 2006). Although biogeoclimatic conditions are predicted to change, it is unclear how long it will take for species distribution to respond since migration of species is much slower than predicted change in climatic conditions (Price et al. 2013). Warmer temperatures may result in increased productivity in non-peatland habitats, which in turn may result in more favourable habitats for other prey species. Drying of peatlands may result in shifts in vegetation community composition and increased competition from vascular plants and subsequent declines in terrestrial lichen abundance. Increases in the frequency and severity of natural disturbance events, such as wildfire and forest insect infestations, will further alter the landscape within Boreal Caribou Ranges. In BC, overall climate suitability for MPB is expected to shift north to the western boreal forest (Safranyik et al. 2010).

Potential changes in vegetation composition could result in more favourable habitat conditions for other species such as white-tailed deer, which could in turn result in increased predator numbers. Novel or increased prevalence of parasites and pathogens resulting from changing conditions may affect Boreal Caribou health and condition, and increase the risk of disease and parasite transmission. Warmer climatic conditions could lead to earlier green-up, but if timing of calving does not change then caribou may no longer be able to take advantage of the period of highest quality forage availability when the physiological demands of late pregnancy and lactation are greatest (Vors and Boyce 2009).

Climate change could also affect snow conditions, which may alter the ability of Boreal Caribou to move within peatlands during winter, or could affect the permafrost layer resulting in changes in water levels in peatlands and their associated effects on caribou movement and vegetation composition. Warmer temperatures could result in increased snow accumulation if winter temperatures stay below freezing, or reduced snow accumulations and/or increased ice/crusting conditions if temperatures oscillate above and below freezing. Warmer and more erratic winter weather conditions that result in increased frequency of mid-winter freeze-thaw cycles and the formation of hard crust conditions may also impede the ability of Boreal Caribou to forage for terrestrial lichens. Increased ice crusting could also make caribou more susceptible to predation if caribou have difficulty walking in deep, hard-crusted snow while wolves readily travel on top of the crust (Schramm et al. 2002, Dehcho First Nation 2011).

Warmer summer temperatures could also potentially lead to heat stress in Boreal Caribou. Yousef and Luick (1975 *in* Hagemoen and Reimers 2002) found reindeer with access to water were relatively heat tolerant below ambient environmental temperature of 30–35 °C. However, summer maximum daytime temperatures in and adjacent to BC's Boreal Caribou Ranges can exceed this threshold. Between 1981 and 2010, the average daily maximum temperature recorded at the Fort Nelson A weather station (N58°50'11" W 122°35'50")[11] for July was 23.2°C, with the July extreme maximum daytime temperature recorded at 36.7°C; extreme maximum daily temperatures exceeding 30.0°C have been recorded for May through September during that monitoring period. On

[11] http://climate. weather.gc.ca/climate

occasion, daytime temperatures during the late March BCIP telemetry study calf recruitment surveys (2013-2016) fluctuated from a few degrees below freezing in the early morning to the mid-teens (°C) by late afternoon (Culling and Culling 2013, 2014, 2015, 2016). The response of Boreal Caribou to high or rapidly changing ambient temperatures is unknown, particularly during late spring, prior to the loss of the winter coat.

First Nations and Métis knowledge-holders recognize the importance of heat regulation in Boreal Caribou. Members of the Dehcho First Nation believe caribou lay in heavy moss that has permafrost under it in order to stay cool (Dehcho First Nation 2011). One MTK holder interviewed suggested that "with the lack of snow patches, where the caribou like to avoid bugs and heat, later into spring in some areas the caribou are not where they once were" (Métis Nation British Columbia 2011).

Climate change could also impact Boreal Caribou habitat with changes to permafrost (summarized in Price et al. 2013). Except for the southern half of the Chinchaga Range, Boreal Caribou Ranges in BC lie within the zone of discontinuous permafrost (permafrost occupying 50-90% of land area). By warming and melting permafrost, climate change can result in alterations to the hydrological regime, with increased water levels in low-lying areas leading to replacement of forest communities with treeless wetlands. Presence of surface water can lead to further degradation of permafrost. Older black spruce forests with thick organic layers are more resistant to loss of permafrost, while habitat alteration due to fire and anthropogenic disturbances can contribute to permafrost thaw, especially when habitat alteration results in permafrost-free wetlands.

DRFN knowledge-holders suggest observed overall warmer temperatures (including winters), several consecutive years of drought, and mineral licks drying up may be the result of climate change (Leech et al. 2016b).

There are few recent studies that directly assess effects of climate change on Boreal Caribou and their habitat.

The first year of a study recently initiated to assess the relative contributions of climate change and human development on caribou dynamics is focussing on creating climate-related data sets (winter severity, icing events, fire history) across Western Canada (Serrouya 2015). In Québec, Beguin et al. (2013) found that variation in habitat selection by Boreal Caribou was a function of proximity to roads rather than a function of climate. They suggest that Boreal Caribou distribution will continue to be influenced by anthropogenic habitat alteration until the climate changes sufficiently from current conditions.

Rapid freeze-thaw cycles witnessed throughout recent winters created hard crusting conditions in BC's Boreal Caribou Ranges during the BCIP telemetry study. As noted above, daytime temperatures during the March calf recruitment surveys frequently rose to the mid-teens (°C), then fell below freezing each night, creating conditions that could impede caribou movement while allowing wolves to travel easily on top of the snowpack.

Bjerke (2011) found that simulated winter icing on two terrestrial forage lichens, (*Cladonia stellaris, Cladonia rangiferina*) led to decreased photosynthetic and chlorophyll fluorescence rates, indicating that the algal portion of the lichens were dying.

Dawe and Boutin (2016) found that climate change explained 88% of the increase in area occupied by white-tailed deer distribution in Alberta.

8.3 Predator/prey dynamics

A number of projects have been or are currently being conducted in Boreal Caribou Ranges in northeastern BC that include various components of the predator/prey system and relationships among those components (Table 17). In addition, a number of moose inventories (see Section 7.4 Moose) and two beaver surveys (see Section 7.6 Beaver) have been conducted providing information on moose and beaver densities.

Key findings on predator/prey dynamics from those studies include:

- the primary cause of adult female Boreal Caribou mortalities is wolf predation (Culling and Culling 2016);
- wolf predation on adult female Boreal Caribou was typically highest in late winter and spring between March and May (Culling and Culling 2016);
- most mortalities (all causes combined) of adult female Boreal Caribou occurred between March and July (Culling and Culling 2016);
- mortality rate was higher during the long harsh winter of 2012/13 (Culling and Culling 2016);
- adult female Boreal Caribou survival rate was lower for the BCIP telemetry study (2013-2016) ranging from 0.73 to 0.87, than for the Snake Sahtaneh study (2000-2004) which was 0.94 (Culling et al. 2006, Culling and Culling 2016);
- calf recruitment was generally higher for the BCIP telemetry study (2013-2016), ranging from 12 to 21 calves/100 cows, than in March recruitment surveys in 2003 (5 calves/100 cows) and 2004 (9 calves/100 cows) during the Snake-Sahtaneh study, but recruitment was lower during both studies than the 28.9 calves/100 cows recommended by Environment Canada (2012) for population stability (Culling et al. 2006, Culling and Culling 2016);

Table 17. Projects that include information on components of predator/prey systems on Boreal Caribou Ranges in northeastern BC.

Project	**Information on components of predator/prey systems**
Ecology and seasonal habitat selection of Boreal Caribou in the Snake-Sahtaneh watershed, British Columbia (Culling et al. 2006)	• Boreal Caribou demographics (adult female survival, pregnancy rate, seasonal calf survival, calf recruitment, adult female mortality factors) • Boreal Caribou adult female seasonal habitat selection and seasonal movements • Boreal Caribou calving site selection • Wolf habitat selection (summer, neonate period) • Wolf diet (denning sites - scat analysis) • Black bear habitat selection (summer, neonate period)
Snake-Sahtaneh Boreal Caribou study: cumulative effect component (Antoniuk et al. 2007)	• Boreal Caribou adult female habitat selection in relation to anthropogenic features • Boreal Caribou adult female mortality risk
Boreal Caribou and wolf movement and habitat selection within the Chinchaga Range (Rowe 2007)	• Boreal Caribou demographics (adult female survival, seasonal calf survival, calf recruitment) • Boreal Caribou calving site selection • Boreal Caribou habitat selection in relation to disturbance levels (8 adult females, 1 adult male) • Boreal Caribou diet (fecal analysis; disturbance vs. undisturbed) • Wolf movements • Wolf habitat selection in relation to disturbance levels
BCIP Telemetry study (Culling and Culling 2013a, 2014, 2015, 2016b)	• Boreal Caribou demographics (adult female survival, pregnancy rate, calf recruitment, adult female mortality factors)
Assessing spatial factors affecting predation risk to boreal caribou calves (DeMars and Boutin 2014)	• Boreal Caribou demographics (parturition rates, neonate survival) • Boreal Caribou calving site selection • Boreal Caribou adult female seasonal habitat selection • Wolf habitat selection (calving season) • Wolf selection of linear features (calving season) • Black bear habitat selection (calving season) • Spatial factors affecting Boreal Caribou calf survival
Black bear use of seismic lines in northern Canada (Tigner et al. 2014)	• Black bear use of seismic lines • Black bear use of upland forests vs. lowland forests
Censusing wolves to determine associations between industrial activity and caribou population growth rates (Serrouya et al. 2015, 2016)	• Wolf densities • Boreal Caribou population growth rates (pre-existing) • Moose densities (pre-existing) • *Relationship between Boreal Caribou, wolf density, human footprint, land cover (preliminary results)*
Assessing caribou survival in relation to distribution and abundance of moose and wolves (Mumma and Gillingham 2016b)	• Moose seasonal habitat selection in relation to anthropogenic disturbances (female, male) • Influence of anthropogenic disturbances on moose densities (moose densities: pre-existing) • Influence of linear features on the probability of a Boreal Caribou encountering a wolf (summer, winter, juvenile, adult, >10 years) • Probability of a Boreal Caribou being killed given an encounter with a wolf (summer, winter, juvenile, adult, >10 years) • *Boreal Caribou survival in relation to disturbance and abundance of moose (pending)*
Adaptive management of woodland caribou under current and future change to climate and human footprint (Serrouya 2015)	• *Relationship between climate, human footprint and caribou demographics (pending)*
Predicting the Population-Level Response of Boreal Caribou to Seismic Line Restoration (Serrouya 2016)	• *Predicted Boreal Caribou population abundance following restoration of linear features (pending)*

- since the start of the BCIP telemetry study, the population rate of change ranged from 0.78 to 0.97, suggesting that the population is declining (Culling and Culling 2014, 2015, 2016);
- preliminary results suggest that there is an inverse relationship between wolf density and Boreal Caribou population rate of change (Serrouya et al. 2016);
- while caribou used treed peatlands throughout the year and both wolves and bears showed strongest selection for deciduous and mixedwood upland and riparian habitats, there was considerable overlap of use between the species during the May-June neonatal period (Culling et al. 2006);
- although habitat selection by black bears and Boreal Caribou differed during the calving season, calf survival was best explained by predation risk by bears, which was characterized as the density of high quality bear habitat within a 500-meter radius (DeMars and Boutin 2014);
- beaver accounted for the majority (81%) of items in a sample of wolf scats (n=27) collected at den sites, with waterfowl (11%), neonate moose (4%) and neonate caribou (4%) comprising secondary components (Culling et al. 2006);
- moose was the largest contributor to estimated total prey biomass, followed by beaver, Boreal Caribou and then deer in the Parker and Prophet Ranges; Boreal Caribou made up roughly 10% of available prey biomass (Thiessen and DeMars 2012);
- preliminary results indicate that 9 of 11 moose mortalities were suspected or known to be caused by wolf predation, all of which occurred from January to April (BC OGRIS unpubl. data) and that the 2 mortalities in May were not predator-related;
- of two areas surveyed in BC Boreal Caribou Ranges, the highest wolf density corresponded to the survey area with the highest moose density, however, wolf densities in both BC survey areas were 6-7 times higher than expected based on moose densities in those areas (Serrouya et al. 2015);
- preliminary results suggest that human footprint positively affected wolf density and negatively affected Boreal Caribou population rate of change (Serrouya et al. 2016);
- moose density was positively associated with proportion of burns, but there was no relationship between moose density and proportion of cutblocks, density of roads or density of seismic lines (Mumma and Gillingham 2016b);
- the probability of a caribou being killed given an encounter with a wolf increased in areas with more conifer and hardwood swamps in both summer and winter, and in winter decreased in areas with more treed bogs and rich and poor fens (Mumma and Gillingham 2016b);

- black bears used most types of seismic lines more frequently than undisturbed forest interior (Tigner et al. 2014);
- black bears generally selected areas with high linear feature density and were closer to early seral vegetation (DeMars and Boutin 2014);
- there are no estimates of abundance of white-tailed deer in Boreal Caribou Ranges in BC but they are known to be present in the Chinchaga and Parker Ranges and in the vicinity of Fort Nelson, and are likely expanding northward (see Section 7.5 Other ungulates);
- elk are present in agricultural lands south of the Chinchaga Range, and along the valleys and foothills on the western edge of Boreal Caribou distribution in BC, including the Muskwa River valley, which bisects the Parker Range; approximately 50-100 elk are found in the vicinity of Fort Nelson (see Section 7.5 Other ungulates);
- approximately 150 wood bison are present in the Chinchaga Range (see Section 7.5 Other ungulates);
- several plains bison have recently been detected in the Parker Range (see Section 7.5 Other ungulates); and,
- little is known about other potential predators including wolverine, cougars and lynx (see Section 7.3 Other predators).

Consistent with other studies of Boreal Caribou mortality (Stuart-Smith et al. 1997, Rettie and Messier 1998), during the BCIP telemetry study, the primary cause of adult female mortality in Boreal Caribou Ranges in BC was wolf predation (Culling and Culling 2016). Preliminary results suggest that there is an inverse relationship between wolf density and Boreal Caribou population rate of change (Serrouya et al. 2016). Most of the adult female mortality due to wolf predation occurs from March to May (Culling and Culling 2016), while preliminary results suggest that adult moose mortality due to wolf predation occurs primarily during mid and late winter from January to April (BC OGRIS unpubl. data).

Currently, predators other than wolves appear to play a relatively minor role in adult female Boreal Caribou mortality in northeastern BC. During the BCIP telemetry study, 3 mortalities were due to wolverine predation (Culling and Culling 2016) and during the Snake-Sahtaneh study, 1 mortality was suspected to be due to black bear predation (Culling et al. 2006). Black bear predation has also been observed as a minor component of Boreal Caribou adult female mortality in other areas (Rettie and Messier 1998, Schaefer et al. 1999). Cougars have not yet been implicated in any Boreal Caribou mortalities in BC, but expanding white-tailed deer populations could result in increased cougar abundance on BC Boreal Caribou Ranges in the future. In Alberta, cougar numbers have increased and their distribution has expanded northward (Knopff et al.

2014), coincident with increased abundance and a northward range expansion of white-tailed deer (Latham et al. 2011c, Dawe and Boutin 2016). In northeastern BC, cougar sightings are increasing in the vicinity of the Peace River valley, which supports high densities of white-tailed and mule deer. Cougars are a significant predator on caribou in southeastern BC (Kinley and Apps 2001). Lynx have also not been implicated in Boreal Caribou mortalities in northeastern BC, however, an unsuccessful lynx attack on a young adult male caribou travelling along a ploughed road was observed in the Snake-Sahtaneh Range in the deep snow winter of 2013 (Culling and Culling 2013). The lynx opportunistically used a high snow berm at the edge of the right-of-way to jump onto the passing caribou (which was being herded by the helicopter), but was unable to hang on. There are accounts of lynx ambushing adult ungulates, including caribou, by jumping on their backs and killing them with bites to the nape of the neck (Naughton 2012).

Although RSF models found neonate calf survival was best explained by predation risk due to black bears (DeMars and Boutin 2014), little direct evidence of causes of calf mortality are available. While no formal studies on causes of calf mortality have been conducted in BC's Boreal Caribou Ranges, Culling et al. (2006) reported evidence of wolves preying on caribou calves. Both black bears and wolves overlap with Boreal Caribou during the neonatal period (Culling et al. 2006, DeMars and Boutin 2014) and can be potential sources of calf mortality. Black bear predation accounted for 57% of Boreal Caribou calf mortalities in Québec (Pinard et al. 2012) and was suspected as a significant source of calf mortality in Saskatchewan (Rettie and Messier 1998). Wolf predation is thought to be a significant mortality factor for Boreal Caribou calves. In Alberta, wolf control resulted in increased calf recruitment on the Little Smoky Boreal Caribou range (Hervieux et al. 2014). During the denning season, beaver comprised the majority of items in a sample of wolf scats collected at den sites in the Snake-Sahtaneh Range; the proportion of waterfowl remains in the sample exceeded that of ungulate (moose and caribou) calf remains (Culling et al. 2006). In northeastern Alberta, Latham et al. (2013) found beaver to be an important driver of seasonal changes in wolf resource selection, with the hunting of beaver by wolves resulting in reduced spatial separation between wolves and caribou during summer.

No information is available on the diet of wolves in Boreal Caribou Ranges in northeastern BC during seasons other than spring, and little is known about abundance or relative abundance of other prey species, other than moose. In northeastern Alberta, Latham et al. (2013) suggest that apparent competition may be resulting in increased predation pressure on caribou as wolves seasonally switch predation effort between moose, white-tailed deer, and beaver. The importance of each prey species in wolf diets varied seasonally, with wolves selecting for areas used by each respective prey species. Moose were used consistently throughout the year, with deer and beaver most abundant in wolf diets during winter and summer, respectively. Similar to the pattern of Boreal Caribou adult female mortality observed in northeastern BC (Culling and Culling 2016), the majority of caribou mortalities occurred in summer, when spatial overlap between wolves and caribou was highest while wolves hunted beaver. Latham et al. (2013) also found there was potential for greater spatial overlap between wolves and caribou in peatland habitats during the transitional months between winter and summer. Wolves are frequently seen near beaver impoundments during the snow-free season.

Although wolf predation is the primary cause of Boreal Caribou mortality in BC (Culling and Culling 2016), wolves are usually sustained by moose or other prey, with Boreal Caribou a secondary prey species (Festa-Bianchet et al. 2011). As noted previously, Serrouya et al. (2015) found that for two survey areas in BC, the highest wolf density corresponded to the survey area with the highest moose density, however, wolf densities in both BC survey areas were 6-7 times higher than expected based on moose densities in those areas. They suggested that the results could potentially be due to 1) an underestimate of moose density; 2) wolves being sustained by another food source that had not been accounted for; and, 3) inclusion of edge packs in the final estimate. They further suggested that wolf diet analysis could show if other prey should be considered in biomass equations, and that moose estimates be updated.

Preliminary results suggest that the probability of a caribou being killed given an encounter with a wolf increased in areas with more conifer and hardwood swamps in both summer and winter, and in winter decreased in areas with more treed bogs and rich and poor fens (Mumma and Gillingham 2016b).

Potential expansion of distribution and abundance of other prey and predator species could result in additional changes to predator/prey dynamics in Boreal Caribou Ranges in BC.

Since being reintroduced into the Etthithun Lake area in 1999, wood bison have subsequently expanded into the Fontas and Milligan areas (Thiessen 2009). Given the recent return of the species after almost a century of extirpation, caribou-bison interactions in the Chinchaga Range are not well understood (Leech et al. 2016b). However, DRFN knowledge-holders did not note any significant negative interactions between Boreal Caribou and other ungulates, as caribou are understood to use different habitat (Leech et al. 2016b).

Wood bison and Boreal Caribou were seen cratering in close proximity in the Milligan and Etthithun Core Areas on numerous occasions during

BCIP telemetry study field activities (D. Culling, pers. observ.). Harper et al. (2000) note that while there is little dietary overlap between wood bison and other large ungulates within the species' historic range, there is some potential for spatial/temporal competition for forage items that represent a minor component of the bison diet in areas where those items may be limited. In the NT, Larter (1988) found the summer growing season diet of wood bison was a diverse mix of sedges, grasses and willow (*Salix* spp.), with lichen (*Cladina mitis*) becoming a major dietary component during fall (52% of the October diet). In the Yukon, Jung et al. (2015) found lichens to comprise <1.5% of wood bison summer and winter diets. Jung and Czetwertynski (2013) concluded that there was little potential for wood bison and caribou competition based on a combined assessment of seasonal diet, habitat and spatial overlap.

8.3.1 Effects of habitat alteration on predator-prey dynamics

Habitat alteration can affect predator/prey dynamics through changes in prey and predator abundance and distribution, increased predator efficiency, and increased access for predators and humans. As noted previously, recent studies reveal interaction of factors, including:

- human footprint positively affected wolf density and negatively affected Boreal Caribou population rate of change (Serrouya et al. 2016);
- with increased anthropogenic disturbance, the spatial overlap between wolves and caribou increased as did the caribou component of the wolf diet (Latham et al. 2011c);
- moose density was positively associated with proportion of burns, but there was no relationship between moose density and proportion of cutblocks, density of roads or density of seismic lines (Mumma and Gillingham 2016b);
- black bears were found to use most types of seismic lines more frequently than undisturbed forest interior (Tigner et al. 2014), and,
- black bears generally selected areas with high linear feature density and were closer to early seral vegetation (DeMars and Boutin 2014).

Results of Tigner et al. (2014) and DeMars and Boutin (2014) suggest black bears could be using seismic lines for travel and/or for foraging, and as a consequence could be coming into closer contact with Boreal Caribou.

Another possible effect of habitat alteration may be the concentration of caribou into undisturbed patches, resulting in bigger group sizes, which may affect seasonal predation risk from wolves. As noted previously, Boreal Caribou in BC are widely dispersed in the snow-free season, but are found in fluid groups of varying size throughout the fall and winter

(Culling and Culling 2006, 2017; D. Culling pers. observ. from BCIP telemetry study). Based on field observations and March surveys during the BCIP telemetry study, it is not unusual to find multiple animals, which were radio-collared at different times and locations, concentrated in large groups in late winter, particularly when snow pack is high. As caribou population size decreases, animals tend to occupy less of their range (Bergerud 1996, Schaefer 2003), often contracting into the best habitat. Contracting distribution of Boreal Caribou within Ranges may lead to increased vulnerability to wolf predation, particularly if anthropogenic disturbance facilitates improved predator efficiency (see Section 8.1.3 Anthropogenic habitat alteration) and access into favoured caribou winter habitats. In late winter 2013, the deep and hard-crusted snowpack impeded caribou movement but allowed wolves to travel easily on top of the snowpack (see Appendix 12). With caribou concentrated in small habitat patches, wolves that encountered those patches had the opportunity to kill more caribou since more caribou were finding refuge in them.

8.4 Knowledge gaps

Since 2010, a number of studies have been or are currently being conducted on habitat alteration and/or predator/prey dynamics in Boreal Caribou Ranges in BC. Wolf predation has been identified as the primary cause of mortality of adult female caribou (Culling and Culling 2016) and predation risk due to black bears has been linked to calf survival (DeMars and Boutin 2014). However, wolf and black bears are not sustained by Boreal Caribou and available estimates of moose abundance suggest that estimated moose numbers are not sufficient to sustain estimated wolf numbers (Serrouya et al. 2015).

Knowledge gaps for predator/prey dynamics and habitat alteration include:

- seasonal diets of wolves (what is driving wolf population numbers?);
- the primary cause of Boreal Caribou calf mortality;
- the significance of available early seral habitat on linear features to moose abundance;
- the significance of available early seral habitat on seismic line, access and pipeline right-of-ways to the relative abundance of black bears, and thus predation pressure on adult and juvenile caribou within BC's Boreal Caribou Ranges; and,
- the abundance/relative abundance of alternate prey species other than moose.

In addition to knowledge gaps, a digital inventory of habitat alterations on Boreal Caribou Ranges should be developed and periodically updated.

Although there is increasing spatial overlap of Boreal Caribou and wood and plains bison in the Chinchaga and Parker Ranges, respectively, it is unknown whether bison represent a significant source of competition for the lichen forage base. Wolves, grizzly bears, and black bears are known to prey on bison (Harper et al. 2000), therefore the recent appearance of bison in Chinchaga and Parker may enrich the ungulate prey base and potentially contribute to apparent competition within Boreal Caribou Ranges.

9 HABITAT RESTORATION

Habitat restoration can be defined in terms of habitat structure/ composition and habitat function (Ray 2014). Restoration of habitat structure/composition focuses on restoring vegetation and site characteristics and initially, was the primary focus of restoration activities. Habitat structure/composition restoration includes mechanical site preparation (e.g. mounding, ripping), spreading of coarse woody debris, and tree/shrub planting (Pyper et al. 2014, Golder Associates 2015a). Restoration of habitat function, which has become the focus of more recent restoration activities, aims to reduce predator efficiency (predator mobility, line of sight), human activities, and alternate prey forage/habitat. Habitat function restoration includes mechanical site preparation, tree/shrub planting, spreading of woody material, tree felling/tree bending, and installing fences (Pyper et al. 2014, Golder Associates 2015a).

To be effective for caribou, restoration activities should result in a behavioural response (e.g. increased use by caribou) and a population response (e.g. increased caribou survival). This would require both a behavioural response (e.g. reduced mobility and/or use) and population response (reduced numbers) by predators and alternate prey as well (Ray 2014).

Habitat restoration is especially important where conditions are challenging for natural regeneration to occur. Recent studies (Bayne et al. 2011, van Rensen et al. 2015, Kansas et al. 2015) support earlier studies that found poor or no recovery on seismic lines in wet lowland areas (see Section 8.1.3 Anthropogenic habitat alteration). Van Rensen et al. (2015) predicted disturbed fens were unlikely to regenerate to a 3-m height even after 50 years.

In BC, five projects have or are currently addressing effectiveness of structure/composition (1) or functional (4) habitat restoration (Table 18).

Table 18. Recent projects assessing restoration of linear features on Boreal Caribou Ranges in northeastern BC.

Project	Activities completed	Current and Planned Activities
Structure/Composition		
BCIP-2016-18 Natural Recovery on Low Impact Seismic Lines in Northeast British Columbia (Golder Associates and Explor, 2016)	• Collecting data on recovery of mulched low-impact seismic (LIS) lines • Collecting natural structure/composition data along LIS lines including influence of light penetration, soil conditions, disturbance, compaction	•
Functional		
BCIP-2016-17 Developing and monitoring the Efficacy of Functional Restoration of Linear Features for Boreal Woodland Caribou (De Witt et al. 2016)	• Sampling design developed • Motion-sensitive monitoring cameras deployed at disturbed (linear features) and undisturbed (game trails) sites	• Collecting data on rates of habitat use at camera monitoring sites as part of the Parker Caribou Range Boreal Caribou Restoration Pilot Program (Golder Associates 2016)
BCIP-2016-10 Testing Functional Restoration of Linear Features within Boreal Caribou Range (DeMars and Benesh 2016)	• Framework developed • Tree felling and fencing identified as promising techniques	• Testing techniques at a small scale (individual lines) using remote cameras and GPS radio-telemetry locations to monitor wolf use (Year 1) • Evaluating effective techniques on their efficacy in excluding predators from defined areas (sample blocks/areas) using remote cameras and GPS radio-telemetry locations to assess wolf use and movement rates (Year 2) • Deploying techniques over >50% of a wolf pack's territory to determine their efficacy in limiting wolf movement rates, kill rates, and productivity using GPS radio-telemetry locations, den site monitoring and periodic aerial counts
Restoring Functional Caribou Habitat: Testing Linear Feature Mitigation Techniques in Northeast BC (Bohm et al. 2015)	• Snow fences established along seismic lines • Deployed remote cameras at treatment and control sites	• Deploying GPS collars on wolves to assess wolf movements
BCIP-2016-11 Predicting the Population-Level Response of Boreal Caribou to Seismic Line Restoration (Serrouya 2016)	•	• Define a model containing Ordinary Differential Equations (ODEs) • Conduct simulations using the model that vary the abundance of seismic lines and travel speed • Conduct sensitivity analysis for all parameters

One study assessed natural regeneration on mulched low-impact seismic lines (Golder Associates and Explor 2016). Results include:

- controlling for forest type, LIS lines typically support shrubs >0.8 m high within 10 years;
- overall vegetation height was greater on:
  - lines that were oriented north-south;
  - lines with no mulch or clumped mulch, compared to lines with continuous mulch; and,
  - lines in deciduous uplands compared to wetlands, lowlands and upland coniferous sites;
- black spruce seedling height was greater on:
  - narrower lines;
  - lines in lowland stands versus upland coniferous stands; and,
  - on lines with continuous mulch compared to scattered mulch;
- black spruce seedlings were more likely to occur on older rather than younger lines, and on east-west oriented lines;
- willow was more likely to occur on wider lines and on lines with scattered mulch compared to a continuous distribution;
- alder was more likely to occur on:
  - lines in upland deciduous sites than wetlands;
  - on younger versus older lines; and,
  - on wider lines;
- alder and willow height were greater on older lines;
- alder and willow abundance was greater on wider lines;
- alder abundance was greater on lines than in adjacent stands, but willow abundance was similar; and,
- LIS lines supported fewer game trails (16% of lines) than conventions seismic lines in the region (64% of lines).

Although four studies address functional habitat restoration, results of effectiveness of techniques are still mostly forthcoming. DeWitt et al. (2016) have developed a sampling design and have deployed motion-sensing cameras to collect pre-treatment data on wildlife and human use; however, habitat restoration treatments have not yet been conducted. The study is designed to assess restoration activities associated with the Boreal Caribou Restoration Pilot Program on the Parker Range (Golder Associates 2015b, 2016). DeMars and Benesh (2016) developed a framework for assessing wolf response (use, movement rates, productivity) to habitat restoration techniques at incrementally larger scales over a three- year period. However, the framework has yet to be implemented. They also assessed tree felling and fencing as two of the most promising techniques for functional restoration of seismic lines. Bohm et al. (2015) tested effectiveness of snow fences from August 2014 to January 2015 along seismic line intersections and concluded that they were not effective in excluding predator use of intersections. Several factors may have influenced results, including small sample size (14 wolf encounters) and the use of lures at line intersections, which may have been too strong of an attractant for the snow fences to act as a deterrent (Bohm et al. 2015). Also, the study only assessed wolf use and did not assess wolf movement rates. One key finding was that snow fences deployed in the summer were buried, pushed over and ripped by snow, and so would likely be ineffective during winter months. A fourth study predicting the population-level response of Boreal Caribou to seismic line restoration is still underway (Serrouya 2016).

A number of habitat restoration projects for Boreal Caribou are also being conducted in Alberta. Most projects have focussed on restoring structure/composition, and using woody debris manipulations for restoring both structure/composition and function (Pyper et al. 2014). Functional habitat restoration techniques using line blocking or fences have been used in three project areas. In their review of habitat restoration projects in Alberta, Pyper et al. (2014) categorized habitat restoration techniques as: those that were working (mounding, ripping, rollback and coarse woody material, tree felling, summer planting, winter planting); those that were not working (tree hinging, tree transplants); and, those that were still being tested (tree bending, line blocking, fencing, bar mounding, angle slicing). Most projects have been monitoring vegetation response to treatments, while projects that are monitoring functional response have generally focussed on wildlife use and to a lesser extent on wolf movements. Only one project includes monitoring of population response (Pyper et al. 2014).

The *Boreal Caribou Habitat Restoration Operation Toolkit for British Columbia* provides prescriptions for conducting mechanical site preparation, tree/shrub seedling planting, spreading of woody material, tree felling/bending and installing wooden fences (Golder Associates 2015a).

A recent advance in monitoring habitat restoration is the use of techniques such as LiDAR, or Ladybug®5 360 photography in assessing height of regenerating vegetation, which have been used to assess height of natural regeneration on seismic lines (van Rensen et al. 2015, Golder Associates 2016, MacNearney et al. 2016). In addition, SPOT imagery was tested to identify potentially overgrown features, which were defined as sites where <30% of the feature was captured by the model (Caslys 2016). Caslys (2016) concluded that restoration status attributes could be successfully derived from SPOT imagery but that the model needs to be adjusted when existing feature boundaries do not match the disturbance footprints visible in the SPOT imagery. The Ladybug®5 360 imagery was interpreted by tree species; however, the LiDAR and SPOT imagery methods did not distinguish between deciduous and coniferous species, and therefore do not provide a measure of the amount of potential moose forage. The SPOT imagery method did not provide a measure of height and therefore an "overgrown" state appears to correspond to percent vegetation cover regardless of height. None of the methods provide an estimate of vertical structure or information on trails that might be present under the vegetation cover. Tigner et al. (2014) found distinct game trails on 50% of the seismic lines sampled, and on 64% of seismic lines that they classified as "closed".

Restoration efforts need to address both structural and functional components of disturbed areas including: caribou forage, alternate prey forage, alternate prey use, predator hunting efficiency and use, and human use. Therefore, techniques for assessing restoration status need to address all components that affect habitat effectiveness for caribou. For example, height thresholds that do not consider vegetation species do not address the effects of alternate prey forage. Dickie (2015) recommends restoring vegetation on linear features to a height of at least 5 m (which reduced wolf travelling speeds to nearly the same as those in surrounding forests) for the purpose of reducing wolf use and movement, but cautions that it is important to consider when linear features become functionally restored for caribou.

With respect to prioritization of restoration efforts, Dickie et al. (2016) recommended focussing on conventional seismic lines and pipelines, where wolves travelled twice as fast as they did in forests, and not on low-impact-seismic lines, where wolves travelled slower than in forests.

9.1 Knowledge gaps

There are a number of projects that are currently being conducted that will aid in identifying the most effective techniques for restoring vegetation under various site conditions. An increasing number of studies are assessing wildlife behavioural response (use, wolf movements) to various structure/composition and functional habitat restoration techniques. While important advances have been made, knowledge gaps include:

- what conditions (e.g. shrub height, shrub abundance) are required on linear features for functional restoration with respect to moose forage;
- what are the most effective functional and/or structure/composition habitat restoration techniques that will result in desired behavioural responses by predators and alternate prey (e.g. reduced use, impeded wolf movements, reduced predator efficiency) over both the short term and long term?
- what are the most effective functional and/or structure/composition habitat restoration techniques that will

result in desired population responses by predators and alternate prey (e.g. reduced survival and/or abundance) and by Boreal Caribou (e.g. increased survival and abundance)?
- what scale of habitat restoration is required to result in desired population responses by predators, alternate prey, and Boreal Caribou?

Currently, some information is available on vegetation height that results in reduced wolf movement rates on linear features (Dickie 2015), however, similar information is required to assess conditions that make linear features unattractive to moose for foraging.

Another knowledge gap is whether restoration activities may unintentionally predispose restored areas to wildfire. For example, heavy loads of coarse woody debris from tree felling coupled with young regenerating conifers could result in hotter burns if ignited.

10 SUMMARY OF KNOWLEDGE GAPS

Since 2010, numerous projects have contributed to a better understanding of Boreal Caribou dynamics in northeastern BC. Information collected has included:

- traditional ecological knowledge of DRFN, BRFN, members of the MNBC, and First Nations from the NT and Alberta;
- annual monitoring (2012-2016) of radio-collared caribou distribution, calf recruitment, and adult female mortality rates and causes;
- health, body condition and pregnancy rates of adult female caribou captured during radio-collaring sessions;
- an assessment of spatial factors affecting predation risk to calves;
- wolf census in the Calendar and Parker Ranges and the Chinchaga RRA (January-February 2015) and in the Clarke Core Area (December 2015);
- distance sampling to estimate moose abundance in 2010 in Parker, Paradise, Kiwigana, Tsea, Fortune West, Fortune East, Calendar, and Capot Blanc Core Areas;
- distance sampling to estimate moose abundance in seven Core Areas and the Chinchaga RRA in 2013;
- distance sampling to estimate moose abundance in the Fortune and Clarke Core Areas and Chinchaga RRA in 2016;
- a beaver survey in the Prophet and Parker Ranges in October 2011,
- a beaver survey in the Prophet, Parker, Maxhamish, Snake-Sahtaneh, Chinchaga, and Calendar Ranges in 2012;
- Boreal Caribou behaviour and calving success in relation to oil and gas development;

- foraging trials using tame, adult female caribou to evaluate summer food habits and diet selection, and forage value in plant communities in boreal, montane, and alpine ecosystems;
- natural regeneration on low impact seismic lines;
- testing functional restoration of linear features;
- caribou survival in relation to distribution and abundance of moose and wolves (not yet completed);
- efficacy of functional restoration of linear features (not yet completed); and,
- predicting population level response to seismic line restoration (not yet completed).

Population information collected for Boreal Caribou in BC since 2010 indicates that calf survival continues to be low, and that pregnancy rates and adult female survival is lower than during studies conducted in the 2000s. Although population size is difficult to determine for Boreal Caribou, low adult and calf survival rates suggest that populations are declining. While wolf predation is the primary source of mortality for adult caribou, information on overall distribution and abundance of wolves in BC Boreal Caribou Ranges is still lacking. Little information is available on cause of calf mortality, however, based on resource selection models, calf survival is best explained by predation risk from black bears, and Culling et al. (2006) reported evidence of wolves preying on caribou calves..

Habitat alteration leading to higher densities of alternate prey and predators, increased predator efficiency, and disrupted anti-predator strategies is considered the ultimate cause of Boreal Caribou declines. Information on habitat alteration collected since 2010 indicates that females with neonate calves avoid landscapes associated with increased predation risk, including upland deciduous forests and areas of natural and anthropogenic disturbance. If avoidance of disturbed areas results in females selecting secure habitats over those with higher forage quality, habitat alteration may also play a role in Boreal Caribou health and body condition. Ongoing studies on habitat restoration have not yet provided information on the effectiveness of functional restoration of linear features.

Although an extensive body of information has been collected since 2010, knowledge gaps still exist, with some gaps identified by studies conducted during the last 5 years. Priority knowledge gaps include:

- What is supporting wolf abundance in Boreal Caribou Ranges?

  What is sustaining wolves in areas where high wolf densities are not explained by moose abundance (e.g. Calendar Range, the Chinchaga RRA)?

- What is the primary cause of Boreal Caribou calf mortality?

  Successful Boreal Caribou recovery requires determining sources of calf mortality. Previous studies have captured Northern Caribou neonate calves by hand or netgun (Gustine et al. 2006). However, in contrast to *Rangifer* species and ecotypes that calve in open alpine/subalpine or tundra habitats, BC's Boreal Caribou calve in habitats where capture of neonates is difficult, if not impossible. Therefore, novel approaches to addressing this question are required.

- Are there differences in habitat selection and movements among Boreal Caribou Ranges?

  Habitat selection analyses for Boreal Caribou in BC have been conducted for all Ranges combined. However, there is considerable variation in ecological conditions between Ranges, and broadscale analyses could potentially mask Range-specific habitat selection.

- What is the current condition (forage, habitat alteration) of Boreal Caribou Range in BC?

  DeMars and Boutin (2014) suggest further investigation of range condition may be warranted to investigate the effects of climate-induced habitat changes and/or decades of fire-suppression on the distribution, abundance, and quality of terrestrial lichen. The current research collaboration between Cook and Cook (NCASI) and the BC and NT governments will contribute to a greater understanding of Boreal Caribou habitat (forage) condition in BC. To complement information on range/forage condition, information on forage accessibility is also needed.

- What scale of habitat restoration is required to result in desired population responses by predators, alternate prey, and Boreal Caribou?

  What are the most effective functional and/or structure/ composition habitat restoration techniques that will result in desired behavioural responses by predators and alternate prey (e.g. reduced use, impeded wolf movements, reduced predator efficiency) over both the short term and long term? and

  What are the most effective functional and/or structure/composition habitat restoration techniques that will result in desired population responses by predators and alternate prey (e.g. reduced abundance) and by Boreal Caribou (e.g. increased survival and abundance)?

How does configuration of linear features (as opposed to density) affect wolf predation on caribou?

Continued monitoring of Boreal Caribou calf recruitment, and adult mortality rates and causes is needed to understand Boreal Caribou dynamics under varying and changing environmental conditions, and to continue to track population status, which currently appears to be declining.

Reducing encounter rates between Boreal Caribou and their predators is a priority action. This will require addressing both the density and distribution of predator and alternate prey species within and adjacent to Boreal Caribou Ranges (i.e., numerical responses) and functional responses, which are driven by natural and anthropogenic habitat alteration associated with climate change and industrial and recreational land use.

Accurate mapping of the current habitat condition, including restoration status of anthropogenic and natural disturbance features is necessary to assess the effectiveness of mitigation and restoration measures directed at Boreal Caribou recovery. Readily available access to a current inventory of disturbance will support future research and Range-specific management.

Table 19 summarizes knowledge gaps and recommendations for future management actions to support Boreal Caribou recovery in BC.

Table 19. Summary of knowledge gaps and recommendations for future activities to support Boreal Caribou recovery in British Columbia.

Type[1]	Priority	Knowledge Gap/Recommendation	Rationale
Boreal Caribou Demographics and Health			
REC	High	Continued monitoring of adult female caribou maintaining a sample of GPS radio-collared adult females	• continue to track Boreal Caribou population status, including adult female mortality rates and calf recruitment
KG	High	Causes of calf mortality	• little information is available on causes of calf mortality
KG	High	Calving season travel corridors	• DeMars and Boutin (2014) recommend that the identification and protection of calving season travel corridors may be an important management practice to aid Boreal Caribou recovery ○ Culling et al (2006) previously identified a movement corridor between the Clarke and Paradise Core Areas, Snake-Sahtaneh Range
KG	Medium	Movements of mature male Boreal Caribou between and within Ranges and between adjacent jurisdictions	• deploy GPS radio-collars on a sample of mature males to investigate and describe movements of mature males within and between Ranges to better understand genetic exchange and disease transmission • provide additional information on Boreal Caribou demographics, including more precise minimum population counts and sex ratios during annual recruitment surveys
Habitat Use			
KG	High	Range-specific habitat selection	• variation in ecological condition across ranges
KG	High	Boreal Caribou winter forage site selection	• use snow tracking surveys to collect information on Boreal Caribou winter foraging site selection within habitats
KG	Medium	Boreal Caribou use of early seral habitats	• use radio-telemetry data to investigate narrower categories of early seral habitat (e.g. 0-10 years, 10-20 years, etc.) to determine whether caribou are using recently disturbed sites or slightly older disturbed sites
Habitat Condition and Alteration			
KG	High	Current habitat condition within BC's Boreal Caribou Ranges	• develop a habitat alteration database that will be updated regularly • determine winter forage quantity and quality (abundance and availability of terrestrial lichen) • determine summer forage quantity and quality (availability of an abundant and diverse deciduous shrub and herbaceous forage) • determine whether habitat alteration is affecting range (forage) condition and/or forage accessibility • investigate whether there is a link between range quality and caribou body condition and productivity • identify areas of high terrestrial lichen biomass within Boreal Caribou Core Areas
KG	Medium	Plant response following wildfire in peatland habitats in BC Boreal Caribou Ranges	• plant responses to fire in peatlands may vary from responses to fire in upland forests

Type[1]	Priority	Knowledge Gap/Recommendation	Rationale
Predator/Prey Dynamics			
REC	High	Standardize survey areas for moose and wolf inventories within and adjacent to Boreal Caribou Ranges	• provide consistency between surveys over time to allow trend assessment
REC	High	Conduct periodic moose and wolf surveys in Boreal Caribou Ranges[1]	• determine changes in moose densities and distribution • determine changes in wolf density and distribution • collect spatial and temporal information on alternate prey and predators active within Boreal Caribou Ranges in mid to late winter • supports research on apparent competition within Boreal Caribou Ranges
KG/REC	High	Create a geo-referenced database of predator scat samples to collect information on predator diet and populations across Boreal Caribou Ranges	• design and distribute scat sample kits to be used by researchers, First Nations, and industry workers in Boreal Caribou Ranges. Information gathered from the analysis of samples includes: ○ the relative proportion of adult and juvenile caribou remains in predator scat
KG	High	Seasonal diets of wolves	• investigate the role of beaver in supporting high wolf densities within Boreal Caribou Ranges
KG	Medium	Role of black bear predation in Boreal Caribou calf survival	• DeMars and Boutin (2014) suggest further investigation is required on the role of bear predation on calf survival in Boreal Caribou population declines • early seral vegetation on linear features may be providing a seasonal food source for black bears and affecting caribou calf survival?
KG	Low	Potential interaction between Boreal Caribou and wood bison in the Chinchaga Range and plains bison escaped from domestic herds in the vicinity of the Parker Range	• the DRFN recommends further research to investigate interactions between introduced wood bison and Boreal Caribou in the Chinchaga Range
Human Factors Affecting Boreal Caribou			
REC	Medium	Potential human functional response to habitat alteration in Boreal Caribou Ranges	• identify potential areas where mitigation to reduce wolf-caribou encounters conflict with recreational use (i.e., recreational snowmobiling in Parker Core Area) • develop mitigation strategies (i.e., education/outreach programs with local user groups
KG	Low	Historic and current patterns and intensity of fur-bearer trapping in BC's Boreal Caribou Ranges	• determine potential effects of historic and current predator/prey systems on Boreal Caribou
KG	Low	Historic and current patterns and intensity of predator control in BC's Boreal Caribou Ranges	• determine potential effects of historic and current predator/prey systems on Boreal Caribou

[1] KG- knowledge gap; REC – Recommendation for future work
[2] Acknowledging issues of jurisdictional responsibility

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12 APPENDICES

Appendix 1. Technical reports and published articles on species, population, and habitat management in BC's Boreal Caribou Ranges, 1990-2017.

Year	Document
1990	Backmeyer, R.J. 1990. Ring Border ungulate inventory – January 1990. Prep. For BC Ministry of Environment, Fort St. John, BC. and Canadian Hunter Exploration Ltd., Grande Prairie, AB. 10p.
2004	Backmeyer, R.J. 2004. Moose and boreal caribou inventory: Management Units 7–55 and 7–56. BC Min. Environ., Wildlife Branch, Victoria, BC. Tech. Rep. 6p. (note: survey encompasses the Snake-Sahtaneh, Maxhamish, and Calendar Ranges).
2004	Culling, D.E., B.A. Culling, R.J. Backmeyer, and T.M. Antoniuk. 2004. Interim oil and gas industry guidelines for boreal caribou ranges in northeastern British Columbia. Prep. for Oil and Gas Commission, Fort St. John, BC. 32p.
2006	Culling, D.E., B.A. Culling, T.J. Raabis, and A.C. Creagh. 2006. Ecology and seasonal habitat selection of boreal caribou in the Snake-Sahtaneh watershed, British Columbia. Prepared for Canadian Forest Products Ltd., Fort Nelson, BC. 80p.
2006	Rowe, M.R. 2006. Summary report: 2006 Maxhamish Range boreal caribou inventory, Kiwigana, Fortune, and Capot-Blanc areas. Project No. 2005-7B-2 (Wildlife Inventory Program: 2005–2006) Peace Region: 7B. BC Min. Environ., Wildlife Branch, Fort St. John, BC. 8p.
2007	Rowe, M.R. 2007. Boreal caribou and wolf management and habitat selection within the Chinchaga Range – 2004 to 2007. BC Min. Environ., Wildlife Branch, Fort St. John, BC. 28p.
2007	Rowe, M.R. 2007. Boreal caribou movement and habitat selection within the Maxhamish Range. BC Min. Environ., Wildlife Branch, Fort St. John, BC. 14p.
2009	Thiessen, C. 2009. Peace Region Boreal Caribou monitoring: annual report 2008–09. BC Min. Environ., Wildlife Branch, Fort St. John, BC. 36p.
2010	Thiessen, C. 2010. Horn River Basin Moose inventory January/February 2010. BC Min. Environ., Wildlife Branch, Fort St. John, BC. 44p.
2010	Wilson, S. F., C. Pasztor, and S. Dickinson. 2010. Projected boreal caribou habitat conditions and range populations for future management options in British Columbia. Prep. for Ministry of Energy, Mines and Petroleum Resources and Ministry of Environment, Victoria, BC. 11p.
2011	DeMars, C., C. Thiessen, and S. Boutin. 2011. Assessing spatial factors affecting predation risk to boreal caribou calves: implications for management. 2011 annual report. University of Alberta, Edmonton, AB. 41p.
2012	DeMars, C., D. Leowinata, C. Thiessen, and S. Boutin. 2012. Assessing spatial factors affecting predation risk to boreal caribou calves: implications for management. 2012 annual report. University of Alberta, Edmonton, AB. 54p.
2012	Golder Associates. 2012. Boreal caribou habitat restoration: March 2012. Prep. for Ministry of Forests, Lands, and Natural Resources Operations, Prince George, BC. Rep.# 12-1372-0012.
2012	Thiessen, C. 2012 (Draft). Relative abundance of beaver in B.C. Boreal Caribou ranges. Unpubl. draft report, Ministry of Forests, Lands, and Natural Resource Operations, Fort St. John, BC. 10p.
2013	Culling, D.E., and B.A. Culling. 2013. BC Boreal Caribou Implementation Plan: 2012-13 collar deployment and late winter recruitment survey. Prepared for SCEK, Victoria, BC. 29p + appendices.
2013	Culling, D.E., and B.A. Culling. 2013. BC Boreal Caribou Implementation Plan: 2013

Year	Document
	Fall Calf Survey. 14p + appendices.
2013	DeMars, C.A., M. Auger-Méthé, U.E. Schlägel, and S. Boutin. 2013. Inferring parturition and neonate survival from movement patterns of female ungulates: a case study using woodland caribou. Ecology and Evolution, 3, 4149–4160.
2013	DeMars, C., and S. Boutin. 2013. Assessing spatial factors affecting predation risk to boreal caribou calves: implications for management. 2013 annual report. Univ. Alberta, Edmonton, AB. 60p.
2013	McNay, S., D. Webster, G. Sutherland. 2013. Aerial moose survey in North East BC 2013. Submitted to the Research and Effectiveness Monitoring Board (REMB) - inventory project, Science and Community Environmental Knowledge, April 15, 2013 (revised May 3, 2015).
2014	Cook, J., and R. Cook. 2014. Nutritional condition of caribou in northern British Columbia, 2012- 2014. Annual Progress Report, 30 May 2014. National Council for Air and Stream Improvement, La Grande, OR. 14p
2014	Culling, D.E., and B.A. Culling. 2014. BC Boreal Caribou Implementation Plan: 2013-2014 field activities progress report. Prepared for SCEK, Victoria, BC. 22p + appendices.
2014	DeMars, C.A., and S. Boutin. 2014. An individual-based, comparative approach to identify calving habitat for a threatened forest ungulate. Ecological Applications (in review).
2014	DeMars, C.A., G.A. Breed, J.R. Potts, and S. Boutin. 2014. Spatial patterning of prey at reproduction to reduce predation risk: what drives dispersion from groups? The American Naturalist (in review).
2014	Macbeth, B.J., H. Schwantje, S. Kutz, K. Haman, J. Cook, R. Cook, D. Culling, B. Culling, and M. Watters. 2014. The role of health in management and conservation of boreal caribou herds in Northeastern British Columbia. Research Poster. Presented at: 15th North American Caribou Workshop, Whitehorse, YT, Canada, May 12-16, 2014.
2014	Schwantje, H., B. J. Macbeth, S. Kutz, and B. Elkin. 2014. British Columbia boreal caribou health program - progress report: Year 1 (November 1, 2013 - December 31, 2014). Prepared for the BC Science and Community Environmental Knowledge (SCEK) Funding Board, Victoria, BC. Prepared by the British Columbia Boreal Caribou Health Research Program Working Group, Victoria, BC. 78p.
2015	Bohm, A., R. Dunham, C. DeMars, S. Williams, and S. Boutin. 2015. Restoring functional caribou habitat: testing linear feature mitigation techniques in northeast BC. 2014/2015 annual report. Prep. for Nexen, Victoria, BC. 28p.
2015	Caslys Consulting Ltd. 2015. Image classification system for anthropogenic features - project status report. Prep. for Science and Community Environment Knowledge Fund, Victoria, BC. 21p.
2015	Cook, J., and R. Cook. 2015. Nutritional condition of caribou in northern British Columbia, 2012-2015 and southern NT, 2015. Annual Progress Report, 8 June 2015. National Council for Air and Stream Improvement, La Grande, OR. 16p.
2015	Culling, D.E., and B.A. Culling. 2015. BC Boreal Caribou Implementation Plan: Year III (2014-2015) field activities progress report. Prepared for BC Science and Community Environmental Knowledge Fund, Victoria, BC. 28p + appendices.
2015	Gillingham, M., and M. Mumma. 2015. Assessing caribou survival in relation to the distribution and abundance of moose and wolves: progress report, September 2015.

Year	Document
	Prepared for the BC Oil and Gas Research and Innovation Society (BC OGRIS). UNBC, Prince George, BC. 15p.
2015	Golder Associates. 2015. Boreal Caribou habitat restoration operational toolkit for British Columbia (BCIP-2015-05). Submitted to BC SCEK REMB, Victoria, B.C.
2015	Golder Associates. 2015. Parker Range Restoration: Zone 1 implementation plan (BCIP-2017-01). Submitted to BC SCEK REMB, Victoria, B.C.
2015	Wilson, S. F., and C. A. DeMars. 2015. A Bayesian approach to characterizing habitat use by, and impacts to anthropogenic features on, woodland caribou (Rangifer tarandus caribou) in northeast British Columbia. Can. Wildl. Biol. & Manage. Volume 4, No. 2:107-118.
2016	Bondo, K., B. Macbeth, H. Schwantje, and S. Kutz. (*in prep*). Pathogens, parasites, and other health determinants in free-ranging boreal caribou from British Columbia. British Columbia Boreal Caribou Health Research Program Working Group, Victoria, BC.
2016	Caslys Consulting Ltd. 2016. Restoration Status Accuracy Assessment. BCIP-2016-23. Project Profile. Prepared for BC-OGRIS, Victoria, B.C.
2016	Culling, B. A., and D. E. Culling. 2016. BC Ministry of Forests, Lands and Natural Resources Operations: boreal moose recruitment survey, March 23-29, 2016. Prep. for BC MFLNRO, Fort St. John, BC. 14p. (conducted in the Clarke and Fortune Core Areas and the Chinchaga RRA)
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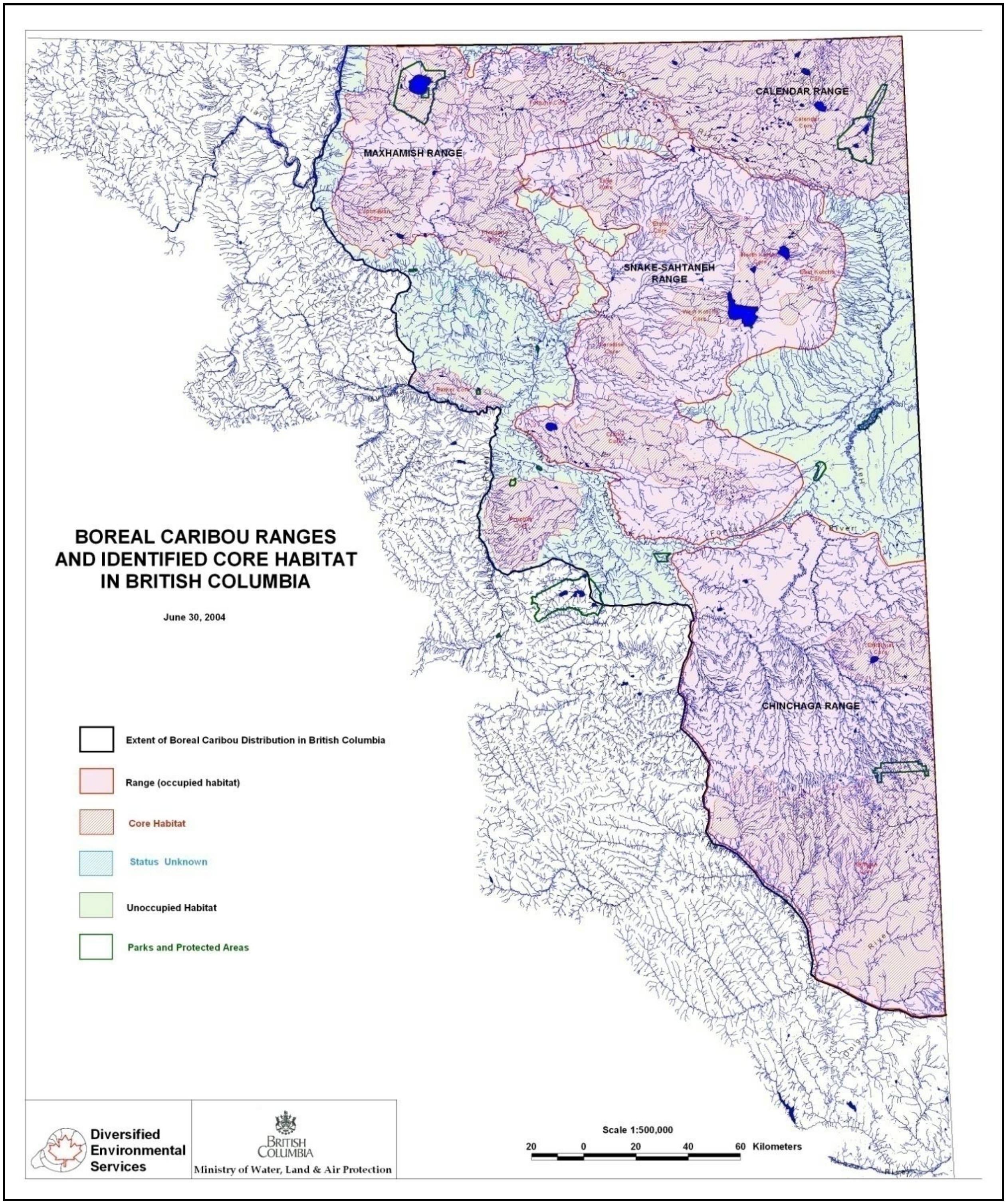
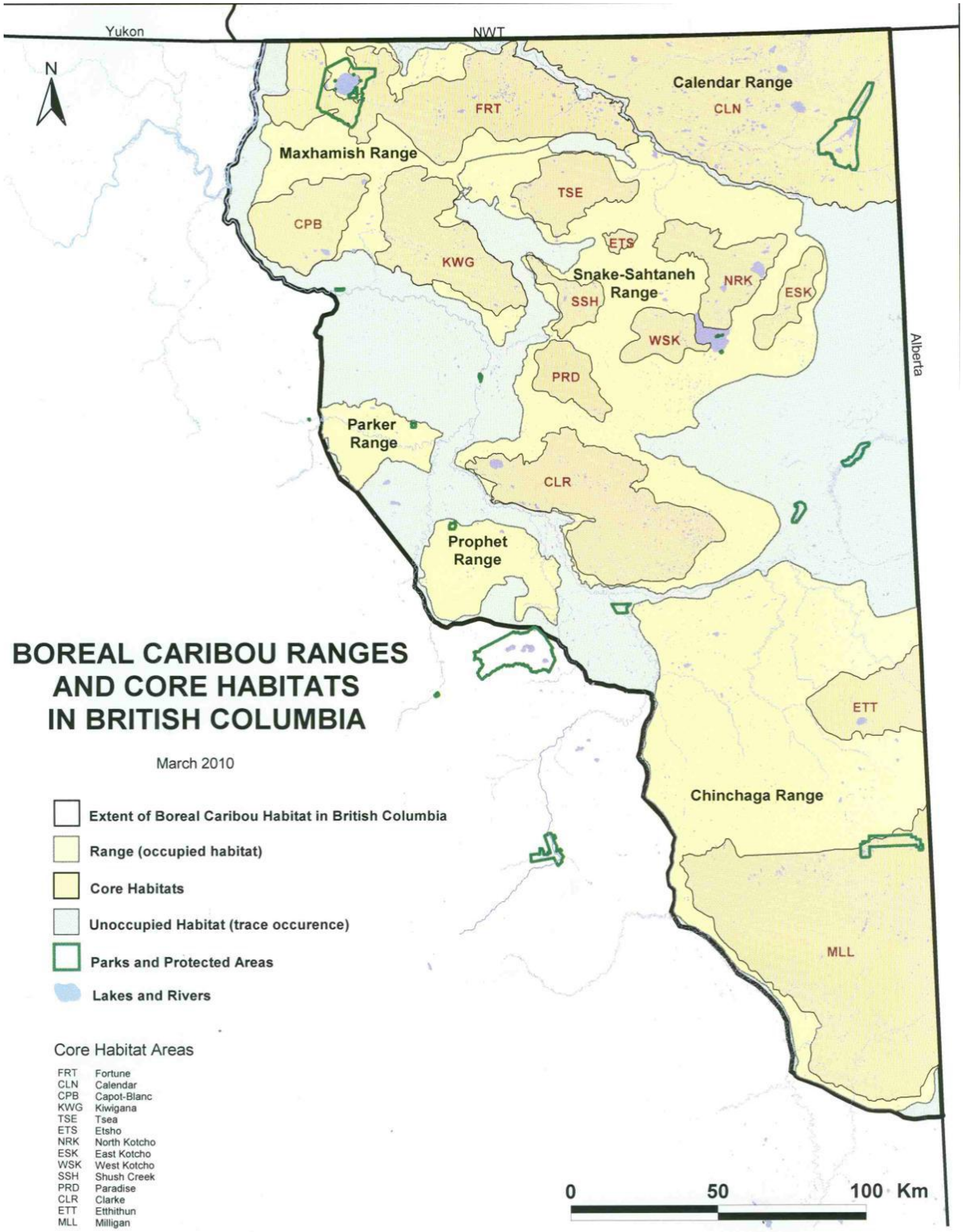
2016	Culling, D.E. and B.A. Culling. 2016. BC Boreal Caribou Implementation Plan: Year IV (2015-2016) field activities progress report. Prepared for BC Oil and Gas Research and Innovation Society, Victoria, BC. 30p +appendices.
2016	DeMars, C., and K. Benesh. 2016. Testing functional restoration of linear features within boreal caribou range - January 2016. Prep. for BC OGRIS, Victoria, BC. 47p.
2016	DeWitt, P., J. Keim, N. Jenni, J. Fitzpatrick, and S. Lele. 2016. Developing and monitoring the efficacy of functional restoration of linear features for boreal woodland caribou: 2015 progress report. Prepared for BC Oil and Gas Research and Innovation Society (BC OGRIS), Victoria, BC. 8p.
2016	Golder Associates. 2016. Parker Caribou Range - boreal caribou restoration pilot program plan. Report No. 1529978/5000. Prep. for BC REMB and BC OGRIS, Victoria, BC. 61p + appendices.
2016	Leech, S., P. Bates, and Blueberry River First Nations. 2016a. BRFN indigenous knowledge study of Chinchaga Muskeg Caribou and Pink Mountain Caribou. - 2015-2016 Final Non-Confidential Report (Draft), November 28, 2016. 58p + appendices
2016	Leech, S.M., C. Whittaker, and the Doig River First Nation. 2016b. Boreal Caribou (caribou) Tsáá? ché ne dane Traditional Knowledge and Restoration Study. Report prepared for DRFN and the David Suzuki Foundation by the Firelight Group December 2016. 60p.
2016	MacNearney, D., K. Pigeon, and L. Finnegan. 2016. Behaviour and calving success of boreal caribou in relation to oil and gas development. Final Report prepared for the Petroleum Technology Alliance Canada, Alberta Upstream Petroleum Research Fund (15-ERPC-06) and British Columbia Oil and Gas Research and Innovation

Year	Document
	Society (2016-15), April 2016. vii + 42p.
2016	Mumma, M., and M. Gillingham. 2016. Assessing caribou survival in relation to the distribution and abundance of moose and wolves: annual report, March 2016. Prepared for the BC Oil and Gas Research and Innovation Society (BC OGRIS). UNBC, Prince George, BC. 34p.
2016	Pigeon, K., M. Hornseth, D. MacNearney and L. Finnegan. 2016. Analysis and improvement of linear features to increase caribou functional habitat in west-central and north-western Alberta. Final Report prepared for the Forest Resource Improvement Association of Alberta (FRIP OF-13-006), Alberta Upstream Petroleum Research Fund (15-ERPC-01) and BC OGRIS (BC OGRIS 15-04), March 2016. 84p.
2016	Schwantje, H., B. J. Macbeth, S. Kutz, and B. Elkin. 2016. British Columbia boreal caribou health research program - progress report: Year 2 (February 1, 2015 - March 31, 2016). Prepared for the British Columbia Oil and Gas Research and Innovation Society (OGRIS), Victoria, BC. Prepared by the British Columbia Boreal Caribou Health Research Program Working Group, Victoria, BC. 26p.
2016	Webster, D., and M. Lavalle. 2016. Aerial moose survey in north east BC 2016. Submitted to research and Effectiveness Monitoring Board (REMB) - Inventory Project BC Oil and Gas Research and Innovation society. Prep. for BC MFLNRO, Fort St. John, BC. 42p + appendices.
2016	Watters, M. and C. DeMars. 2016. There and back again: one caribou's (*Rangifer tarandus caribou*) migratory behaviour hints at genetic exchange between Designatable Units. Canadian Field-Naturalist. Accepted September 2, 2016.
2017	Denryter, K.L., R.C. Cook, J.G. Cook, and K.L. Parker. 2017. Straight from the caribou's (*Rangifer tarandus*) mouth: detailed observations of tame caribou reveal new insights into summer-autumn diets. Can. J. Zool. 95:81-94.

Appendix 2. Identified Boreal Caribou Ranges and Core Habitat Areas in northeastern British Columbia, 2004 version (from Culling et al. 2004).



Appendix 3. 2010 Boreal Caribou Ranges and Core Areas in northeastern British Columbia (from Ministry of Environment 2010a).



Appendix 4. Estimating Parturition and Neonate Calf Survival

Advances in GPS technology have resulted in the acquisition of increasingly higher quality radio-telemetry data, including finer spatial and temporal resolution, which supports refinement of techniques for analysing animal movement data. Previously, visually screening GPS data for spatial clustering of locations or changes in daily movement rates of female caribou has been used to identify parturition dates and calving sites. However, DeMars et al. (2015) note that these subjective methods have not been rigorously validated. They suggest that a reliable method for estimating neonate survival using movement data of maternal females would provide a more cost-effective and less invasive alternative to traditional methods, such as spring aerial surveys or deploying radio-collars on newborn calves, and could be used to retroactively analyze historical radio-telemetry data sets to examine long-term trends in both rates.

Using both population-based and individual-based methods, DeMars et al. (2015) tested whether parturition status and neonate (age 0-4 weeks) survival could be reliably inferred from female caribou movement patterns. They used movement data from reproductive-aged (≥3 years old) female Boreal Caribou to develop and test two novel movement-based methods of estimating parturition and neonate survival based on movement "break-points" (i.e., sudden and marked changes in normal movement patterns). Data from caribou captured in four Boreal Caribou Ranges in 2011 and 2012 was used for method development and testing, with method performance further evaluated using data from the 2000-2004 Snake-Sahtaneh study (Culling et al. 2006). They predicted that calving events could be identified by abrupt changes in step length (i.e., distance between successive GPS locations), with neonate period movement rates remaining depressed as long as the calf was alive. They further hypothesized that a second break point would be evident if the calf was lost during this period, with female movement rates abruptly returning to pre-calving levels. Both population-based and individual-based methods predicted parturition with >97% accuracy, producing reliable predictions of calving dates. For both methods, prediction of neonate survival was affected by data quality; however, the individual-based method predicted neonate survival status with an accuracy rate of 87% when high quality data was available.

In the NT, Nagy (2011) examined daily calving period movements rates of female Boreal Caribou that were known to be pregnant and confirmed to have given birth. Ninety-three percent of these animals displayed three movement states ±10 days around parturition including: 1) high daily movements (up to 40 km/day), 2) a sharp precipitous decline in daily movement rates to near zero on or just before parturition, and 3) a gradual increase in daily movement rates. The remaining females displayed movements consistent with the first two states, but then movement rates increased rapidly. In these cases, Nagy suggests parturition had occurred, but the calves of these females died shortly after birth. Similar patterns of behaviour were observed by parturient female Boreal Caribou in the northeast BC (Culling and Culling 2017).

Appendix 5. Calf survival estimates from radio-telemetry studies conducted in Boreal Caribou Ranges in northeastern British Columbia between 2002 and 2016.

Range/Core Area	Date	Survey Type[1]	Total No. Groups	Total Caribou Counted	Adult Females	Calves	Calves/ 100 Cows	Reference
Snake-Sahtaneh	June 2002	Neonate Calf Survival	20	24	20	4	20	Culling et al. 2006
Snake-Sahtaneh	June 2003	Neonate Calf Survival	15	18	15	3	20	Culling et al. 2006
Snake-Sahtaneh	June 2004	Neonate Calf Survival	23	31	24	7	29	Culling et al. 2006
Chinchaga	June 2004	Neonate Calf Survival	NR[2]	25	15	9	(60)[3]	Rowe 2007
Calendar Range, Tsea Core	June 2008	Neonate Calf Survival	17	21	17	4	24	Culling and Culling 2016
Calendar Range, Tsea Core	July 2009	Neonate Calf Survival	14	23	16	5	31	Culling and Culling 2016
Snake-Sahtaneh	Oct 2002	6-Mth Calf Survival/Rut	14	92	67	8	12	Culling et al. 2006
Snake-Sahtaneh	Oct 2003	6-Mth Calf Survival/Rut	12	76	60	8	13	Culling et al. 2006
Snake-Sahtaneh	Oct 2004	6-Mth Calf Survival/Rut	19	109	72	10	14	Culling et al. 2006
Chinchaga	Nov 2004	6-Mth Calf Survival	NR	130	83	19	23	Rowe 2007
Kiwigana, Capot Blanc, Parker cores[4]	Oct 2008	6-Mth Calf Survival/Rut	11	36	22	7	32	Thiessen 2009
Calendar Range, Tsea Core	Oct 2008	6-Mth Calf Survival/Rut	16	79	53	8	15	Culling and Culling 2016
All B.C. Ranges and Cores	Nov 2013	6-Mth Calf Survival	118	668	483	68	14	Culling and Culling 2013b
Snake-Sahtaneh	Mar 2003	10-Mth Recruitment	17	82	74	4	5	Culling et al. 2006
Snake-Sahtaneh	Mar 2004	10-Mth Recruitment	23	160	123	11	9	Culling et al. 2006
Chinchaga	Mar 2005	10-Mth Recruitment	NR	24	12	2	17	Rowe 2007
Maxhamish	Mar 2006	Stratified random block	NR	40	31	3	10	Rowe 2006
Calendar Range, Tsea Core	Mar 2008	10-Mth Recruitment	14	80	54	13	24	Culling and Culling 2016
Calendar Range, Tsea Core	Mar 2009	10-Mth Recruitment	19	176	135	23	17	Culling and Culling 2016
All B.C. Ranges and Cores	Mar 2013	10-Mth Recruitment	130	952	617	128	21	Culling and Culling 2013a
All B.C. Ranges and Cores	Mar 2014	10-Mth Recruitment	107	723	546	63	12	Culling and Culling 2014
All B.C. Ranges and Cores	Mar 2015	10-Mth Recruitment	127	678	454	67	15	Culling and Culling 2015
All B.C. Ranges and Cores	Mar 2016	10-Mth Recruitment	129	728 (686)[5]	515	103	20	Culling and Culling 2017

1 Seasonal minimum population count and calf survival and recruitment surveys were conducted by relocating all radio-collared adult females; incidental observations of uncollared groups were included.

2 Cow/calf ratio for all Core Areas combined

3 Based on a sample of 25 animals (15 adult females, 9 calves, and 1 unknown), including 10 radio-collared females observed during a June 4 calf survey; by the subsequent November 2004 survey there were 23 calves/100 cows, with recruitment to 10 months (March 2005) 17 calves/100 cows.

4 NR - Not reported

5 A total of 728 caribou were counted in 129 groups, including 9 caribou collared in the Calendar Range, but located in 9 separate groups (52 caribou) in the NT; including only the groups found within the BC, plus the 9 radio-collared caribou in the NT and 1 calf-at-heel, the total count for the survey was 686 (including 487 females and 98 calves; 20 calves/100 cows).

Appendix 6. Preliminary results from the Boreal Caribou Health Research Program (BCHRP; from Schwantje et al. 2014, 2016).

Pathogen/ Parasite	**Category**	**Comments**
Alphaherpesvirus	Viral Pathogen	• overall prevalence of exposure was 62% (n=101/162), ranging from 22% (n=2/9) in Prophet to 86% (n=6/7) in Parker • relatively high and variable prevalence of exposure compared to NT, AB, SK • potential to compromise the survival and reproductive success of Boreal Caribou
Pestiviruses	Viral Pathogen	• prevalence of exposure to pestiviruses among adult female Boreal Caribou captured in northeast BC in 2012 and 2013 was 0.6% (*n*=1/161; Maxhamish) • first record of exposure to pestiviruses in Boreal Caribou in BC
Brucellasuis biovar 4	Bacterial Pathogen	• a bacterial pathogen of caribou and reindeer found in herds throughout Northern Canada and Alaska • infection may be subclinical or associated with severe chronic disease, including bursitis and arthritis and a variety of reproductive disorders that can lead to reproductive failure and neonatal morbidity or mortality • no evidence that any adult female Boreal Caribou captured in BC in winter 2012/2013 and 2014/2015 had been previously exposed to *Brucella* sp. (*n*=222)
Erysipelothrix rhusiopathiae	Bacterial Pathogen	• approximately 30% of caribou captured in both years may have been previously exposed to the pathogen • overall prevalence (i.e., proportion of sample with exposure) appeared to vary across the six ranges, from 0% in Parker (n=0/7) to 44% in Prophet (*n*=4/9) • the number of *Erysipelothrix* culture/PCR positive mortalities may have decreased as caribou condition increased, which could suggest that nutritional stress experienced by caribou in the harsh winter of 2012/2013 may have contributed to the occurrence of disease caused by *Erysipelothrix* in the following spring and summer

Pathogen/ Parasite	**Category**	**Comments**
Neospora caninum	Tissue Inhabiting Protozoan	• protozoan parasite with a canid definitive host (in caribou range most likely wolf, coyote, or fox) and a ruminant intermediate host • suspected as a likely cause of abortions and unthrifty calves in free-ranging caribou • the persistent and trans-generational nature of *N. caninum* infections in ungulates also suggests that this parasite could limit the recovery of caribou populations even if it occurs at low levels • white-tailed deer, elk, and moose may support this parasite, therefore, as the number of alternate intermediate hosts increase in caribou range due to landscape and climatic change, Boreal Caribou could be adversely affected • relative risk of "not being pregnant" was 4.2 times greater in *N.* caninum positive caribou than in *N. caninum* negative caribou in BC • overall prevalence of *N. caninum* in Boreal Caribou from BC appears to be low (~2%) and to fall within the range previously recorded in other free-ranging caribou herds; however, the protozoan may represent an emerging threat to caribou reproductive success, particularly in the Parker and Chinchaga Ranges • continued monitoring of this parasite in caribou as well as in other ungulate intermediate hosts and canid definitive hosts in northeast BC is recommended
Besnoitia tarandi	Tissue Inhabiting Protozoan	• found in caribou throughout their distributional range • 60% of 149 adult female boreal caribou captured in the winter of 2012/2013 exposed • incidence of exposure varied from 40% in Calendar to 85% in Chinchaga
Toxoplasma gondii	Tissue Inhabiting Protozoan	• protozoan parasite with a felid definitive host (in caribou range most likely lynx) and a wide variety of intermediate hosts, including wild ungulates such as caribou • parasite may cause a spectrum of diseases in intermediate hosts ranging from mild/sub clinical to severe/fatal, including pneumonia, enteritis, and encephalitis along with congenital defects, abortions, still births, and weak neonates • tested 229 serum samples collected between winter of 2012/2013 and 2014/2015; no seropositive caribou were detected in any year and no evidence of seroconversion in recaptured caribou was recorded • *Toxoplasma* gondii will not be evaluated further as part of the BCHRP

<table>
<tr><th>Pathogen/
Parasite</th><th>Category</th><th>Comments</th></tr>
<tr><td>Anaplasma sp,.
Trypanosoma
sp.,
Babesia sp.,</td><td>Blood Borne Parasites</td><td rowspan="2">• a caribou that died during the high mortality period in 2013 was found to be iron deficient
• blood borne pathogens and parasites, including Babesia and Anaplasma may be one of many causes of iron deficiency in ungulates; these organisms are also known or suspected to cause an array of subclinical/clinical disease syndromes which may adversely affect the survival and/or reproductive success of infected animals
• the occurrence, distribution, and impact of blood borne pathogens in free-ranging caribou are not currently known
• blood smears from 27 caribou captured in 2015 and blood from 15 caribou that died in 2013 were analysed for evidence of infection with blood borne pathogens or parasites (e.g. Trypanosoma, Anaplasma, Babesia) and/or vector borne nematodes (e.g. Setaria, Onchocerca); no evidence of blood borne pathogens was identified in any of the blood smears examined and results for Babesia and Anaplasma were negative in all 15 caribou tested
• microfilaria (larval Filarid nematodes) were identified in blood smears from 1% of caribou examined; microfilariae identified in Boreal Caribou are most likely Setaria or Onchocerca sp
• no evidence of Trypanosoma sp. was recorded in any blood smear collected from Boreal Caribou in BC; this finding was unexpected as Trypanosoma sp. appears almost ubiquitous in woodland caribou from AB and the NT
• findings may indicate that blood borne pathogens and parasites and vector borne nematodes are unlikely to be limiting factors for BC's Boreal Caribou at the present time, but may increase as climate change supports an increase in the number of arthropod vectors and/or the seasonal duration of arthropod activity in the region</td></tr>
<tr><td>Setaria sp.,
Onchocera sp.</td><td>Vectored Borne
Nematodes</td></tr>
</table>

Pathogen/ Parasite	Category	Comments

Dermacentor albipictus	Ectoparasite	• winter tick (nymph and adult stages)
		• ectoparasite can carry and likely transmit microorganisms (e.g. *Anaplasma* sp.) that have the potential to cause severe/fatal disease in cervids
		• overall prevalence of winter tick associated hair loss in caribou in BCIP telemetry study was 76% (n=182/238), ranging from mild to extreme hair loss (i.e., multiple patches of exposed skin)
		• prevalence of winter tick infestations appeared to vary across the six Ranges in and across study years
		• tick counts from hide samples collected from *n*=5 dead caribou from BC in 2014 and 2015 revealed evidence of tick burdens [mean 5 ticks/cm2 (range 0-14 ticks/cm^2, *n*=5)] in some BC Boreal Caribou that were higher than those previously recorded in woodland caribou from AB (0.005-0.01 ticks/cm^2) and burdens typically recorded in moose (~1-2 ticks/cm^2)
		• parasite may represent an emerging threat to Boreal Caribou health in BC:
		  ○ climate change may be improving conditions for winter ticks and may increase the risk of infestation and related disease
		  ○ recent landscape change may also enhance the risk of winter tick transmission to Boreal Caribou due to increased densities of moose or elk in BC Ranges
		• further research into the occurrence and impact of winter tick infestations on Boreal Caribou is warranted

Hypoderma tarandi	Ectoparasite	• warble fly (warbles; larval stage) • one of the most important parasites of tundra *Rangifer*; heavy infections (1,000+larvae) have been reported; migrating and developing larvae may cause significant pathology in the skin and subcutaneous tissue; harassment by adult flies may result in decreased foraging efficiency and increased energy expended by caribou, which may lead to decreased body condition and reproductive success of adult caribou and diminished condition and overwinter survival in juvenile caribou • warble fly larvae were found in nine of 262 caribou capture events of 240 individual Boreal Caribou between December 2012 and March 2016; all incidents were in late winter, between February 27 and April 1 • warbles do not appear to be a limiting factor for BC's Boreal Caribou at the present time

Appendix 7. Biophysical attributes for Boreal Caribou critical habitat in the Boreal Plain ecozone (from Environment Canada 2012).

Scale of Selection	Description
Broad Scale	• late seral-stage (> 50 years old) conifer forest (jack pine, black spruce, tamarack), treed peatlands, muskegs or bogs; use dry islands in the middle of muskegs, with abundant lichens. Hilly or higher ground, and small lakes • restricted primarily to peatland complexes • higher elevations (~1135 m) • selected old (>40 yrs.) burns
Calving	• bogs and mature forests selected for calving as well as islands and small lakes • peatlands and stands dominated by black spruce and lowland black spruce stands within muskeg are used for calving
Post-calving	• forest stands older than 50 yrs. • upland black spruce/jack pine forests, lowland black spruce, young pine and open and treed peatlands and muskeg are also selected during summer; use lichen and low muskeg vegetation • in some areas, sites with abundant arboreal lichen are selected during summer
Rutting	• mature forests • upland black spruce/jack pine forests, lowland black spruce, young jack pine and open and treed peatlands and muskeg during summer (sic)
Winter	• treed peatlands, treed bog and treed fen and open fen complexes with >50% peatland coverage with high abundance of lichens • use of small lakes, rock outcrops on lakes for lichen access • mature forest > 50 yrs. old • upland black spruce/jack pine forests, lowland black spruce, young jack pine and open and treed peatlands

Appendix 8. Biophysical attributes for Boreal Caribou critical habitat in the Taiga Plain ecozone (from Environment Canada 2012).

Scale of Selection	Description
Broad Scale	• mature forests (jack pine, spruce, tamarack) ≥100 years, and open coniferous habitat • large areas of spruce peatland and muskeg with preference for bogs over fens and upland and lowland black spruce forests with abundant lichens, and sedge and moss availability • flatter areas with smaller trees and willows, hills and higher ground
Calving	• open coniferous forests, tussock tundra, low shrub, riparian, recent burned areas, south and west aspects and hills and higher locations • muskegs, marshes, staying close to water sources • caribou observed on small islands of mature black spruce or mixed forests within peatlands, in old burns at the edge of wetlands, in alder thickets with abundant standing water and on lake shores
Post-calving	• muskegs or areas with access to muskegs, open meadows on higher ground, close to water (lakes and rivers) and mixed bush areas • open coniferous forests with abundant lichens, low shrub, riparian, tussock tundra, sparsely vegetative habitat, recent burns and west aspects • old burns and neighbouring remnant unburned forests selected in late spring and early summer
Rutting	• open coniferous and mixedwood forests, low shrub, riparian, tussock tundra, recent burns and west aspect • muskeg areas that harbor ground lichen and sedges, mixed bush areas, and areas of higher ground • regenerating burns and sparsely vegetated habitat
Winter	• open coniferous forests (black spruce and pine) that provide adequate cover with abundant lichens, riparian areas • muskeg areas in early winter • spruce-lichen forests, fire regenerated, sparsely vegetated habitat, herbaceous and tall shrub habitat and sphagnum moss with scattered spruce • as snow depth increases, remain more often in areas of dense pine or thickly wooded black spruce, with hanging lichen and access toto open, mixed vegetation for ground forage
Travel	• females show high fidelity to calving sites among years (i.e. within 14.5 km) • many caribou shift the pattern of use based on seasonal preferences, in large multi-habitat areas • rates of movement increase during the rut and are greatest in winter.

Appendix 9. General knowledge of movements and seasonal habitat use of Boreal Caribou in northeastern British Columbia, the Dehcho area, NT, and the southern escarpment and central plateau of the Caribou Mountains, northern Alberta.

Season	Range	Source	Boreal Caribou Habitat Selection
General	BC Chinchaga	BRFN/ Leech et al. 2016a	• terrestrial lichen is the most important food source, arboreal lichens also used • lichen particularly important in winter • caribou forage on available vascular plants in other seasons • fidelity to travel routes and seasonal ranges • avoid burns, clear-cuts, and linear corridors • select for areas near water for predator avoidance • select for older forest with high lichen load • avoid steep slopes (>20%)
General	BC Chinchaga	DRFN/ Leech et al. 2016b	• DRFN information on Boreal Caribou harvesting sites, areas where caribou/caribou signs have been observed (including data from DRFN caribou monitoring), caribou migration corridors and caribou habitat areas in the Chinchaga Range and Milligan Core were mapped[1] • one knowledge-holder reported that the Chinchaga Lakes, Hunter Lakes and Milligan Creek areas are connected and make up a large caribou habitat/corridor • ecosystems important for Boreal Caribou in all seasons include dry" and "wet" muskeg and forested areas with large spruce and pine trees • ecological description of site-specific habitats important in all seasons include treed bogs, nutrient-poor fens, nutrient-rich fens, upland deciduous and coniferous forests, and deciduous swamps • Boreal Caribou feed on lichens in all seasons • supplement diet with other foods (especially from spring to fall), including grasses, young leaves, Labrador tea, various types of grasses and cattails growing near water and in shallow water, berries and clover • mineral licks are important in all seasons except winter and should be protected from impacts
General	Dehcho Region, NT	Dehcho First Nations 2011	• a general seasonal trend to spread out throughout marsh and wetlands during spring/ calving, stay close to/within areas with greater amounts of muskeg terrain throughout summer, move more freely throughout a range of habitats in fall/early winter while gathering into larger groups, and to overwinter in larger groups in areas that have higher amounts of thicker brush (both black spruce and pine) while remaining close to muskeg and 'willow prairie' areas that harbor ground lichens and sedge grasses • largest concentrations of Boreal Caribou are generally seen in late winter/early spring, prior to dispersing to calving areas • traditional knowledge about boreal caribou recruitment activities (calving) not extensive, likely given that boreal caribou spread out over large areas and generally stay in wetlands and burned areas that are difficult to access during the spring calving season

Season	Range	Source	Boreal Caribou Habitat Selection
			• rely on ground (terrestrial) and hanging (arboreal) lichens as well as sedge grasses for forage; Boreal Caribou remain close to habitat where this type of food is accessible • areas with 'white muskeg' and rich 'hanging moss' known to be good habitat • Boreal Caribou generally do not congregate in the same areas as moose (habitat preference and predator avoidance) • appears to be a correlation between boreal caribou presence and pine forested areas • 'endaa' (wallows or licks) located throughout the Dehcho Region are important • many groups of Boreal Caribou have relatively significant 'linear' seasonal movement or migration patterns while others remain for the most part in large multi-habitat areas and simply shift the pattern of use of those areas based on seasonal habitat preferences • historic seasonal movements of some Boreal Caribou groups have diminished, possibly due to expansion of the wood bison population
General	Southern Escarpment and Plateau of the Caribou Mountains, northern Alberta	LRR/TC and Schramm et al. 2002	• central plateau of the Caribou Mountains is important summer and winter habitat for local woodland caribou; in spring, the southern slopes of the Caribou Mountains are of particular importance to woodland caribou, which migrate there to escape the hard snow crust conditions on the central plateau and to feed on tree lichen • in fall and winter, caribou on the central plateau forage on caribou lichen and horsetail (*Equisetum* spp.) • caribou will leave the area affected by a fire, but return the following year to "see if some of the caribou lichen patches survived" • caribou lichen habitat is lost for decades if the fire is severe • caribou avoid cutblocks for many years • observation that caribou frequently travel on seismic lines, but past displacement of caribou by road construction
General	Snake-Sahtaneh	Culling et al. 2006	• radio-collared females selected treed peatlands (bog/fen) and areas of extremely low gradient terrain (< 0.60° slope) • females avoided upland mixedwood and deciduous habitats and cutblocks • RSF models indicate significant selection for lake clusters (defined as ≥ 2 lakes with areas greater than two ha each, with overlapping 250 m buffers) in all seasons • some caribou showed evidence of seasonal patterns of use of individual core habitat areas, no unified movements were observed at the population level • nine of 33 collared females with a minimum of 11 months of GPS data used a single core habitat area; 24/33 used multiple cores, including four caribou that used four different cores and two caribou that used five cores
General	All BC Boreal Caribou Ranges	DeMars and Boutin 2014, 2015	• females generally avoided well sites and areas with high densities of linear features • and in general, female Boreal Caribou selected habitats to reduce predation risk; intensity of response varied across scales • females used winter ranges comprised of lichen-rich bogs

Season	Range	Source	Boreal Caribou Habitat Selection
Spring/Calving	BC Chinchaga	BRFN/ Leech et al. 2016a	• females select fens/ bogs with hummocks • calving sites in sheltered shrub/swampy areas surrounded by water • females venture further from water as calves get more mobile • females show fidelity to calving grounds, with tendency to use same routes • important spring foraging areas include: peatlands, margins of waterbodies and areas of early green-up • males select south-facing aspect for forage (early snow free/early green-up) • access to water was identified as important from spring through fall for predator avoidance and to escape insects
Spring/Calving	BC Chinchaga	DRFN/ Leech et al. 2016b	• important habitats include nutrient-poor fens nutrient-rich fens, treed bog, and small amount of upland deciduous and coniferous forest • DRFN knowledge-holders noted that calving in the Chinchaga range can occur from March to May, depending on timing of the rut. • Boreal Caribou calve in wet areas (as described by knowledge-holders: near beaver dams, swampy areas, rivers, lakes and muskeg) • ecological classifications for each of the habitat areas identified specifically as important spring/calving habitat include nutrient-rich and nutrient-poor fens, treed bog, and upland deciduous and coniferous forest (limited) • females are thought to calve in shallow water (four to six inches deep) to suppress the scent of birth. During calving, DRFN knowledge-holders have observed cows eating diamond willow for pain relief • important foods during spring include lichen, roots, new greens and leaves in the muskeg; specific grass and plant species growing at edges of water bodies were identified as important • areas where new greens appear earlier (e.g., south-facing slopes) may be most important during the early part of spring
Spring/Calving Spring	Dehcho Region, NT	Dehcho First Nations 2011	• late March through May • once the snow crust softens, Boreal Caribou move from their overwintering habitat in relatively large groups and begin to travel to and spread out over calving areas • calving areas generally in wetlands, marshlands, or even burn areas that are difficult for predators to access

Season	Range	Source	Boreal Caribou Habitat Selection
Spring/Calving	Southern Escarpment and Plateau of the Caribou Mountains, northern Alberta	LRR/TC and Schramm et al. 2002	• females retreat to the lakes with their calves in order to escape wolf predation • in spring, the southern slopes of the Caribou Mountains are of particular importance to caribou, which migrate there to escape hard snow crust conditions on the central plateau and to feed on arboreal lichen • Boreal Caribou are found throughout the whole central plateau region with the exception of large burned areas; they display seasonal movements, including migrating in early spring from the plateau to white spruce habitat on the southern rim of the escarpment • on the plateau, spring melting produces a hard ice crust on top of the snow that impedes foraging and walking • at the southern rim, the snow tends to be softer and thaws faster, thus allowing easier access to food. • on the south side, caribou feed on spruce tree lichen (*Usnea* spp.) • they start returning to the plateau in April
Spring/Calving through Late Summer	Snake-Sahtaneh	Culling et al. 2006	• RSF models based on Spring-Late Summer (SLS; April 9 to September 16); includes nested Neonate season (May and June) • Snake-Sahtaneh females were distributed within Core Areas throughout range at calving • 65 of 66 identified caribou calving sites fell within the 7 Core Areas • 14 of 48 collared caribou collected GPS data through 2 or more identifiable calving events, including seven with two calvings, four with three calvings, two with four calvings and one animal monitored through five consecutive calvings; the multi-annual home ranges of all 14 caribou encompassed between two and four Core Areas each, but with only one exception, all caribou showed consistent calving fidelity to a single core • RSF models indicate significant avoidance of streams and individual lakes during SLS • RSF models indicate significant selection for “lake clusters” (defined as ≥ 2 lakes with areas greater than two ha each, with overlapping 250 m buffers) • habitat at calving and postpartum sites variable - in spring calf surveys, females were located in small islands of mature black spruce forest or mixedwood habitat within surrounding peatlands, in old burns on the edge of wetlands, in alder thickets with abundant standing water, and along lakeshores; caribou were observed within the perimeter of older fires (in burned patches and remnant unburned patches) in late spring and early summer
Spring/Calving	All BC Ranges	DeMars and Boutin 2014, 2015	• females generally selected landscapes comprised of high proportions of fens and treed bog and within these landscapes avoided aquatic features and areas of natural and anthropogenic disturbance • parturient females selected fens that were likely transitional between nutrient-poor and nutrient-rich fens • the majority of calving sites were situated in treed bogs and nutrient-poor fens; females also used conifer swamp, upland conifer, rich fen, mixed-wood swamp, and open bog as calving sites

Season	Range	Source	Boreal Caribou Habitat Selection
			• females generally selected calving sites with slightly higher concealment cover and less lichen cover compared to winter locations • forage attributes of calving sites did not differ from winter locations • females continued to select for treed bogs and nutrient-poor fens when moving within calving areas[2] • females showed weak selection for locations with higher forage productivity • females moved from winter ranges dominated by treed bogs to calving areas situated in landscapes mosaics with a high proportion of nutrient-poor fen; may indicate a forage-risk trade off (fens more productive than bogs but provide less of a predator refuge) • within these mosaics, females situated calving areas away from rivers, lakes and anthropogenic disturbance • females selected calving sites with relatively high concealment cover • the presence of a neonate calf intensified the selection behaviours associated with reducing predation risk • probability of calf survival was best predicted by a model representing predation risk from bears; calf survival depended on density of high quality bear habitat surrounding locations selected by females within the calving area
Summer	BC Chinchaga	BRFN/ Leech et al. 2016a	• summer considered the "fattening season" • females/calves remain near calving grounds (fens/bogs with hummocks) during neonate period until calf is more mobile • avoid deciduous forests in summer because " too easy to be seen and there is no good food" • preferred habitat = rich sites, old growth, areas that are easy to move through with long site lines for predator avoidance
Summer	BC Chinchaga	DRFN/ Leech et al. 2016b	• knowledge-holders identified lakes, marshes, swamps and thick, dark muskeg habitat (i.e., with denser trees) as important during summer • habitats that provide relief from insect harassment are identified as important, including both wet areas and open areas with wind • lakes provide relief from the heat and insects, and are important escape strategy for avoiding wolves and bears • Boreal Caribou foraging diet in summer is much more varied than in winter
Summer	Dehcho Region, NT	Dehcho First Nations 2011	• June through early August • primarily use muskeg areas or areas with access to muskeg • Boreal Caribou lay in heavy moss that has permafrost under it in order to stay cool • caribou appear to move around less frequently during the mid summer months, but begin to move more in late summer/early fall
Summer	Southern Escarpment	LRR/TC and	• areas around the lakes of the plateau are of particular importance as females retreat there with their calves to avoid wolves

Season	Range	Source	Boreal Caribou Habitat Selection
	and Plateau of the Caribou Mountains, northern Alberta	Schramm et al. 2002	• caribou stay near the water in areas with small willows and caribou lichen • site-specific information suggesting calving grounds where the bush is very thick and dominated by small spruce trees and muskeg • traditional knowledge indicates males and females separate during calving season.
Fall/Rut	BC Chinchaga	BRFN/ Leech et al. 2016a	• no specific information on rutting habitat (habitat supply model rules assume association with open peatland habitat near water) • use of deciduous stands
Fall/Rut	BC Chinchaga	DRFN/ Leech et al. 2016b	• DRFN knowledge-holders report that the rut can occur from the end of September to November • caribou often seen in herds; bulls are sometimes seen foraging in fields in PeeJay area • ecological classifications for important fall/rut habitat include upland deciduous and coniferous forests, treed bog, poor fens, and "other" (i.e., a catch-all category for a series of natural/anthropogenic open areas)
Fall/Early Winter	Dehcho Region, NT	Dehcho First Nations 2011	• late August through November • fall is a transitional period - Boreal Caribou begin to move around over a wider and more diverse habitat area during the rut/post-rutting period • Boreal Caribou are often seen along or crossing water bodies at this time of year • primarily found in 'open' country • Boreal Caribou spend considerable time in muskeg areas that harbor ground lichens as well as sedge grasses
Fall/Early Winter	Snake-Sahtaneh	Culling et al. 2006	• RSF models based on "Fall-Early Winter" season: September 17 to December 16 • females show relative selection for Burn Regeneration habitat category (< 50 years) • within treed peatlands complexes, caribou found in relatively open habitats during the rut • rutting activity was distributed within core habitat areas throughout the study area. • fidelity to geographic areas by individuals during the rut was variable, with some radio-collared females displaying relatively strong fidelity to general areas within individual cores
Winter	BC Chinchaga	BRFN/ Leech et al. 2016a	• select mature spruce/pine with high lichen loads • drier areas (less snow) important • forage on terrestrial and arboreal lichens from pine/spruce • avoid open water as caribou "too easily seen"

Season	Range	Source	Boreal Caribou Habitat Selection
Winter	BC Chinchaga	DRFN/ Leech et al. 2016b	• a mosaic of habitat types including muskeg and large spruce and pine were consistently identified as being most important for boreal caribou in the winter • ecological classifications for important winter habitat include nutrient-rich and nutrient-poor fens mixed with upland deciduous and coniferous forest, treed bog, and “poor and rich fen with a stretch of older forest through middle (likely corresponding to the route of the Doig River)” • Knowledge-holders have consistently observed caribou pawing through the snow to access • food during winter — primarily ground lichens but other plants as well. • caribou forage in mature spruce and pine stands to access lichen during the winter, where they are sheltered from storms and where snow depth is shallow. They often seek out lichen at the base of trees, which are clear of snow. • caribou avoid logged areas in winter • According to traditional knowledge, caribou are fattest in winter, possibly because they travel less compared to the longer distance movements in summer. • individual knowledge-holders reported k’aazuudle (Beaver for cattails) as an important winter food source and foraging on “white moss” and Labrador tea
Winter	Dehcho Region, NT	Dehcho First Nations 2011	• November through March • as winter progresses, caribou spend less time in open and muskeg areas and concentrate in larger groups on higher ground in thicker brush areas where there is still access to open areas that support terrestrial lichen • as the snow gets deeper and crusts (generally January through mid March), caribou remain more often in areas of dense pine or thickly wooded black spruce (referred to as '*dedłini*' in Trout Lake) where “snow is softer, where there is ground lichen, and where there remains access to open, mixed vegetation for ground foraging”; this particular mix of habitat, which supports larger groups in smaller habitat use areas, appears critical for over-wintering survival

[1] Ducks Unlimited enhanced wetland classification was used as the base layer
[2] DeMars and Boutin defined calving areas as those areas used by females with neonate calves

Appendix 10. Classification of eight land cover types used to model resource selection by Boreal Caribou in northeastern British Columbia (DeMars 2015; DeMars and Boutin 2014). Land cover types were developed from Ducks Unlimited Enhanced Wetlands Classification data (DU 2010).

Land Cover Class	**Enhanced Wetland Classification Class**	**Description**
Treed bog	Treed bog Open bog Shrubby bog	Black spruce and *Sphagnum* moss dominated bogs with no hydrodynamic flow.
Nutrient poor fen	Graminoid poor fen Shrubby poor fen Treed poor fen	Low nutrient peatland soils influenced by groundwater flows. Treed poor fens dominate, comprised of black spruce, tamarack and bog birch (25-60% tree cover).
Nutrient rich fen	Graminoid rich fen Shrubby rich fen Treed rich fen	Low nutrient peatland soils influenced by groundwater flows. Shrubby fens dominate, comprised of bog birch, willow and alder.
Conifer swamp	Conifer swamp	Tree cover >60% dominated by black or white spruce. Occur on peatland or mineral soils.
Hardwood (Deciduous) swamp	Shrub swamp Hardwood swamp Mixed-wood swamp	Mineral soils with pools of water often present. At least 25% of tree cover is deciduous. Dominant deciduous tree species: paper birch and balsam poplar.
Upland conifer	Upland conifer	Mineral soils with tree cover >25%. Dominant tree species: black spruce, white spruce and pine.
Upland deciduous	Upland deciduous Mixedwood deciduous	Mineral soils with tree cover >25% and >25% deciduous trees Dominant tree species: aspen and paper birch.
Other	Upland other Cloud shadow Anthropogenic Burn Aquatic	Uplands: mineral soils with tree cover <25%. Anthropogenic: urban areas, houses, roads and cut blocks. Burns: recent burns where vegetation is limited or covered by burn Aquatic: includes a continuum of aquatic classes from low turbidity lakes to emergent marshes where aquatic vegetation is >20% of the cover.

Appendix 11. GIS data sources used to model resource selection functions (from DeMars and Boutin 2014).

Variable	Source
Land Cover	Enhanced Wetlands Classification Ducks Unlimited Canada 100, 17958 106 Ave, Edmonton, AB T5S 1V4
Forest Structure	Vegetation Resource Inventory, BC MFLNRO
Rivers, Lakes	Digital Baseline Mapping BC Integrated Land Management Bureau, Geographic Data Discovery Service
Forest Fire History	Fire Perimeters – Historical BC Integrated Land Management Bureau (ILMB), Geographic Data Discovery Service
Cut Blocks	Forest Tenure Cut Block Polygons, BC MFLNRO
Pipelines	BC Oil and Gas Commission
OGC Seismic Lines	BC Oil and Gas Commission /
Major Roads	Digital Baseline Mapping, BC ILMB, Geographic Data Discovery Service
Forestry Roads	Forest Tenure As-Built Roads, BCGOV FOR Resource Tenures and Engineering
Other Secondary Roads	BC Oil and Gas Commission
Well Sites	BC Oil and Gas Commission
TRIM Lines	TRIM miscellaneous annotation BC Integrated Land Management Bureau, Geographic Data Discovery Service
NDVI	U.S. National Aeronautics and Space Administration MODIS database

Appendix 12. Observations of Boreal Caribou vulnerability to wolf predation during periods of deep, hard crusted snow (from Culling and Culling 2013).

High snow accumulations (>100 cm) and hard crusting occurred throughout all BC boreal caribou ranges in the winter of 2012/2013. Caribou were often seen concentrated in relatively small patches of good habitat. By late winter, caribou were observed to have difficulty moving through the deep, crusted snow and many individual groups appeared to be "yarded up" in small areas, cratering for terrestrial lichens. In contrast, wolves were able to move easily on top of the crust to access areas of caribou concentrations with relatively little effort. These conditions increased caribou vulnerability to wolf predation during March and April. Culling and Culling (2013) describe two events in late winter 2013 that reveal how climatic conditions (snow depth and crusting) can affect wolf predation pressure on Boreal Caribou:

- deep, hard-crusted snow resulted in caribou being concentrated at a number of sites from February through April 2013, including within a relatively intact lake complex in the centre of the Fortune Core Area, Maxhamish Range. Several mortalities sites of both collared and incidentally discovered uncollared caribou were investigated during this period. Wolf predation was determined to be the cause of death at all but one site and there were multiple sites where more than one caribou had been killed in a single predation event. Wolves were found to be making extensive use of ploughed roads and RoWs to access caribou concentrated at cratering sites in otherwise relatively undisturbed habitat. At one caribou mortality site, a wolf pack was back-tracked over 15 km from the kill site on a small lake to a ploughed water source access on the same lake, then onto the adjacent ploughed winter road network originating from upland habitat to the south;
- At the end of March 2013, a group of 10 Boreal Caribou, including two radio-collared animals, were located in a small patch of habitat in the Fort Nelson Core Area. The snowpack was >100 cm, with a hard crust. Extensive localized cratering and deeply-incised trails indicated the animals had been in the area for some time. Several days later, radio-collared wolves were tracked to the site, where four caribou were found dead and either partially consumed or left uneaten, including both collared animals. The remaining caribou were tracked visually by helicopter through deep snow from the kill site for roughly 10 km, however, the search was aborted prior to locating them.

A series of successive events such as this could have a relatively large impact on caribou populations at the local level.