May 2015

CARIBOU – "STATE OF THE SCIENCE" 2014 UPDATE (BIOLOGY, IMPACT PATHWAYS AND NEXT STEPS; ALBERTA AND BRITISH COLUMBIA)

Woodland Caribou "State of the Science" Backgrounder

Submitted to:
Canadian Association of Petroleum Producers
Species Management Committee

CANADIAN ASSOCIATION OF PETROLEUM PRODUCERS

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REPORT

Golder Associates

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1.0 BACKGROUND

Woodland caribou (*Rangifer tarandus caribou*) are listed as a threatened species in Alberta and British Columbia (BC) (ASRD 2007, B.C. CDC 2010) and nationally; with the Central Mountain and Southern Mountain Populations listed as endangered (COSEWIC 2003, 2014). In general, populations of woodland caribou have declined substantially in recent decades (AWCRT 2005; Edmonds 1988; Hervieux et al. 2013; McLoughlin et al. 2003). Concurrently, resource-based industries have expanded into previously undeveloped areas and the distribution, intensity, amount and type of human activity in and near caribou ranges has been linked to compromising the integrity of caribou habitat (BCC 2003a; EC 2011a; Goddard 2009; Hervieux et al. 2013; Jones 2007; McLoughlin et al. 2003; Smith 2004).

Under the Accord for the Protection of Species at Risk, federal, provincial and territorial governments agreed to establish complimentary legislation and programs to protect species at risk in Canada (EC 2011a). The *Species at Risk Act (SARA)* places the preparation of recovery strategies for listed extirpated, endangered, and threatened species on competent government ministers. In 2012, the Minister of the Environment released the "Recovery Strategy for the Woodland Caribou *(Rangifer tarandus caribou)*, Boreal Population in Canada" (EC 2012). The Recovery Strategy identified the risk assessment for all 12 boreal caribou populations in Alberta and all 5 boreal populations in BC as "not self-sustaining" (EC 2012). Primary responsibility for the management of wildlife and lands within caribou range falls on the provinces and territories in which they are found and therefore the jurisdictional mandate for recovery and conservation of boreal caribou falls to them. For the Recovery Strategy to be successful, many stake holders/constituencies will have to work together at the landscape-level planning stage (EC 2012). The Recovery Strategy identifies a target of 65% undisturbed habitat for a caribou range as the threshold to providing a 60% chance that a local population will be self-sustaining. Actions to meet the recovery strategy include restoring industrial landscape features such as roads, seismic lines, pipelines, cut-lines, and cleared areas in an effort to reduce landscape fragmentation and the changes in caribou population dynamics associated with changing predator-prey dynamics in fragmented landscapes. In 2014, the "Recovery Strategy for the Woodland Caribou, Southern Mountain population *(Rangifer tarandus caribou)* in Canada" was released in 2014 (EC 2014).

Multi-stakeholder standing committees were formed throughout Alberta in the early 1990's in order to develop procedures which would allow industrial activity on caribou ranges to be sustained, while at the same time ensuring the integrity and supply of caribou habitat (Alberta Department of Energy 1991). The role of the committees was to advise the government on caribou management based on sound research and to search for effective and efficient industrial operating guidelines (Rippin et al. 1996). The Alberta Caribou Committee (ACC) was formed in 2005, amalgamating the previous Boreal Caribou Committee (BCC) and the West-central Alberta Caribou Standing Committee (WCACSC). The ACC was essentially dismantled in 2009 in response to the Federal recovery strategy's guidance that each jurisdiction was responsible for range plan development. In 2011, the Government of Alberta released the Alberta Woodland Caribou Policy (Government of Alberta 2011) which stated that "caribou conservation is a shared government, public and private sector responsibility, led by government. A comprehensive, integrated partnership approach is needed to commit financial and other resources, in a manner which maximizes their effectiveness." The Alberta Caribou Range and Action Planning Multi-stakeholder Advisory Group was formed in 2013 and continues to meet as range plans are being developed.

Operating guidelines which currently apply to petroleum producers within Alberta include the “Strategic Plan and Industrial Guidelines for Boreal Caribou Ranges in Northern Alberta” (BCC 2001; with updates on timing of activities within Government of Alberta 2012a), the “Operating Guidelines for Industry Activity in Caribou Ranges in West Central Alberta” (WCACSC 1996) with updates provided in IL 2003-23 (Alberta Energy 2003) and the integrated standards and guidelines associated with the Alberta Enhanced Approval Process (EAP) (Government of Alberta 2013; Government of Alberta and AER 2013; ESRD 2014). In NE BC, the “Interim Oil and Gas Industry Guidelines for Boreal Caribou Ranges in Northeastern British Columbia” apply (Culling et al. 2004). As woodland caribou are listed federally as a threatened species, requirements under the federal Species at Risk Act have resulted in the development of provincial policies and recovery plans (AWCRT 2005; BCTAC 2004; Government of Alberta 2011). Recovery plan recommendations were initiated in Alberta in the late 2000s (ACCGB 2008; ALT 2009) (Appendix A). Management options were recommended by the Alberta Caribou Committee Governance Board (ACCGB) to the Deputy Minister of SRD, for implementation to recover and sustain woodland caribou in all populations consistent with the provincial woodland caribou recovery plan (2004/5 – 2013/14).,

In the first state of the science report, recommendations were made to the Canadian Association of Petroleum Producers (CAPP) to develop a woodland caribou research agenda. Since that time, a research agenda has been developed which addresses the key pathways and research gaps as identified from the scientific review of caribou biology (Golder 2008). In addition to this, it was recommended that mitigation practices that eliminate or reduce the impact of known pathways to caribou population declines be identified (e.g., Golder 2012), tested to evaluate effectiveness and applied at appropriate scales. Although mitigation measures have been identified and an initial review of effectiveness conducted (CLMA and FPAC 2007), testing and application at appropriate scales is still in its infancy.

Members of CAPP that operate within caribou ranges were actively involved within the ACC and provide representatives on the Alberta Caribou Range and Action Planning Project. They are committed to the operating guidelines and using best practices in their operations in Alberta and BC. The purpose of this document is to summarize available information on woodland caribou biology and population limiting factors (i.e., “pathways) for the boreal and mountain (Alberta) ecotypes in Alberta and BC.

2.0 REGULATORY FRAMEWORK

Alberta	*Wildlife Act*- Current status: “Threatened”
British Columbia	*Wildlife Act*- Current status: Central Mountain and Southern Mountain Populations and Boreal Population “Red Listed” (defined as “Threatened” or “Endangered”)
	Northern Mountain Population 15 of 31 herds ‘Red Listed’)
Saskatchewan	*Species at Risk Act* (SARA) – Boreal Population Current status: “Threatened”
NWT	*Species at Risk Act* (SARA) - Current status: “Threatened”
Federal	*Species at Risk Act* (SARA) - Current status Boreal: “Threatened”
	Species at Risk Act (SARA) - Current status Central Mountain: “Endangered”
	Species at Risk Act (SARA) - Current status Southern Mountain: “Endangered”
	Species at Risk Act (SARA) – Current status Northern Mountain: ‘Special Concern”

3.0 BIOLOGY

3.1 Caribou Ecotypes

Woodland caribou in western Canada have been classified into three ecotypes, the Boreal, Southern Mountain, Central Mountain and Northern Mountain ecotypes, based principally on seasonal movement patterns, life history strategy and habitat use (Edmonds 1991; Cichowski et al. 2004; Ray and Cichowski 2014; Thomas and Gray 2002) (Figure 1, from COSEWIC 2011). Given the habitat and behavioural differences between the woodland caribou ecotypes, the impacts of industrial development on their habitat may vary as might their management (Edmonds 1991). This document reviews the Boreal Ecotype and Central Mountain Population (referred to here as Mountain ecotype) in Alberta and BC. A less comprehensive review is included for the Northern Mountain and Southern Mountain populations in BC.

Boreal Ecotype

Boreal ecotype caribou do not undergo seasonal migrations, although they do make extensive movements throughout the year in their home ranges. Boreal caribou occur within large tracts of old conifer forested habitats with abundant lichens, or in peatland (muskeg) complexes, dominated by black spruce and larch (EC 2008). They may also occur within adjacent lichen-rich upland stands of jackpine or lodgepole pine (Dzus 2001; BCTAC 2004).

Boreal caribou can be found across Canada in nine provinces and territories including British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, Labrador, Northwest Territories and Yukon Territory (Figure 1). Research indicates that the southern limit of the boreal range has been and continues to recede northward across Canada since the 1900s. The number of boreal caribou currently estimated to be within Canada is 34,000 individuals in 51 local populations. Of the 51 populations, 37 are not self-sustaining (λ <1.0), and 14 are self-sustaining ($\lambda \geq 1.0$) (EC 2012a).

Alberta

- The Boreal ecotype primarily inhabits peatland complexes dominated by black spruce and larch, in combination with varying use of lichen-rich stands of jack pine or lodgepole pine in the boreal forest (Edmonds 1991; Dzus 2001).
- Caribou populations occur at low densities (0.03-0.12 caribou/km^2) and are sparsely distributed across available habitat (Dzus 2001).
- Caribou evolutionary strategy is understood as selection of low-productivity wintering habitat, (i.e., large continuous peatland areas), creating a spatial separation from other prey species (commonly moose), as an anti-predator strategy against wolves (Bergerud et al. 1984a; Cumming et al. 1996; James 1999; supported by data in James et al. 2004).
- Boreal ecotype herds in Alberta inhabit large home ranges (average adult home range 711 km^2), using different parts of their range on a seasonal basis (i.e., high spatial overlap between summer and winter ranges) with winter ranges larger than summer ranges (Stuart-Smith et al. 1997; Rettie and Messier 2001; Tracz 2005).
- The extent of occurrence for boreal ecotype caribou is estimated to be 118,535 km^2 in Alberta (ASRD and ACA 2010).
- Caribou are gregarious herd animals; this adaptation is thought to help them evade predators and protect young. Group size is highest in the winter and lowest in the summer. Spacing out in the summer is believed to be an “isolation” strategy employed by females with calves to reduce the probability of detection by predators (Stuart-Smith et al. 1997).
- Caribou are relatively long-lived ungulates, with the average age of cows believed to be 6 years in northeast Alberta (Fuller and Keith 1981). Barren-ground caribou have been reported to have life expectancies of 11 to 13 years for males and 15-16 years for females (Bergerud 2000). Females are fertile at 2 to 3 years of age, with reproducing females producing one calf per year (Dzus 2001).
- Alberta’s Boreal ecotype caribou are non-migratory compared to barren ground caribou herds in the Yukon, Nunavut and Northwest Territories which migrate thousands of kilometres every year.
- There are 12 recognized populations of boreal caribou in Alberta. Some evidence exists that caribou ranges in Alberta have been relatively isolated for some time (as reported within ASRD and ACA 2010). For example, McLoughlin et al. (2004) suggested genetic differences in caribou in northern Alberta, with discrete genetic types bisected by the Peace River. In west-central Alberta, genetic analysis demonstrated differences between the boreal ecotype Little Smoky herd and the adjacent mountain ecotype populations (McDevitt et al. 2009).

British Columbia

- Boreal caribou range is found exclusively in the lowlands of the Boreal Plains and Taiga Plains ecozones in the northeastern corner of BC (Culling and Culling 2006). Prior to 2000, research on boreal caribou in northeastern BC was very limited, with some inventories of herds conducted by the Ministry of Environment (MoE), Fish and Wildlife Section, Peace Region (Goddard 2009). Herd ranges were defined by Culling et al. (2004) as broad areas of known historical or assumed current use that supply resources necessary to

support local populations of boreal caribou, and cores as areas of high current capability and suitability based on general habitat requirements and documented occurrence. Four Boreal caribou ranges and 15 core habitats have been identified using telemetry and computer modelling, prior to 2010 (Culling et al. 2004). The four ranges are the Chinchaga, Snake-Sahtaneh, Maxhamish and Calender ranges (BCTAC 2004). In February 2010 a review of caribou ranges and core habitats was completed using all radio-telemetry and survey data collected in northeastern BC between 2000 and 2010 (Culling and Cichowski 2010). The result was the addition of two caribou ranges (formerly the Prophet and Parker core habitats) and one core habitat polygon (Shush Creek) (Culling and Cichowski 2010).

- The total extent of Boreal caribou distribution in BC is 51,171 km^2. Within that area, 39,155 km^2 has been identified as critical habitat (BCTAC 2004). It is estimated that there are approximately 1,300 boreal caribou in BC (Culling and Cichowski 2010).
- Since 2000, studies of the BC Boreal caribou herds have been consistent with Alberta studies, identifying that Boreal caribou utilize black spruce peatlands (with 10% to 60% crown closure) and areas of extremely low slope (0.0° to 0.30° slope) (Culling and Culling 2006). The use of lake clusters as refugia from predators during calving was considered important during early work (e.g., Culling and Culling 2006, D. Culling pers. comm), but DeMars and Boutin's work (2014) rejected the lake refugia hypothesis, showing instead that wolves and bears select for rivers and lakes, thus forcing caribou to use low-nutrient fens during calving to avoid predators. Lakes in NE BC may not be effective escape terrain for caribou given the marshy shorelines and lack of island refuges (DeMars and Boutin 2014).
- Boreal ecotype herds in BC inhabit large home ranges (average adult home range 1,468 km^2), moving between core habitats through matrix habitats throughout the year. Some movements appear to be associated with the selection of seasonally available resources, such as wintergreen vascular plants located along lake margins (Culling and Culling 2006), and the avoidance of predators during the calving period (DeMars and Boutin 2014).

Mountain Ecotype

Mountain ecotype caribou inhabit alpine areas in the Rocky Mountains in summer and migrate to mature and old forest in the foothills for the winter. This ecotype is generally referred to as "Mountain Caribou" within Alberta for caribou management purposes and as "Northern Ecotype" in B.C. and can be best described as terrestrial lichen feeding caribou (equivalent in feeding behaviour to the northern ecotype in B.C., but classed as the Central Mountain DU by COSEWIC (COSEWIC 2011).

Habitat use by mountain caribou changes seasonally. During the spring, summer and breeding seasons, these caribou use alpine or subalpine meadows (Edmonds 1991; Edmonds and Smith 1991). In winter, their movement to lower elevations is triggered by snow accumulation (usually late October or November; Brown and Hobson 1998) where they feed on terrestrial and arboreal lichen within mature lodgepole pine or mixed pine/spruce/fir forests (Edmonds and Bloomfield 1984). Some mountain caribou are sedentary, remaining in the mountains year-round. Caribou wintering in the mountains may cope with snow cover by moving upward to alpine areas where lichens are exposed by wind (Brown and Hobson 1998). Seasonal movements, whether local or migratory, are influenced by severe weather (e.g., snowstorms, late snow) (Brown and Hobson 1998). Elevational migrations exhibited by the mountain ecotype create a spatial separation from moose and wolves, which remain at lower elevations (Edmonds 1988; Seip 1991). In recent years some mountain caribou herds

have failed to migrate to traditional winter range in the foothills and have remained in the mountains year-round (Smith 2004).

Research conducted by McDevitt et al. (2009) in the Canadian Rocky Mountains (Alberta and BC) has shown that current caribou populations in this area are descendants of both barren ground *(Rangifer tarandus groenlandicus)* and woodland caribou *(Rangifer tarandus caribou)*. This information may explain why some individuals within a herd are more migratory than others (McDevitt et al. 2009; Hebblewhite et al. 2010).

Alberta

- In Alberta, the Mountain ecotype is confined to habitat within the Rocky Mountains and adjoining foothill regions (Figure 1). There are 3 populations of mountain caribou in Alberta (not including National Parks): A La Peche, Narraway, and Redrock-Prairie Creek. Both Narraway and Redrock-Prairie Creek populations are trans-boundary and cross into BC. In Jasper National Park, there are 3 additional populations of mountain caribou (Tonquin, Brazeau, Maligne).
- Alberta's Mountain ecotype exhibit migratory behaviour, moving approximately 80 km into the Rocky Mountains in the spring from lower elevation foothills which provide winter habitat (Brown and Hobson 1998; Saher 2005).
- The extent of occurrence for mountain ecotype caribou in Alberta is estimated to be 16,298 km^2 (ASRD and ACA 2010).
- Terrestrial lichens account for 60% to 83% of winter diet matter. In summer, mountain caribou diets are dominated by willow leaves, sedges and lichens (Brown and Hobson 1998).

Figure 1: Designatable Units for Caribou (Rangifer tarandus) in Canada. (taken from Figure 4, COSEWIC 2011) (Occupied Habitat)

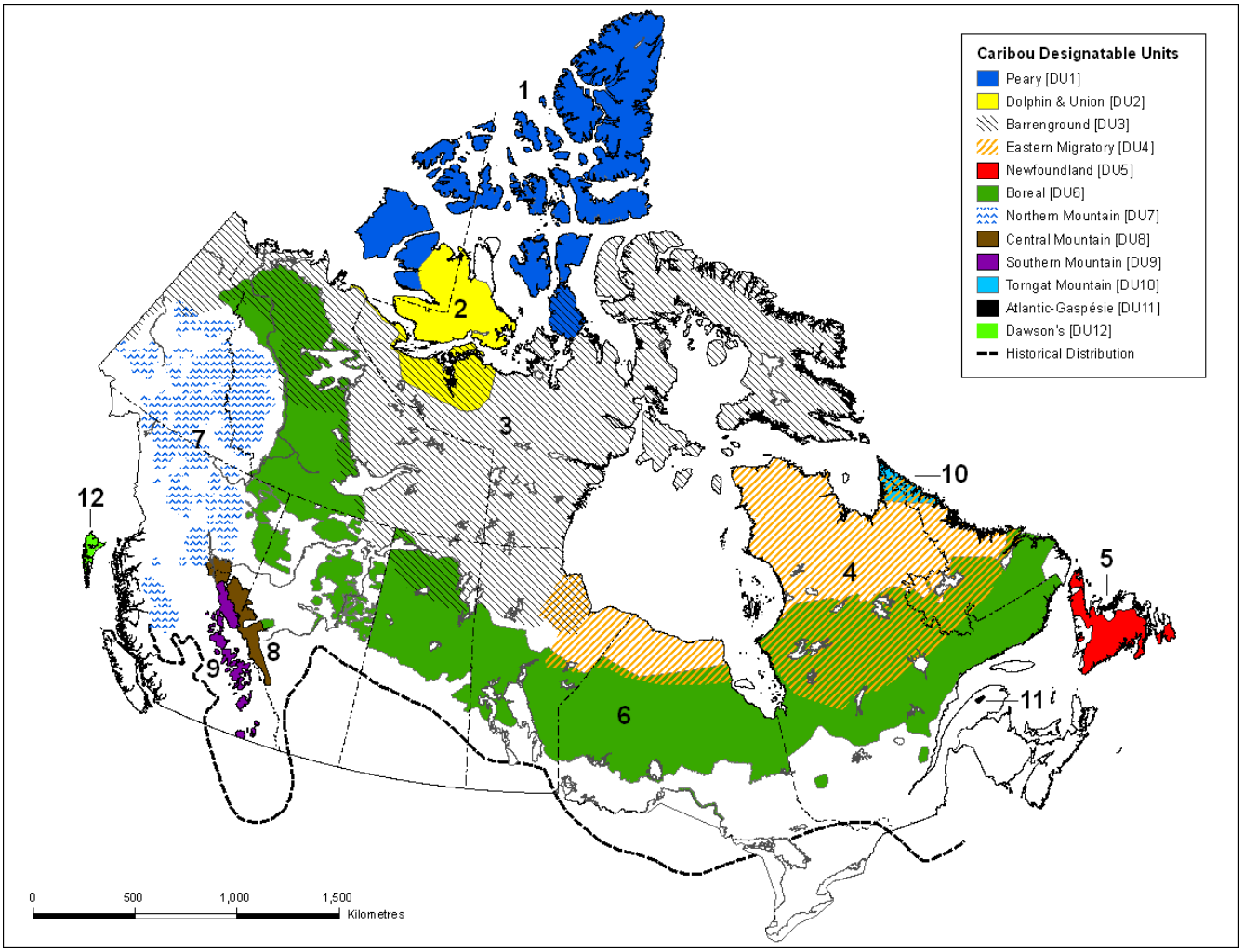
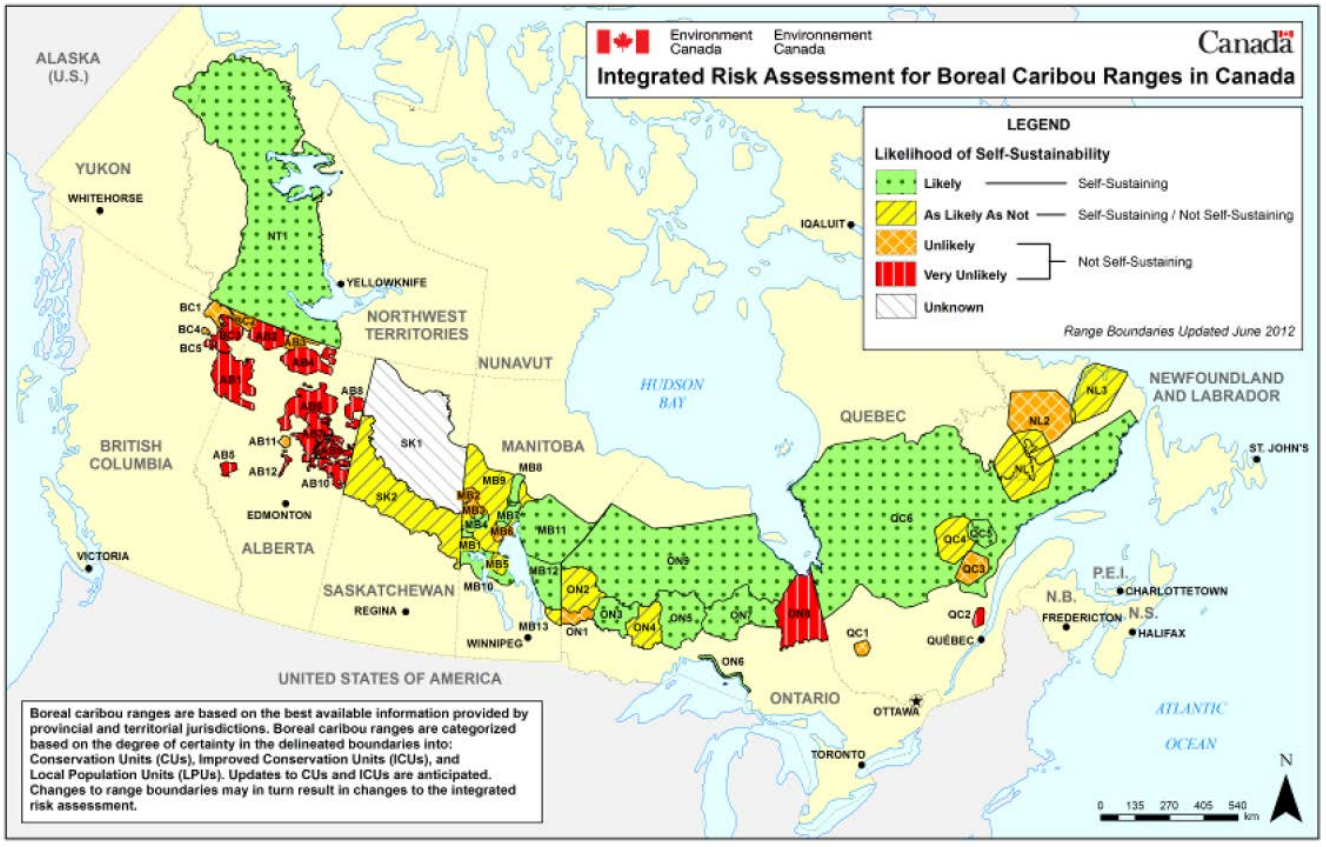


Figure 2: Integrated risk assessment for boreal caribou ranges in Canada, reflecting the capacity of each range to maintain a self-sustaining local population of boreal caribou (from EC 2012)



British Columbia

- In British Columbia, three metapopulations of caribou are recognized in the Southern Mountain ecotype population (Thomas and Gray 2002). Two of these metapopulations (west central and the north central metapopulation which overlaps with Alberta mountain and Northern Caribou ranges respectively) are considered to be terrestrial lichen-feeding, while the most southern metapopulation is best described as the arboreal lichen-feeding ecotype (Thomas and Gray 2002; Jones 2007).
- Northern Mountain ecotype caribou occur in northern British Columbia and the Yukon (Figure 1). There are 31 herds of northern caribou in BC, and they are found in mountainous and adjacent plateau areas with relatively low snowpacks in northern interior BC (Cichowski et al. 2004). This ecotype spends much of the summer in alpine and upper subalpine range and in winter moves down to coniferous forest in lower subalpine and, rarely, to the montane. Most of the northern mountain caribou winter in areas where snow cover is relatively low at low elevations. They feed primarily on terrestrial lichens and secondarily on arboreal lichens, inhabiting mature lodgepole pine or spruce forests (Thomas and Gray 2002).
- The Northern Mountain and Southern Mountain boundary in BC is approximately between spruce-willow-birch and the Engelmann spruce-subalpine fir biogeoclimatic zones (Thomas and Gray 2002).

3.2 Caribou Populations

Census techniques for caribou are limited in boreal regions because the animals occur at low densities over large areas, often occur in small groups (i.e., clumped distribution), have cryptic coloration and behaviour that makes them difficult to locate from aircraft (Dzus 2001; Wynes 2000), and are expensive to conduct given the species' low densities. These survey limitations preclude accurate and precise population size estimates (Thomas and Gray 2002).

General woodland caribou population trends (lambda and realized population growth) can be measured through systematic monitoring (Boutin 2010, EC 2012a, Hervieux et al. 2013). In Alberta, population trends are based on adult mortality and calf recruitment data obtained from radio-collared animals and herd composition surveys. Annual values for the finite annual rate of population increase (lambda; λ) are calculated for the adult female component of all provincial caribou populations in Alberta (Dzus 2001; ASRD and ACA 2010; Hervieux et al. 2013). Females have been preferentially selected for collaring as they provide information on adult survival, reproductive success, and calf survival (Applied Ecosystem Management 2001). For population stability, Environment Canada (2008) suggests a minimum calf recruitment rate of 28.9 calves/100 cows. Species with naturally low population levels, such as woodland caribou, are highly vulnerable to extinction if fertility/mortality rates change (e.g., predator-prey relationship).

Using non-invasive methods to estimate caribou population sizes, monitor trends and evaluate their health is becoming increasingly popular for researchers. For example:

- Gustine et al. (2011) collected fresh scat on snow during late winter to determine protein status in the Chisana caribou herd by determining dietary and endogenous additions of nitrogen to urinary urea. Nitrogen found in a penned caribou and predator exclosure found that lichens were the main forage (>40%) caribou fed on and δ15N of fiber marked the major forages in their diets. A comparable amount of animals lost core body mass and body protein. Nutritional condition of individual caribou was assessed using

nitrogen isotopes from feces and urine to assess protein status of 4 groups of free-ranging migratory and sedentary woodland caribou herds. The researchers found numerous concerns and problems with random collections of excreta in snow, and the extent of variation in isotopes limited the ability to make concrete inferences at the herd level.

- Fecal pellets have been collected as a source of DNA to sample animals and estimate population demographics in Jasper National Park (Hettinga 2010), North Interlake region of Manitoba (Hettinga et al. 2012), and northeast Alberta (Wasser et al. 2012, AESRD unpublished). Population estimates from fecal DNA collected in Jasper National Park and Manitoba were comparable to the mark-resight estimates over the same sampling period (Hettinga 2010; Hettinga et al. 2012), and showed declining trends.
- Fecal pellets have been collected to better understand age-class, mating systems and fitness of caribou in Jasper National park and North Interlake. Calves were able to be distinguished from adult age-classes, and a polygynous mating system was identified in the South Jasper population (Flasko 2014).

Boreal Ecotype

Alberta

Circumstantial evidence in the past suggested that caribou had declined throughout most of their range in Alberta (Edmonds and Bloomfield 1984, Bradshaw and Hebert 1996, Brown and Hobson 1998). Reasons for the decline and its magnitude were disputed by Bradshaw and Hebert (1996) and Wasser et al. (2011) but with rebuttal in Boutin et al. (2012). McLoughlin et al. (2003) provided the first concrete assessment of these long-term population declines within the Boreal ecotype herds occurring in northeastern Alberta. In their study of 6 northeast caribou populations, McLoughlin et al. found that four ranges had declined substantially (East Side of the Athabasca River (ESAR), Red Earth (RE), Caribou Mountains, and Cold Lake Air Weapons Range-Saskatchewan), while populations in two ranges appeared to be stable (CLAWR-AB and West Side of the Athabasca River [WSAR]). A dramatic decline occurred between McLouglin et al.'s 2003 study and a report published in 2010. Boutin (2010) identified four caribou populations in the NE (ESAR, CLAWR, WSAR, Red Earth) that had all declined by at least 70% since the mid-1990s.

- The declining state of Alberta boreal caribou over the past 2 decades was previously summarized in ASRD and ACA 2010, and recently analyzed in Hervieux et al. 2013. Between 1994 and 2012, 1337 adult female caribou were captured and radio-collared; overall, the annual population growth rate (lambda, λ) across all populations was an average of 0.918 (when lambda value is >1, population is increasing; equals 1, population is stable; <1, the population is declining). High calf mortality and female mortality are the primary factors leading to the decline. Caribou in Alberta have experienced a nearly 50% decline in the past 10 years (ASRD and ACA 2010).
- Evidence suggests that high calf mortality rates, within the first month of their birth (Pinard et al. 2012), are a substantial contributor to Boreal ecotype caribou population declines in Alberta (Stuart-Smith et al. 1997). This is consistent with woodland caribou populations throughout Canada (Culling and Culling 2006; Mahoney et al. 1990, Rettie and Messier 1998; Whitten et al. 1992). High calf mortality implicates poor winter energetics or predation, or a combination of both (Thomas and Gray 2002).
- Boreal ecotype caribou population monitoring data supports the correlation between caribou population decline (finite rate of increase) with linear feature density and the percent of young habitat (Sorensen et al.

2008 equation updated by Boutin and Arienti 2008). In the correlation, linear features include seismic lines, roads, and pipelines and young forest includes stands that were cut or burned within the last 30 years).

British Columbia

- Boreal Caribou range is located in the northeast corner of British Columbia, in approximately 15% of the province. Areas include the Etsho Plateau, Maxhamish Upland, Petitot Plain and the Fort Nelson Lowland ecosections of the Taiga Plains Ecoprovince and the Clear Hills ecosection of the Boreal Plains Ecoprovince (BCTAC 2004).
- In the late 1970's aerial overview flights were conducted in Boreal caribou range in BC as part of environmental impact surveys for the Alaska gas pipeline. During those flights, few caribou or signs of caribou were seen. Incidental observations of caribou in the boreal forest increased following wolf reduction in the adjacent Muskwa-Kechika area in the 1980's. A linear transect survey conducted in the Milligan Hills area found 68 caribou for an average density of 70 caribou /1,000 km^2 although the reliability of the survey was considered poor (BCTAC 2004).
- The first estimate of Boreal caribou in BC was 725 in 1996. The population trend was unknown. The reliability of the 1996 estimate is questionable given the lack of information on population structure or on population trend at that time. New techniques have suggested that there are approximately 1,300 Boreal caribou in northeastern BC (Culling and Cichowski 2010).
- Because so few population surveys or density transects have been conducted on Boreal caribou in northeastern BC, it is difficult to determine the current population trend. However, some biologists believe that Boreal caribou numbers in northeastern BC have declined from historic levels (R. Bachmeyer, pers. comm. *as cited in* BCTAC 2004).
- Based on Sorenson's 2008 model, Thiessen (2009) evaluated the level of anthropogenic disturbance within BC's former caribou ranges and core habitats. Thiessen's results suggest that the majority of BC's boreal caribou populations are declining as three of the four ranges and 12 of the 15 core habitats exceeded 61% disturbance.
- Late winter surveys conducted between 2003 and 2009 in the boreal caribou ranges resulted in estimated calf recruitment numbers from five to 24 calves/100 cows (Culling and Cichowski 2010). These estimates fall below the threshold of 28.9 calves/100 cows as recommended by Environment Canada (2008).
- Boreal caribou in northeastern BC do not appear to occur in discrete herds, but instead in small, dispersed, relatively sedentary bands throughout the year (BCTAC 2004). Herd ranges were defined by Culling et al. (2004) as broad areas of known historical or assumed current use that supply resources necessary to support local populations of boreal caribou, and cores as areas of high current capability and suitability based on general habitat requirements and documented occurrence.
- In October 2008, the Peace Region Boreal Caribou Monitoring Program's activities included determining a 'minimum number known alive'. During the rut (when caribou aggregate), 36 caribou were counted (25 in Parker Lake core, 10 in Kiwigana core and 1 in the Capot Blanc core). For all animals counted, there were 31.8 calves/100 cows and 31.8 bulls/100 cows, above the threshold ratio of 28.9 calves: 100 females for minimum recruitment (EC 2008). However, the MoE has a low confidence in this ratio as the count was not

conducted in March which would give a true representation of calf recruitment to the population and the count involved a small sample size (Thiessen 2009).

- In 2011 the BC Ministry of Environment prepared an Implementation Plan for managing BC boreal caribou (BC 2011). The plan provided a goal to decrease the decline of boreal caribou in BC, and outlined numerous management targets including deploying radiocollars on approximately 15% of the population of each herd. In winter 2012/13, 164 females were collared and monitoring continues of the animals; to date, calf recruitment surveys and minimum population counts indicate a declining population of boreal caribou in all 6 herds (Culling and Culling 2013).

Mountain Ecotype (Alberta)

- Seven mountain caribou ranges are recognized in Alberta: Redrock/Prairie Creek, Narraway, A La Peche, Maligne (Jasper), Tonquin (Jasper), Brazeau (Jasper) and Banff (Hervieux et al. 2013; Parks Canada 2011a).
- In 2009, it is believed that the Banff population was extirpated when the five remaining caribou died (A. Dibb and J. Whittington pers. comm. *as cited in* ASRD and ACA 2010; Hebblewhite et al. 2010a; EC 2014).
- All three mountain ecotype populations on multi-use landscapes in Alberta (Redrock-Prairie Creek, Narraway and A La Peche) are in decline, with lambda values of <1 (Hervieux et al. 2013).
- 534 mountain ecotype caribou were estimated to be present in Alberta in spring 2009, and of these, 451 were mature individuals (ASRD and ACA 2010). This estimate was less than the 2005/06 estimate of 662 individuals (ASRD and ACA 2010).
- Population projections in west-central Alberta appear to be more sensitive to adult female survival than calf recruitment, as is expected for a long-lived species. However, management programs that focus on enhancing calf recruitment may be more practical and effective because there is little variability in adult female survival (Smith 2004).

Mountain Ecotype (British Columbia)

- Over a 20 year period (from 1984 to 2004), 386 adult caribou were captured and fitted with either very high frequency (VHF) or global positioning system (GPS) collars across the entire distribution of the endangered mountain caribou ecotype in British Columbia (Wittmer et al. 2005a). Seventeen subpopulations of mountain caribou were identified (with the exclusion of the South Selkirks subpopulation). The total population estimate across all subpopulations was 1,540 with an average overall lambda of 0.92 (trends varied across individual subpopulations with southern populations decreasing at a faster rate than northern ones, of which “some were relatively stable”) (Wittmer et al. 2005a).
- Calf recruitment surveys and adult mortality for five northern mountain herds (Quintette, Bearhole/Redwillow, Burnt-Pine, Moberly and Kennedy Siding) have been conducted/assessed by the BC Ministry of Environment beginning in 2003 (Seip and Jones 2008, 2011). In 2008, the lambda for the entire group was 1.07, however individual herds within the population were likely declining (Seip and Jones 2008). Very low calf recruitment and high adult mortality rates between 2003 and 2011 indicated that all caribou herds were declining (Seip and Jones 2011).

- Seip and Jones (2012) incorporated accessible habitat models and GPS locations for the Quintette caribou herd to characterize a central region of the most high-elevation locations for this herd in the winter. 21,028 core winter habitat locations were documented within the Peace Forest District from 2002-2012 which integrated 95% of the high-elevation caribou locations within this 71,276 hectare region (Seip and Jones 2012).
- Updated information provided in 2013 for the northern mountain herds (including Quintette, Bearhold/Redwillow, Burnt-Pine, Moberly, Kennedy Siding, and Scott) indicated that Burnt-Pine was extirpated, and all but 1 of the remaining populations had low calf recruitment and low adult survival. Biologists estimated a total of 266 to 305 animals for the BC portion of the central mountain DU (Seip and Jones 2013).
- The South Peace Northern Caribou Implementation Plan for Graham, Moberly, Scott, Burnt Pine, Kennedy Siding, Quintette and Narraway herds, identified the need to increase the populations to greater than 1,200 animals within 21 years and protect 90% of high elevation winter habitat (BC Ministry of Environment 2013).
- The Science Update for the South Peace Northern Caribou implementation plan estimated approximately 1,000 northern caribou remaining and all herds on the decline (BC Ministry of Environment 2014).

3.3 Habitat Availability, Quality and Use

In 2011, Environment Canada updated the scientific review for boreal caribou critical habitat (EC 2008) which was designed to "provide a probabilistic evaluation of critical habitat relative to the set of conditions (demographic and environmental) within each range (EC 2011b). Critical habitat for boreal caribou was defined as "the resources and environmental conditions required for self-sustaining populations, or groups of animals under similar local conditions, throughout their current distribution in Canada" for the purpose of conducting the current assessment. Local caribou population range was identified as the relevant spatial scale for the identification of critical habitat, with 17 of the 57 boreal caribou ranges assessed as self-sustaining (with three assigned "very likely" and 14 "likely"), seven were assessed as not self-sustaining/self-sustaining (with an assignment of "as likely as not"), and 33 were assessed in the not self-sustaining category (with 14 assigned "very unlikely" and 19 "unlikely") (Figure 2). The advances made to the conceptual and methodological designs to address key uncertainties/limitations identified in the 2008 scientific review improved the robustness of the results with respect to providing a scientific description of critical habitat for boreal caribou. A critical habitat framework was implemented with a scientific description of critical habitat that focused on "an integrated risk assessment of whether or not the current set of habitat and population conditions within a range are sufficient to support a self-sustaining population, a methodology to identify range specific disturbance thresholds, and a description of the bio-physical attributes of boreal caribou habitat. Meta-analysis of recruitment in relation to disturbance was also undertaken and the updated combined disturbance (includes areas burned within the last forty years, and non-overlapping linear and polygonal human land use features buffered by 500 m) model explained approximately 70% of the variation in caribou recruitment (EC 2011).

Boreal Ecotype

Alberta

- In Alberta, caribou prefer mature to old forests because their primary winter food, lichen, is most abundant in these forest stands (Dzus 2001). Older forests (40+ years) in fen/bog/peatland complexes are considered primary caribou habitat in the boreal forest. While caribou show a preference for these habitats (Anderson 1999; Bradshaw et al. 1995; Stuart-Smith et al. 1997; Schneider et al. 2000; Thomas et al. 1996; Tracz 2005), they also use other areas with high lichen cover such as upland jackpine and lodgepole pine stands (Dzus 2001).

- Caribou movements appear to be random within peatland complexes with no aggregation areas for calving, rutting or wintering in northeastern Alberta. Movement rates (km/day) are greater during the rut and late-winter periods (Stuart-Smith et al. 1997) and are lowest during the post-calving and summer seasons (Rettie and Messier 2001). Caribou tend to move into areas of higher tree cover when snow depths increase, as movement and feeding are easier (Fuller and Keith 1981). The availability of extensive range areas is a key habitat characteristic for caribou to minimize predation risk (Bergerud 1984).

- Caribou tend to distance themselves and avoid young forests, more productive forests and river valleys which help to spatially segregate them from alternate prey species and predators (ASRD and ACA 2010). Survival probabilities are higher for individual boreal caribou that are able to space themselves away from upland habitat (McLoughlin et al. 2005). However, due to declining caribou populations in northern Alberta, Latham et al. (2011) suggest that peatlands may no longer shelter caribou from wolf predation.

Alberta has designated caribou habitat range areas which have been mapped based on historical caribou location data, as well as defined caribou habitat. These range area boundaries can be obtained at:

- Availability of quality habitat for summer and winter forage and for breeding are not believed to be limiting for the Boreal ecotype in northeastern Alberta. However, habitat changes from anthropogenic disturbances are considered the root cause of a proximate increase in predation risk to caribou (Boutin 2010).

- Large-scale distribution patterns of caribou had little relationship with the loss of lichens to wildfires, even though wildfires are considered detrimental to caribou lichen forage supply in the short-term (Dunford 2003). It has been suggested that burning may be necessary to rejuvenate older forests with declining lichen productivity (Klein 1982, *as cited in* Culling and Culling 2006).

- Boreal ecotype caribou exhibit strong site fidelity, even when ranges are heavily impacted by fire or industrial activities (Dunford 2003; Tracz 2005).

British Columbia

- Boreal caribou habitat use in northeastern BC was first investigated during a study conducted on radio-collared Boreal caribou in the Snake River and Sahtaneh River area north of Fort Nelson. Within the Snake-Sahtaneh caribou area, seven core habitats were identified and mapped (Culling et al. 2006) and represent the critical habitat for Boreal caribou in BC (BCTAC 2004). Boreal caribou movements and habitat use in northeastern BC are similar to those reported for Alberta Boreal caribou (BCTAC 2004; Culling and Culling 2006). These similarities include:

- Boreal caribou prefer large black spruce peatlands (muskegs) throughout the year, but also use mosaics of habitat to a lesser extent (including wetlands, clusters of lakes and lake margins where caribou were observed from November to January foraging for winter-green vascular plants as well as pawing up muskrat push-ups, and use of regenerating burns during spring, summer and fall);
- use of commercial forested areas is limited;
- Boreal caribou use of muskegs/peatland complexes may provide some habitat separation from moose and wolves, which use adjacent upland areas;
- during spring and calving, Boreal caribou cows tend to be widely dispersed and are usually found alone or with a calf;
- pine stands are limited in Boreal caribou ranges in BC and therefore are not an important habitat; (commercial pine stands appear to be important in heavy snow years in Alberta).

- Results from the Snake-Sahtaneh area indicate that all female caribou monitored showed consistent calving fidelity to a single core habitat (Culling and Culling 2006). Monitoring revealed the importance of seven core habitat areas within the Snake-Sahtaneh range; the Paradise, Clarke, West Kotcho, North Kotcho, East Kotcho, Etsho and Tsea Cores. Upon completion of the study, 94% of 96,645 3D GPS caribou locations collected fell within these cores, as did 65 of 66 identified calving sites. Caribou activity was concentrated in the cores throughout the year, including during calving and rutting periods. Home ranges of individual caribou encompassed up to five of the seven cores, with caribou typically making direct movements between cores while travelling throughout the range (Culling and Culling 2006).
- The Snake-Sahtaneh research and subsequent resource selection function (RSF) models identified that boreal caribou in BC utilize black spruce peatlands (with 10% to 60% crown closure), areas of extremely low slope (87% of caribou locations were on terrain of less than 600 slope), and lake clusters comprised of lakes between 5 and 50 ha in size (Culling and Culling 2006). Similar to other jurisdictions, boreal ecotype herds in BC inhabit large home ranges (average adult home range 1,468 km^2), moving between core habitats through matrix habitats throughout the year. Some movements appear to be associated with the selection of seasonally available resources, such as wintergreen vascular plants located along lake margins (Culling and Culling 2006). Although lake margins may provide important forage, DeMars and Boutin (2014) rejected the lake refugia hypothesis and instead showed movements away from lakes, rivers and nutrient-rich bogs during the calving season as an ecological trade-off to avoid predators. Nutrient-poor fens provide important calving habitat despite the lack of forage, and is considered an important habitat characteristic to maintain on the landscape.
- Boreal caribou monitoring within the Maxhamish Range has indicated that caribou occur primarily within the defined core areas (Rowe 2007a; Thiessen 2009; Goddard 2009). Caribou had limited use outside of the Capot-Blanc core area in wet meadow habitats to the southeast of Patry Lake as well as short forays outside of the core to the north and east. In the Kiwigana core, a small portion of habitat was utilized outside the delineated core in the south. All potential calving sites occurred within the core areas. Rowe (2007a) suggested that the lack of caribou use of the northern extent of the Kiwigana core was likely due to no caribou being collared in the area, and that lack of use should not suggest that this area is unoccupied. Although an analysis of selection of low slope areas was not as comprehensive as in the Snake-Sahtaneh

Range (Goddard 2009), Rowe (2007a) suggests that it appears that extreme low gradient areas are also important within the Maxhamish Range.

- The BC Chinchaga boreal caribou range is comprised of two delineated core areas; the Milligan core and the Etthithun core, located north of Fort St. John, BC. A GPS collaring project was conducted from 2004 to 2006 (Rowe 2007b). Home ranges of the collared caribou occurred almost entirely within core habitats (94% of observations). There was however, no inter-core movement observed. A strong selection for swamps (low-lying wetlands) was observed during the calving period (Rowe 2007b).
- Boreal caribou selection of burn regeneration habitats (<50 years since disturbance) during the snow-free period in northeastern BC (Culling and Culling 2006) is believed to occur because these sites offer access to herbaceous shrubs and vegetation, insect relief and predator avoidance (Nagy et al. 2005 *as cited within* Culling and Culling 2006).
- Terrestrial lichens provide a critical food source for Boreal caribou in BC. During winter, arboreal lichens may also be an important component of their diet depending on lichen availability and snow conditions that affect the ability for caribou to crater for terrestrial lichens (BCTAC 2004). Boreal caribou typically crater for ground lichens in peatland areas and remain within the boreal forest in all seasons (Jones 2007).
- Although Boreal caribou in the Snake-Sahtaneh area are non-migratory, they do make frequent movements through matrix habitats to core habitats. Unimpeded movement between core habitats is imperative; failure to adequately manage the matrix habitats will lead to fragmentation and isolation of individual local populations (BCTAC 2004).

Mountain Ecotype

- Mountain caribou habitat use varies seasonally, with calving, summer and the rut occurring in subalpine or alpine habitats. As snow accumulates, mountain caribou move down in elevation to winter ranges within the forested foothills where moderate snow depths allow for primary winter foraging on terrestrial lichens (Edmonds and Bloomfield 1984; Brown and Hobson 1998).
- Mountain caribou in west central Alberta select dense forest stands (typically dominated by pine) over 80 years old, with a preference for stands aged 120-160+ years during the winter. At a coarse scale, mountain caribou select habitats which reduce predation risk and focus on foraging habitats at a finer scale. Cratering sites are associated with moderately dense stands (around 50% canopy closure) and shallow soft snow. Arboreal feeding sites are associated with old stands containing greater amounts of spruce (*Picea* spp.). During harsh snow conditions, mountain caribou move into spruce and fir dominated stands aged over 130 years (Szkorupa 2002a).
- Mountain caribou in west central Alberta select for larger habitat patches, patches with more black spruce and less fir tree species content, patches with higher area to perimeter ratios and for habitats with less rugged terrain during the winter. During the spring migration period, mountain caribou exhibit different habitat selection patterns when traveling versus when resting or foraging. When traveling, mountain caribou select for less rugged terrain closer to water (i.e., restricted to valley bottoms in the mountains). When foraging or resting during the migration period, mountain caribou occur further from water and prefer less dense, older forest stands (Saher 2005).

- Radiocollar data for the Redrock-Prairie Creek mountain caribou population was collected between 1998 and 2011 and analyzed to evaluate change of habitat use in their winter range (i.e., on Alberta multi-use crown land) through time. Industrial disturbance nearly doubled during the study period, and caribou shifted their winter range distribution away from the highly disturbed foothills to the less disturbed mountain portion of their range as development increased through time (Slater 2012).
- Travel corridors need to be maintained to facilitate inter-population movements and occupation of both summer and winter ranges (Thomas and Gray 2002).
- Jones (2008) studied the seasonal use and selection of three northern ecotype woodland caribou herds (Kennedy Siding, Moberly and Quintette) in the South Peace region of central British Columbia. The Kennedy Siding herd selects alpine areas during the spring and calving, and high elevation subalpine (parkland and fir) in all seasons. They utilize elevations of 750 to 1,950 m and migrate from out of the mountains in early winter to a pine dominated forest containing a clear cut area (Jones 2008). This herd avoided spruce-leading, deciduous/shrub and young-coniferous cover types with the exception of the calving season when they select for spruce-leading and young coniferous stands (Jones 2008).
- The Moberly herd utilizes similar elevations of 750 to 1,950 m and select alpine habitats during all seasons, except early winter (Jones 2008). Pine stands are selected during all seasons with the exception of calving (Jones 2008). The herd avoided or did not use spruce-leading, deciduous/shrub and young coniferous stands in all seasons (Jones 2008).
- The Quintette herd select alpine (parkland or fir) during all seasons, with fir leading during the calving season. Telemetry data on the Quintette herd has been collected since 2002. Both VHF- and GPS-collar data indicates that the Quintette herd is typically located at elevations greater than 1,600 m and selects for alpine habitat and subalpine stands (fir and parkland) during all seasons (Jones 2007, 2008). There is some evidence of caribou movement between the Quintette herd and the adjacent Bearhole-Redwillow herd to the east (Seip and Jones 2011), and also of range overlap with the Parsnip herd to the west (Jones 2007). Core habitat areas for the Quintette herd have recently been identified by the province based on habitat modeling in conjunction with telemetry and aerial survey data (Jones 2008, Seip and Jones 2012, Williamson-Ehlers 2013). Approximately 71,276 ha of the Peace Forest District has been identified as core high-elevation winter habitat for the Quintette herd (Seip and Jones 2012). Windswept, high elevation ridges that provide access to terrestrial lichens constitute the highest value habitat (Jones 2007, 2008). The Kennedy Siding caribou were found in elevations between 700 and 1,700 m and selected the fir and pine leading stands (Jones 2008).
- Waterhouse et al. are developing and testing group selection silviculture systems to maintain caribou habitat, while allowing some timber harvest in high elevation Engelmann spruce-subalpine fir forests in the Quesnel Highland. A second study in also underway to develop and test irregular group shelterwood and group selection silviculture systems to maintain caribou habitat, while allowing for some timber harvesting in dry, high elevation, lodgepole pine forests within the Chilcotin . Both projects are ongoing and long term with no anticipated completion date (as cited within NCASI 2011).

- Polfus et al. (2014) investigated the differences of predicting woodland caribou habitat selection with western sciences' resource selection functions (RSF) and traditional ecological knowledge (TEK) models within the territory of the Take River Tlingit First Nation of northern British Columbia. The models ability to spatially predict the occurrence of 10 collared caribou locations from the Atlin herd was documented. Both modeling approaches accurately predicted that caribou selected low elevation lodgepole pine forests in the winter and high quality alpine habitats in the summer. Polfus et al. (2014) suggest that TEK may be beneficial for determining the quality of habitat in regions that are currently avoided by caribou due to human disturbance, as well as to locate sufficient areas for habitat restoration, guide dynamic estimates of habitat quality, or produce population abundance targets.

3.4 Fecundity and Mortality Rates

To maintain stable populations, naturally low recruitment rates of woodland caribou must be balanced by an equally low mortality rate. Population 'stability' occurs when recruitment (addition of yearling calves) and annual mortality of adult female caribou is about equal, typically ranging from 10% to 16% (Thomas and Gray 2002). Therefore, woodland caribou populations are exceptionally susceptible to losses from any kind of direct mortality. Major mortality factors for woodland caribou populations across Canada include predation, hunting, vehicle collisions, parasites and disease (e.g., meningeal worm carried by deer is fatal to caribou) (Cumming 1992, EC 2012a). Parasites and disease, in combination with accidents (vehicle collisions, avalanche deaths), hunting and predation, have contributed to the disappearance of caribou from New Brunswick, Nova Scotia, and some parts of Ontario (Cumming 1992).

Boreal Ecotype

Alberta

- Although licensed hunting of Boreal caribou has been prohibited in Alberta since 1981, almost 10% of radio-collared Boreal caribou mortalities from 1992 to 2000 were suspected to be caused by humans (Dzus 2001). Mortality due to poaching and vehicle collisions may be closely related to human access.
- Adult female caribou have high pregnancy and calving rates, suggesting that these factors are not responsible for poor calf recruitment (Smith 2004; ASRD and ACA 2010). In Alberta, pregnancy rates have been reported to range from 90-100% with 70-95% of females producing calves (McLoughlin et al. 2003).
- Stress in the third trimester (late winter/early spring) was previously believed to influence miscarriage rates. Subsequent study indicates that miscarriage is not a major factor affecting populations with a high percentage (+95%) of females carrying calves to term (McLoughlin et al. 2003).
- Calf mortality is greatest during the first month after parturition (Culling and Culling 2006; McLoughlin et al. 2003), possibly within the first 1 to 2 weeks of life (D. Hebert, pers. comm.). After one year of life, survival rates approach adult levels (ASRD and ACA 2010).
- Research and field results from the Little Smoky herd have indicated that wolverine and bear play a major role in caribou calf mortality during the spring and summer months (K. Smith pers. comm.). This is similar to results from northeastern BC (Gustine et al. 2006).
- Low calf recruitment rates have been considered to be indicative of declining caribou populations (e.g., calves comprised 9% of spring population in Stuart-Smith et al. 1997 study), with the percent of calves in fall and winter composite counts [12%] having been reported less than annual adult mortality

[15%] (Fuller and Keith 1981). This is based on Bergerud's (1974) suggestion that caribou populations with 12% to 16% of calves in the late winter or spring are stable while those populations with less than 10% calves by spring are likely declining. Although female survival rates in Alberta are comparable to the rest of Canada, calf recruitment to one year of age appears to be lower (McLoughlin et al. 2003).

- Hervieux et al. (2013) measured population trend and growth rate for 13 of Alberta's 16 remaining woodland caribou populations, as well as one population from Saskatchewan from 1994-2012 using adult female survival and calf recruitment data. The mean adult female survival was recorded as 0.85 as a result of capturing 1,337 adult female caribou. Mean recruitment of 0.154 calves/cow was also determined by using late-winter calf recruitment surveys. Annual population growth rates were calculated using age-structured population models and were measured as being 0.918. Ten of the 14 caribou populations are declining rapidly, with realized decline reported at roughly 50% every 8 years across Alberta. Bistcho, Cold Lake (AB), Red Earth, Redrock-Prairie Creek, and Chinchaga caribou herds had the greatest decline in population. The lowest amount of human habitat alteration occurred in Richardson, and Yates ranges, thus, these populations were stable or only slightly declining. A predator management program in Little Smoky has enabled that population to increase to a stable population growth level. Banff National Park caribou herd became extirpated during their study. ESAR, Red Earth, Caribou Mountain, Cold Lake (SK), Cold Lake (AB), and WSAR populations are declining at approximately 10% per year. This decline has two equal drivers; low adult survivability and low calf survivability which are both attributed to human-induced apparent competition, carried out by wolves and broad-scale habitat fragmentation.
- Recruitment is often measured using late winter young:adult age ratios. However, this ratio may be difficult to accurately interpret given the addition of several vital rates to annual ratios. DeCesare et al. (2012) identified that the supplementation of age ratio data with concurrent radio-telemetry monitoring of adult female survival allows both retrospective estimation of empirical population growth rates and the decomposition of recruitment-specific vital rates. The estimation of recruitment and population growth rates for the A la Peche woodland caribou population occurring within west-central Alberta suggests that adult female survival and recruitment rates were approximately equivalent factors driving population growth (DeCesare et al. 2012).

British Columbia

- Consistent with Boreal caribou populations in other regions, Boreal caribou in BC exhibit high pregnancy rates (90% to 97%) (Seip and Cichowski 1996), high parturition rates, and females are in good late winter condition indicating that forage availability is not lacking (Culling and Culling 2006). Also consistent with other regions, caribou calf mortality in BC is generally highest in the first month following birth (Bergerud and Elliott 1986; Culling and Culling 2006; Gustine et al. 2004).
- In the Snake-Sahtaneh study, spring surveys determined calf survival (10 months of age) from 12% to 14% (Culling and Culling 2006). Juvenile recruitment (using late winter surveys) was low in 2003 and 2004 (5 calves/100 cows and 9 calves/100 cows, respectively) (Culling and Culling 2006).
- Monitoring of calf mortality over the first five weeks of life resulted in predation from wolves (5), wolverines (5), unknown (3), bears (2) and eagles (2) (Gustine et al. 2006).
- The Ministry of Water, Land and Air Protection (MWLAP) found recruitment of 23.7 calves/100 cows in their 2004 late winter surveys in Management Units 7-54 and 7-55 in northeastern BC (BCTAC 2004). Goddard

(2009) summarizes calf survival estimates for northeastern BC and indicates that at current levels, the boreal caribou in the Snake-Sahtaneh, Chinchaga, and Maxhamish ranges are below Bergerud's (1974, 1996) threshold, suggesting that the populations are in a state of decline.

- Although calf recruitment was indicative of a declining population, adult survival for the Snake-Sahtaneh herd was estimated at 0.94% (Culling and Culling 2006). However, the Snake-Sahtaneh study was not of a sufficient duration to establish a long-term population trend and further investigations are required to determine herd status (Culling and Culling 2006).
- As there is almost no historical information on Boreal caribou population numbers in BC, it is unknown whether liberal hunting regulations had an impact on Boreal caribou numbers. However, poor access prior to oil and gas development possibly contributed to limited hunting pressure on Boreal caribou. Caribou hunting was closed in Boreal caribou ranges from 1978/79 to 1987/88 and has again been closed since 2001 (BCTAC 2004). Poaching may also be a mortality factor for Boreal caribou in BC.
- DeMars et al. (2013) developed and evaluated two methods, movement patterns using population-based and individual-based methods, for inferring parturition and survival of neonatal offspring (0 to 4 weeks of age) using GPS movement data from female woodland caribou. Results demonstrated that both methods can yield highly accurate estimates of parturition rates and, when applied to high quality data obtained by modern GPS radiocollars good estimates of neonate survival can be made using the individual based model. A sudden and sustained drop in movement rate was indicative of parturition (step length was most informative variable for determining parturition and offspring survival rates). With increasing use of GPS radio-collars, the authors identified that movement-based methods are a viable approach for estimating rates of parturition and offspring survival in ungulates.

Mountain Ecotype

- The majority of calf mortality in west-central Alberta occurs during the summer (Edmonds 1988; Edmonds and Smith 1991; Smith 2004).
- Adult female survival for the A La Peche (mean lambda of 0.939 between 1999-2012) and Redrock/Prairie Creek (mean lambda of 0.892 between 1998-2012) mountain caribou herds is within the range reported elsewhere in Alberta (Smith 2004, Hervieux et al. 2013).
- Adult female mortalities on three west-central Alberta caribou ranges (A la Peche and Redrock/Prairie Creek [Mountain ecotype] and Little Smoky [Boreal ecotype]) occurred throughout the year with peaks in mortality occurring in late winter (March/April) and early fall (September) (data from 1981 to 2003) (Smith 2004).
- Mortality from caribou-vehicle collisions on Highway 40 between 1991 and 1993 was high enough to cause a population decline. However, a program of active deterrence and monitoring has been effective in reducing caribou mortalities (Brown and Hobson 1998).
- In Wittmer et al. (2005a) the mountain ecotype were studied across their entire range in BC. Adult caribou (386) from seventeen subpopulations were captured and fitted with VHF or GPS collars. Overall pregnancy rate was 92.40% (Wittmer et al. 2005a). However, the percentage of calves at approximately 10 months old ranged between 0% and 23.4% (mean = 11.57%). Fifteen of the 17 subpopulations had a mortality recorded during the study, with a total of 165 deaths. Six adult caribou had deaths attributed to human

causes: two involved vehicle accidents, two suffered research-related mortality and two were illegally shot. Of 159 deaths attributed to natural mortality, 98 were due to predation, body condition or accident and 68 were due to unknown causes. Wittmer et al. (2005a) concluded that the calf recruitment observed was inadequate to balance the high adult mortality rates.

- Apps et al. (2013) tested hypotheses associated with relationships between landscape composition and predator-specific mortality of mountain caribou, reporting that caribou were at greater risk of predation at low elevations particularly within otherwise complex terrain (i.e., valleys) with more variation in overstorey canopy closure and greater road densities. Apps et al. (2013) suggested that changes in habitat operate at broader spatial levels including landscapes occupied by winter ranges of primary ungulate prey. This season-dependent distribution of other prey species and their predators can greatly affect predation on mountain caribou.
- Direct habitat loss associated with human development is the leading cause of population decline and extinction among researchers studying caribou populations. However, indirect habitat loss due to displacement from preferred regions near human disturbance can greatly affect population levels. (Polfus et al. 2011).

4.0 RESPONSE TO DISTURBANCE

Boreal Ecotype

The most significant threat to boreal caribou identified in the federal recovery strategy is habitat alteration (loss, degradation or fragmentation) as a result of human land-use activities Forestry, oil and gas exploration and development, mining exploration and development and hydro-electric development have been identified as the primary disturbances to caribou habitat. Direct and indirect functional habitat loss, decreased quality of habitat and linear feature development affect boreal caribou populations by reducing the suitability of habitat, increasing rates of predation and increasing access to hunters. Landscape alteration can possibly lead to the extirpation of local boreal caribou populations by reducing habitat quality and quantity which can result in a reduction in range size (EC 2011).

Vistnes and Nellemann (2008) reviewed 85 studies on the impacts of human activity and disturbance on reindeer and caribou (*Rangifer)* herds. They identified that studies conducted within only a few kilometres of development are often only representing individuals and not the majority of the herd. As a result, these studies are unlikely to detect any distance-related trends and may erroneously conclude that there is no apparent distributional pattern in relation to potential disturbance sources. Eighty three percent of the regional studies and only 13% of local studies found that impacts of human activity were significant. The majority of regional studies found that the majority of *Rangifer* will reduce their use of areas within five kilometres of development by 50% to 95% (Vistnes and Nellemann 2008). Vistnes and Nellemann (2008) recommend that methodologies for exploring the link between disturbance levels and productivity parameters be developed to help increase understanding of the consequences of human development on *Rangifer*.

General

- Population modelling results indicate that a negative correlation exists between industrial activity and adult female survival (Smith 2004).
- Simulation modelling experiments based on Boreal caribou, moose and wolf data from northern Alberta suggests that caribou will be extirpated from the system in less than 40 years assuming a 'business as usual' human affected ecosystem, with declines in woodland caribou when the density of linear features exceeds 1.22 km/km^2 (note: modelling did not account for low-impact seismic) (Weclaw and Hudson 2004).
- Caribou may consider berms associated with pipeline construction as visual barriers to movement (Hanson 1981, Jalkotzy et al. 1997). Other physical barriers to movement recorded for caribou and reindeer include steep road cuts, berms, and slash piles along roads and highways (Bloomfield 1980), snowberms (Klein 1971) and pipelines laid on or near the ground (Villmo 1975).
- Fortin et al. (2013) used normal movement behavior in animal populations as well as movements portrayed by 53 radio-collared boreal caribou to develop a modelling framework, which predicted that caribou occur at 3.7 km from cutovers and roads. Consistent with these predictions, aerial surveys documented caribou abundance peaking at 4.5 km away from anthropogenic disturbances. Fortin et al. (2013) suggest that the congregation of caribou adjacent to human altered areas allows predators to easily target them.
- Avoidance of linear features and timber harvesting activities can concentrate woodland caribou, possibly increasing detection rates by predators (Smith 2004, Beauchesne et al. 2014).
- Woodland caribou range occupancy in northern Ontario is explained by a 6 km threshold buffer from cutblocks, with a 20 year time lag from disturbance (i.e., time of cuts) to caribou disappearance (Vors 2006). Vors et al. (2007) determined that the probability of caribou persistence was negatively related to the presence of timber harvesting.
- In Quebec, Moreau et al. (2012) investigated how caribou change their selection for closed-canopy conifer forests, in relation to the amount of these forests remaining and the quantity of cutovers and roads from 2005 to 2010. Caribou were observed to increase their selection for closed-canopy conifer forests in areas of their home-range that were compromised by a high proportion of recent cutovers during calving and summer and of high closed-canopy conifer forests during winter. Areas that had more human disturbance caused caribou to portray a stronger overall selection for these forests. This result suggests that human alteration to caribou habitat can also increase the relative value of residual patches, along with the functional loss of residual habitat.
- Fifty three forest-dwelling caribou were GPS collared before, during, and after a 7 year period while a major highway was being slowly modified (Leblond et al. 2013). As highway construction increased, more caribou wandered away from the highway throughout their home range. Less caribou were found in a 5000 m road buffer area during and after development than found before. As traffic levels increased, caribou began displaying movements around the highway. Leblond et al. (2013) propose that road construction areas should allow access to critical habitat resources, while also restoring habitat quantity and quality.
- Avgar et al. (2013) used GPS data from 114 woodland caribou across northern Ontario, Avgar et al. (2013) observed that forage quality and availability suppresses movement rates by woodland caribou. Regenerating forest cover and deciduous forests had little effect on caribou movement during the winter.

However, conifer forests and water cover during the summer were more strongly supported. Avgar et al. (2013) suggested that female caribou, along with vulnerable calves, have a greater response to predation pressure during summer.

Alberta

- Caribou response to human activity (i.e., people, vehicles, seismic programs, drill sites and equipment) is moderate, with caribou moving away from areas where human activity is taking place. This response is short-term, as animals are not significantly displaced from their original positions (Bradshaw et al. 1997).
- Caribou use of habitats around developments is less than expected when compared to random use of the landscape controlling for habitat differences. However, complete avoidance has not been documented as individual caribou respond differently (James and Stuart-Smith 2000; Golder 2003). For example, avoidance effects of roads by the boreal ecotype are highest during late winter and calving and lowest during summer, possibly as a result of lower traffic levels in the summer (Dyer 1999). However, human activity and predator population levels were not controlled for in the relationship and are possibly confounding factors.
- Boreal ecotype caribou in open coniferous wetlands used areas near roads less than expected during all seasons, with a maximum statistically-significant avoidance of roads to 250 m. Caribou in closed coniferous wetlands use areas near roads less than expected up to 250 m during the late winter and up to 100 m of roads during summer (Dyer 1999).
- Boreal ecotype caribou have demonstrated significant avoidance of new well sites up to 250 m during the late winter and early winter and up to 1,000 m during calving (Dyer et al. 2001). No response was documented during the summer (Dyer et al. 2001). Caribou use of habitats around old wellsites differs significantly from random during the late winter and summer only (Dyer 1999).
- Boreal ecotype caribou use of habitat near seismic lines is significantly different from random during all time periods. Avoidance is greatest (250 m) during late winter when seismic lines are used as winter roads. During all other seasons, Boreal caribou use of habitat within 100 m of cutlines is less than expected (Dyer et al. 2001). However, during all time periods >50% of expected use by caribou still occurred within 100 m of seismic lines (Dyer 1999; Dyer et al. 2001).
- Roads with moderate vehicle traffic (780 ± 74 vehicles per day recorded in late winter) may act as semi-permeable barriers to caribou movements with the greatest barrier effects during late winter when traffic volumes are highest. Seismic lines do not act as barriers to movement. (Dyer et al. 2002).
- Studies show a significant correlation between caribou presence in non-disturbed versus disturbed areas within their ranges (James 1999; Dyer 1999; Neufeld 2006). Boreal caribou demonstrate a preference for non-disturbed habitats, rather than a complete avoidance of disturbed habitats.
- During the spring calving season, boreal caribou avoid young forests and select against areas with a greater proportion of recent cutblocks, and select against areas with high densities of seismic lines and well sites (Neufeld 2006). In summer, boreal caribou select against areas with high proportions of cutblocks, seismic lines and facilities, and are located further from roads than expected. In winter, boreal caribou select areas further from facilities, pipelines, seismic lines and roads, as well as further from areas with

larger proportions of cutblocks. Caribou display the strongest avoidance response to seismic lines during seasons without snow cover (Neufeld 2006).

- Boreal caribou are not considered as affected by forestry as mountain caribou in Alberta because large-scale forestry operations do not typically occur within the selected peatland habitats. However, boreal ecotype caribou may be affected from the indirect effects of timber harvesting in upland areas adjacent to peatland complexes because timber harvesting may increase the overlap (and reduce spatial separation) between moose/wolf and caribou habitats (Dzus 2001; James et al. 2004).

- Caribou response to Above-Ground Pipelines (AGP) was originally studied using barren-ground caribou (Curatolo and Murphy 1986; Carruthers and Jakimchuk 1987; Jalkotzy et al. 1997). Monitoring pipeline crossing structures and potential barrier effects in northeastern Alberta started over a decade ago and occurs throughout the in-situ operating areas annually (e.g., Canadian Natural 2000; Golder 2004; Golder 2010) and indicate that caribou will use crossing structures on AGP and will cross under pipe provided the placement and height of pipe is favourable to caribou. An example of this was recorded during the winter of 2010 where a caribou cow calf pair was found to travel parallel along AGP until the pipe reached a height of 1.41 m (cable height of 1.31 m). Both crossed under the pipeline during a winter tracking monitoring program of above ground pipeline at an in-situ Project within the CLAWR caribou area (K. Brown pers. comm.). Based on academic sources, literature review and monitoring data for moose (the largest mammal for which above ground pipelines will potentially restrict movement), a minimum pipe height of 1.8 m to allow for wildlife passage has been recommended (Golder 2009a). The Boreal Caribou Committee Guidelines Subcommittee reviewed AGP height for woodland caribou and recommended a minimum pipe height of 1.5 m was necessary for caribou to pass under (*no date*).

- The Alberta Biodiversity Monitoring Institute (ABMI) initiated a review of the impacts of AGP and other linear features on caribou movement after hosting a workshop attended by industry, government and scientific representatives. There, a consensus was reached that it is unreasonable to measure the influence of footprint types because of confounding factors, small samples sizes, and costs related to the long-term monitoring of individual caribou. A review of existing datasets was compiled and analyzed to examine how intensive development areas can best be planned, designed, operated and restored (ABMI et al. 2011). In 2012, the review was expanded by modeling and analyzing the impact of simulated future in-situ developments on caribou. The study found that permeability across in-situ developments was the main factor affecting caribou movement, and that a minimum threshold of permeability (crossing rates of at least 25% relative to an undisturbed site) was needed to maintain step length and home range size (ABMI and Alberta Innovates 2012).

- Stress hormone levels (i.e., corticosteroids) in pellets collected before, during and after a seismic program, both distal (collected at least 1,000 meters from ongoing activities) and proximal (collected immediately adjacent to ongoing activities) to the activity, were found to be consistent across all activity levels (Ernst Environmental Services 2003). No significant differences were found in stress hormone levels between all caribou scat samples collected proximally and distally to oil and gas activities. In addition, stress hormone levels were not significantly different pre-seismic shooting and during the shoot, nor were they significantly different between scat samples collected in the quiet “pre-seismic” phase and those collected during busy, various and ongoing 3-D seismic activities. The authors indicate that based on these results caribou do not, in and of themselves, find encounters with disturbed areas stressful (Ernst Environmental Services 2003).

However, these results should be considered preliminary as the study design and use of controls were poorly described within this project report.

- Research results reported by Tracz (2005) indicate that Boreal ecotype caribou subject to increased industrial activity (specifically heavy oil wells and associated disturbances and activities) do not significantly change the size of their annual or seasonal home ranges, nor do they abandon or shift home ranges when an area has become subject to increased industrial activity. Results indicated that the proportion of peatland within a home range was the significant predictor of home range size, and caribou exposed to high activity continue to select preferred habitats; indicating that habitat requirements may primarily determine home range size. Results do not provide convincing evidence that caribou remaining in areas of high industrial disturbance move into lesser quality habitats as a result of their previously documented avoidance of development activities. However, no comparison of adult survival, fecundity or calf survival was made between caribou found in the areas of variable industrial activity. It remains uncertain if caribou in an area of high industrial activity have decreased fitness as a result of their decision to remain there. Specifically, linear access that may contribute to an infiltration of predators and alternative prey species could potentially result in increased caribou mortality if caribou maintain range fidelity (Tracz 2005).
- Wolf locations (radiocollared 20 wolves from seven packs, and three loners) are closer than random to linear corridors (not separated out into roads, pipelines and seismic lines, although the majority were seismic lines) and wolves travel up to 2.8 times faster on linear corridors (James 1999).
- Caribou mortalities attributed to wolf predation (n = 5) were closer to linear corridors than were live locations from all caribou (mean difference = 316 m, n = 2,616 telemetry caribou locations), and human-caused mortalities have been found within 30 m of a linear corridor (James and Stuart-Smith 2000).
- McCutchen (2006) developed grid based computer simulation models to assess how wolf kill rates, caribou survival, and moose survival are affected by increased use of linear features by wolves, movement of moose into caribou ranges and an increase in predators hunting in caribou and moose range. Results from the modelling exercise indicate that line use does increase wolf predation on moose, but there is no direct effect of wolf use of lines on caribou survival (McCutchen 2006). However, line use may artificially increase the number of wolves which in turn will increase the number of caribou mortalities and possibly drive herd declines (McCutchen 2006). Therefore, wolf and/or alternate prey control is advocated over line mitigation as it is a direct conservation action (McCutchen 2006). Line mitigation is labour intensive and unlikely to have an effect on wolf movement due to the number of ongoing and projected developments within Alberta (McCutchen 2006).
- A remote camera pilot study within the Little Smoky caribou range reported that pooled prey species (caribou, deer, moose) preferentially select restored sites (> 1.5 m vegetation heights, average age of trees 23 years) along seismic lines over non-vegetated sites (Golder 2009b). Deer had the strongest preference for restored sites, with the preference attributed to the increased forage within the restored sites, as well as reduced line of site and potentially predator avoidance. Caribou were shown to have a slight preference for re-vegetated seismic line sites, over non-vegetated, but with limited data there was no statistical difference. However, caribou on control sites were observed to be running much more frequently than on re-vegetated sites and engaged in standing related behaviours only while on re-vegetated sites. This seems to indicate that caribou are more likely to travel quickly through open seismic lines, which may be a response to the minimal cover that is provided by the vegetation.

- Wasser et al. 2011 make two claims; 1) caribou conservation is less urgent than previously thought because numbers are stable and well above provincial estimates, and 2) stress caused by human activity, and not wolf predation, is the proximate cause of caribou declines. A number of caribou researchers and managers in Alberta oppose these claims using long-term caribou population trend data and caribou/wolf/prey research as evidence (rebuttal in Boutin et al. 2012).

- Anthropogenic landscape alteration causes other ungulate prey to relocate to an area which can spatially overlap with caribou. Peters et al. (2013) documented a positive correlation between overlapping ranges of coexisting species, moose and caribou, and the amount of human landscape transformation in the summer. During this season, habitats used by moose foraging for high quality resources were also the site of caribou mortalities. Caribou mortality was greatest when wolf movement rate was highest during snow free months (Peters et al. 2013). The conversion of old-growth forests to early seral stands induces caribou populations to face a higher risk of shared predation when caribou and moose resources overlap.

- Komers and Stanojevic (2013) completed a change detection analysis from 1992-2008 using Landsat and SPOT satellite image data processing. Using the EC recovery strategy definition for disturbed habitat, analyses detected that in 2008 78% of the boreal forest was disturbed and that, based on the current rate of development, 100% would be disturbed by 2028. Yearly addition of disturbance is 714 km^2 (0.8%) as revealed by Landsat image analysis. SPOT images produced depicted fine-scale disturbance implying that the actual disturbance was 1.28 times greater than detected. This means that if the SPOT image based disturbance rates progress, the 22% threshold may be surpassed within the next ten years. Komers and Stanojevic (2013) reported that based on the EC equation, that the 35% threshold of disturbance recorded in the caribou recovery strategy was exceeded in 1992.

- Agent-based modeling (ABM) conducted by Semeniuk et al. (2012) using radiocollar data from Little Smoky caribou from 2004-2005 demonstrated that caribou are sensitive to industrial features that evoke anti-predator responses, even when there are no predators in the area. They concluded that although mortality management tools can stabilize a population, habitat loss is still an issue as caribou will recognize certain habitat features (i.e., industrial features) as areas of high likelihood of predation and will avoid.

British Columbia

- Industrial activities contribute substantially to disturbance in Boreal caribou habitat in northeastern BC. Currently oil and gas development is the most extensive industrial activity in the boreal forests of BC. Preliminary guidelines for oil and gas activities within Boreal caribou ranges are currently being developed for the Oil and Gas Commission (Culling et al. 2004). Increased access from oil and gas development may result in increased forest harvesting activity and potential peat mining operations in the future (BCTAC 2004). Culling et al. 2004 has recommended that based on peak conception rate for the Snake-Sahtaneh Range that a cautionary timing windows from September 15 – October 15 and April 15 – June 30 be set up in order to reduce stress on caribou during late pregnancy, parturition, and the neo-natal period (Culling and Cichowski 2010).

- The current density of linear corridors in Boreal caribou habitat in northeastern BC is a concern. Although high-grade road access is likely limited in Boreal caribou range, an all-weather access road is currently being built through high use caribou areas in the Snake-Sahtaneh study area. Recent government

policies/incentives that promote oil and gas exploration will likely result in increased oil and gas development in critical Boreal caribou habitat in BC (BCTAC 2004).

- Using the Sorensen et al. (2008) caribou habitat equation, Thiessen (2009) reported that when the amount of anthropogenic disturbance in BC boreal caribou ranges was examined relative to the size of caribou ranges and cores, that 12 of 15 cores are above the 61% threshold of anthropogenic disturbance, the remaining three cores had greater than 50% disturbance, and three of the four caribou ranges were above the threshold at which point caribou populations in Alberta have had a negative population growth.
- Using a review of literature, Salmo Consulting (2003) provided indicators for woodland caribou persistence amongst cumulative disturbance. For core areas, because Boreal ecotype caribou populations declined when core area was reduced by 50%, a threshold was identified at <60% of the core area affected (includes areas with reduced habitat effectiveness due to reduced use using a 250 m buffer from all linear features) (Anderson et al. 2002). For corridor density, it was noted that Boreal ecotype caribou populations declined when total corridors exceeded 1.8 km/km^2 (Anderson et al. 2002) and a road and trail density threshold of 0.6 km/km^2 was also derived (using Salmo unpub. data). In addition, caribou biologists have become concerned over the viability and persistence of herds at 0.3 km of linear features/km^2. These thresholds were proposed even though it is recognized that the type of linear feature affects this density relationship (e.g., low impact seismic are a short term impact if allowed to revegetate, and roads cause increased impact over seismic) (K. Smith pers. comm.).
- Two of five caribou mortalities recorded in the Snake-Sahtaneh caribou area were wolf kills located along seismic lines (Culling and Culling 2006).
- Boreal caribou in the Chinchaga area of northeastern BC are subject to vehicle collisions when they move to agricultural areas where they appear to become habituated to vehicles (BCTAC 2004).
- A study conducted in the BC Chinchaga range identified use of lease sites and pipelines by boreal caribou. Dietary analysis performed on fecal samples did not suggest a high intake of domestic cultivars by Boreal caribou, but rather a high consumption of terrestrial and arboreal lichens (Rowe 2007a).
- Forest insects have likely played a minor role in disturbance to Boreal caribou habitat in BC. However, spruce budworm may be a concern where mature patches of spruce are found. Climate change could result in increased forest insect activity (BCTAC 2004).
- Parks and protected areas in BC cover 1.4% of boreal caribou ranges, 1.2% of boreal caribou habitat and 2.0% of core habitats. These areas generally do not contribute significantly to the management or protection of boreal caribou due to their generally small size (Culling and Cichowski 2010).

Mountain Ecotype

- Mountain caribou use habitat within 500 m of roads less than expected. Similarly, when caribou occur within a 500 m buffer of roads, habitat within 100 m of roads is avoided. Mountain caribou also use habitat within 250 m of inactive roads (i.e., snow not ploughed) less than expected during winter months (Oberg 2001).

- Mountain caribou show no avoidance of seismic lines during the winter. However research occurred in caribou areas with considerable natural re-vegetation on older seismic lines (origin greater than 20 years) and all newer seismic lines utilized low impact seismic techniques (Oberg 2001).
- Mountain caribou daily movement rates and individual winter range sizes decrease with progressive timber harvesting (Smith et al. 2000). Caribou avoid recently-harvested, fragmented areas by an average of 1.2 km, that is, caribou were found 1.2 km farther from new cut blocks than were random locations (Smith et al. 2000). Forestry activity on mountain caribou winter range is thought to have negatively affected mountain caribou populations (Edmonds 1988).
- Smith (2004) cited two examples of apparent avoidance of development activities or range abandonment as a result of development. The A la Peche mountain herd has abandoned its forested winter range since 1996 (documented range shift coincided with new timber harvest on the winter range along Highway 40), and the Redrock/Prairie Creek herd animals bypassed their main migration route over Caw Ridge, concurrent with the advancement of mining activity towards Caw Pass (Smith 2004).
- Based on recorded mortalities (n=48) from three herds (A La Peche, and Redrock/Prairie Creek [mountain ecotype] and the Little Smoky [Boreal ecotype]) in west-central Alberta recorded from 1981 to 2001 and industrial disturbance layers over that time for both oil and gas and forestry, Smith (2004) concluded that cumulative road and cutblock densities within home ranges for woodland caribou are negatively correlated with adult female survival. However, there was a lag effect associated with timber harvest. A positive correlation existed until density of cutblocks exceeds 3.4 ha/km^2, after which a negative relationship develops. A risk threshold for adult female caribou mortality is reached when 6.8% (6.8 ha/km^2) of an individual animal's home range is logged. The author hypothesized that the proximal cause of the increase in caribou mortality was attributed to wolf and to a lesser extent bear predation. The ultimate cause, or mechanism, for the increase in mortality was attributed to corresponding increases in alternate prey responding to forage along roads and in cutblocks, a reduction in home range size and therefore a reduction in the ability of woodland caribou to avoid predators, and to the direct removal of lichen forage through industrial disturbance (Smith 2004).
- van Oort et al. (2011) used radio-locations collected from 358 caribou over a 23 year period (1984-2007) to determine if 18 fragmented subpopulations of mountain caribou in interior British Columbia are "operating as metapopulations linked by juvenile dispersal" or if they are moving towards extinction. Within the study area, forestry is the dominant land use with large reservoirs for hydroelectric power and their associated transmission lines. Mountain caribou in interior BC undergo well defined migrations between their spring, summer/fall, early winter and late winter ranges. Dispersion of juveniles was not observed (< one year, two and three years of age) and there were only eight instances of breeding dispersal by adults out of 587 opportunities. Further, the 18 previously identified subpopulations were found to be fragmented further into 41 summer/fall composite ranges resulting in the distribution being 2.3 times more fragmented than previously thought, The lack of dispersion suggests that the mountain caribou in this study are not functioning as a metapopulation or they are a metapopulation in a state of non-equilibrium and the implications of this are serious.
- Polfus et al. (2011) monitored 10 adult caribou from the Atlin mountain caribou herd (home range bordering the Yukon and BC border) between January 2000 and 2002. RSF models were developed at the landscape and home range scales. A cumulative zone of influence (ZOI) was estimated around multiple developments

and realized and potential caribou habitat was modeled. During both winter and summer, caribou avoided low-use roads by 1 km and high-use roads by 2 km. The town of Atlin was avoided by 9 km in the winter and 3 km in the summer and in the summer mines were avoided by 2 km and cabins and hunting camps were avoided by 1.5 km. When human activity was low in the winter months, there was minor avoidance of mines and no avoidance of cabins and hunting camps. The cumulative ZOI resulted in approximately 8% of high quality habitat being lost in the winter and 2% being lost in the summer months.

- Apps et al. (2013) suggest that habitat alterations, except for roads, have had little effect on the location where caribou are predated on. They observed that factors such as elevation, landscape conditions and canopy cover effected where caribou were killed more than early-seral interspersion created by logging. The results from this study "suggest that the population-level numerical response of predators to their primary ungulate prey, likely stemming from habitat enhancement within ungulate winter ranges, is more relevant to caribou mortality risk than the functional response of predators to habitat change within landscapes occupied by caribou" (Apps et al. 2013).

- Wittmer et al. (2010) used stochastic projection models for 10 mountain caribou herds in British Columbia (Purcells-South, Nakusp, Columbia-South, Frisby-Boulder, Columbia-North, Groundhog, Wells Gray, Barkerville, North Cariboo Mtn., and Hart Ranges) to determine rates of extinction. Models were developed, the first using estimates of vital rates from >350 radiocollared caribou from 1984 – 2004 and the second, a set of models that evaluated the effects of habitat conditions and population density via their expected relationships to female adult survival. The initial model found that the Purcells-South, Columbia-North and Groundhog populations had a high probability (>0.95) of extinction within 200 years using current vital rate estimates and with the current amount of forest <40 years remaining static and excluding potential effects of positive density dependence. However, when adult female survival was dependent of habitat condition and population density, all ten herds had a high probability of extinction (>0.95) within 200 years. Changes to forest age structure that result in increasing alternate prey and predator species appear to strongly influence extinction probability. The results of this study suggest that PVA models that do not incorporate anticipated changes to vital rates (deteriorating environmental conditions/Allee effects) may result in overly optimistic assessments of population persistence. Immediate protection and restoration of habitat and management of predators and alternate prey is required to avoid the acceleration of population decline in mountain caribou.

5.0 PREDATOR-PREY DYNAMICS

General

- An imbalance in predator-prey relationships has occurred across most of the boreal caribou distribution in Canada which has resulted in high predation rates (EC 2011). Festa-Bianchet et al. 2011 concur that predation is the main proximate cause for woodland caribou decline in Alberta and Canada and that this may be a result of the ultimate reasons for decline which are the cumulative effects of forestry practices, hydrocarbon exploration, motorized winter recreation and unsustainable harvest.

- Caribou in Alberta and BC are not considered a primary prey species for any major predators because they occur at low population densities in "low-energy" habitats not easily accessed by large predators. Caribou predation is believed to be incidental or opportunistic with wolf and bear (black and grizzly) considered as their primary predators. Other predators may include lynx, wolverine and coyote. As an incidental prey

species and unlike other primary prey species, caribou do not influence predator populations. Human-caused mortality, including poaching, legal hunting (First Nations) and “suspicious” causes, also contribute to caribou mortalities (Stuart-Smith et al. 1997; Dzus 2001; James and Stuart-Smith 2000).

- Wolf predation is considered the major source of caribou mortality in northern Alberta and BC (Bergerud and Elliot 1986; Fuller and Keith 1981; Seip 1992; Dzus 2001; McLoughlin et al. 2003; James et al. 2004; ASRD and ACA 2010); as well as throughout Canada (EC 2011a). Linear corridors (i.e., roads, right-of-ways) affects wolf-prey dynamics by providing wolves with easy travel routes and access to prey (Bergerud et al. 1984a; Edmonds and Bloomfield 1984; James 1999; James and Stuart-Smith 2000).
- If wolves reach a density of 6.5 wolves/1,000 km^2 or more, Bergerud and Elliott (1986) predict that caribou populations will decline. In another study, Hebblewhite et al. (2007) suggested that caribou can be expected to decline when wolves reach a threshold of 2.3 to 4.1 wolves/1,000km^2. Recent surveys (unpublished data from Alberta Fish and Wildlife Division) indicate that several Alberta caribou ranges have wolf densities which exceed the 6.5 wolves/1,000km^2 threshold.
- ASRD and ACA (2010) summarized that current available information indicates that anthropogenic disturbance can lead to an increase in wolf predation in three ways. First, increases in disturbance can lead to an increase in alternate prey, thereby increasing the density of wolves in an area. Second, anthropogenic disturbance can draw wolves into caribou range and potentially increase their hunting efficiency, and thirdly, by reducing the availability of large intact habitat patches, caribou are unable to as effectively space themselves away from wolves.
- Research conducted by DeCesare et al. 2010 suggests that rare or endangered species (caribou) often succumb to a predator population (wolves) that would otherwise be sustained by an abundant primary prey when in apparent competition (also see Hebblewhite et al. 2010).
- Boutin (2010b) conducted research to determine a cost-effective method to estimate wolf densities on caribou ranges and to use the method to obtain preliminary estimates of wolf abundance on ranges throughout Alberta. Aerial surveys were completed in 2008/09 and 2009/2010 to identify wolf tracks within predefined cells within caribou ranges. A high rate of occupancy was identified within all ranges surveyed (Athabasca, Chinchaga, Red Earth/Slave, Richardson), with the possible exception of the Richardson range. Further research must be completed to determine consistency of occupancy rates under different survey conditions (Boutin 2010b).
- Whittington et al. (2011) studied wolf-caribou encounter rates in Banff and Jasper National Parks from 2002 – 2010 and found that transient wolf packs could have a large effect on recovery efforts of caribou as it was these wolves that had the greatest number of encounters with caribou. Results indicate that when ranking a caribou population for recovery, or considering translocations. other factors influencing predation risk (other than predator density) must be considered as the risk of caribou-wolf encounters and predation increased near linear features which may result in caribou being displaced from high quality habitat.
- Anthropogenic disturbances, such as cutblocks, cutlines, and agriculture can create early successional stage habitats that are selected by moose, elk and deer. These ungulates may in turn increase in numbers and lead to a numerical response in wolf numbers ultimately increasing predation risk to nearby caribou (Seip 1992, James et al. 2004).

- Veitch (2001) reported white-tailed deer expansion into the Northwest Territories as early as 1965-1966 with the most northern record of a doe that was harvested approximately 100 km away from the arctic circle in 1996. Rising white-tailed deer populations have been linked to increased risk of wolf predation for caribou (Bergerud pers. comm., Latham 2009, Dawe et al. 2014). Agricultural areas supporting high densities of deer may serve as sources for deer immigration into caribou ranges (Charest 2005).

- Dawe (2011) investigated factors leading to the range expansion of white-tailed deer in Northern Alberta. She found that winter white-tailed deer presence was positively related to land use footprint, deciduous forest, and growing season length and negatively related to winter severity and wetland land cover types. The land use footprint showing greatest association with white-tailed deer presence was the total amount of agriculture, forestry, and well pads within a 500 m buffer of sampling locations. Climate, particularly the severity of the winters, was found to be the most important single factor driving range expansion. The model's prediction ability was tested using data from past decades and was found to have relatively good accuracy. If the observed shifts toward less severe winters and longer growing seasons continue, white-tailed deer are predicted to occupy the majority of the northern Alberta boreal by the 2050's.

- As large contiguous habitat patches for caribou become increasingly altered by forest harvesting and other human activities, it is hypothesized that the caribou's antipredator strategy of spatially separating themselves from wolves and other ungulate species (commonly moose, elk and deer), will be jeopardized (Kuzyk 2002; James et al. 2004).

- Wasser et al. (2011) (rebuttal in Boutin et al. 2012) reported in the ESAR caribou range that base resource selection probability functions (RSPF) for caribou indicate a positive selection for wetlands, less topographically complex terrain (flatter locales), locations farther from primary roads, linear features associated with no or unknown levels of human use, areas of open black spruce tree cover and pine-lichen ecosystems. In this study, caribou selected areas more for security than nutrition, moose selected for forage cover over security and wolf selected for linear features and deer habitat. Deer and caribou habitat were strongly negatively correlated.

- Simulation analysis results from Lessard (2005) indicate that when moose densities are reduced and maintained at lower densities, lower wolf densities would be observed and therefore higher caribou densities would result because of reduced wolf predation on caribou. Lessard (2005) recommended that the direct management of moose densities as a "fast" means to manipulate the system. Although there has been research into the effects of wolf reductions on moose and caribou densities (e.g., Seip 1992, Bergerud and Elliott 1998), only recently has the effect of reducing one ungulate species to increase the density of another, principally caribou, been undertaken (e.g., Serrouya 2013). However, given that the reduction in moose and deer may lead to increased wolf/caribou encounter rates (i.e., time lag prior to seeing wolf numbers decline); wolf manipulation may have to occur simultaneously with the management of other prey species (ALT 2009). Lessard recommends reducing moose to a density which maintains wolves below 0.008 wolves/km^2.

- In British Columbia and Ontario, early decreases in woodland caribou numbers resulted from increased predation (Cumming 1992), primarily from wolves (Seip 1991). Bergerud (1974) argued that habitat loss did not cause declines in caribou populations but that direct mortality from increased hunting and predation did. Logging caribou wintering areas may force caribou to move to areas with greater predation risk (Bergerud 1974). According to Cumming (1992), cutting entire wintering areas has led to the demise of local caribou

herds in Ontario (reaffirmed in Vors et al. 2007). Avoiding timber harvest near caribou winter ranges is believed to leave the areas unattractive to moose and predators (wolves) (Cumming 1992).

- Bowman et al. (2010) looked at the effect of human activity (roads, logging) on woodland caribou distribution in Ontario. Caribou were found to have a positive regression with mature coniferous forest and a negative regression with probability of wolves and road density. Caribou were also found to be negatively associated with logged landscapes, while moose, deer and wolves were positively associated. Bowman et al. 2010 concluded that roads and logging change the environment by increasing moose and deer densities, which increases wolf abundance and contracts caribou range which in turn increases predation on caribou.

- Incorporating analyses of interpatch movements, local residency times, and habitat selection enabled Bastille-Rousseau et al. (2011) to develop a method to show the foraging decisions of omnivores in Quebec. Their main focus was to evaluate the likelihood of predation on ungulate neonates by omnivorous black bears as being an active search or incidental encounter. Twelve bears, 22 boreal caribou and 36 moose were collared during the calving season from 20 May to 30 June 2005 and 2006. They observed that bears chose areas with abundant vegetation as opposed to selecting sites that contained a high probability of neonate encounters. Although 65% of neonate mortality was caused by bears, bears seemed to behave opportunistically. It was also noted that bears moved preferentially, but not frequently, between vegetation-rich habitats to forage, implying shorter residency times in these areas. Bastille-Rousseau et al. (2011) concluded that these increased opportunistic encounters with neonates could be attributed to frequent interpatch movements, whereby bears encountered neonates by chance and were not actively searching for them. To alleviate the impacts of forest harvesting on threatened caribou populations, it was suggested that large areas of conifer forest should be separated from those high quality vegetation regions chosen by bears.

- Caribou exhibit both long and short term behavioural changes (i.e., anti-predator responses) to wolf presence. Changes in movement and habitat selection, e.g., increased selection of conifer stands with lichen after a wolf's passage, can occur for long distances and long time-scales (Latombe et al. 2014).

Boreal Ecotype

Alberta

- James (1999) reported that wolves could travel up to 2.8 times faster on linear corridors and that caribou mortalities attributed to wolf predation were closer to linear corridors than were live locations from all caribou. However, James and Stuart-Smith (2000) recommended that these linear corridor effects should be evaluated further as their work was based on a relatively small sample. Latham et al, (2011c) found no significant difference in the distance to nearest conventional seismic line, pipeline, low impact seismic, minor river/stream, or major river between adult female caribou mortalities (n = 42) and live locations.

- Caribou were identified in only 0.3% (3 out of 969 scats examined) of wolf scats collected during both winter and summer months (James et al. 2004). This provided strong evidence that Boreal ecotype caribou were not killed in proportion to their availability within northeastern Alberta. Although caribou were not an important component of wolf diets, the spatial separation of caribou from moose did not provide a total refuge from wolves (i.e., some predation did occur) (James et al. 2004).

- Work completed by Neufeld (2006) provides the first detailed year-round assessment of simultaneous habitat selection patterns of wolves and caribou (Little Smoky herd) and potential spatial-temporal overlap in Boreal caribou regions. Using RSF modeling, Neufeld (2006) compared used landscape variables (including anthropogenic disturbances) to those available which allowed the development of spatially explicit models to describe animal occurrence. In general, caribou avoided and wolves selected human infrastructure although both species exhibited seasonal variation in these selection patterns. Spatial overlap potential between wolves and caribou was greatest during the spring. During the rendezvous/summer season wolves selected for areas closer to seismic lines than available and that this variable was driving the trend in wolf distribution. Additionally, areas with cutblocks less than 15 years of age were strongly selected for by wolves.

- Results from Latham (2009) suggest that the distributions and relative abundances of moose and deer have changed substantially in the WSAR range and the western portion of the East Side of the Athabasca River (ESAR) caribou ranges in northeastern Alberta (approximately 21 000 km^2 study area) since James' (1999) study (pre-intensive industrial activity) in the mid 1990's. Data were collected between 2005 and 2007, during more intensive industrial activity (Latham et al. 2011a, 2011c). Data from 20 radio collared wolves from seven packs and three loners in the 1990's were compared to data collected from 31 radio collared wolves from 11 packs and one loner. Data were collected on an average of 31 adult female caribou per herd, per year from 1993 to 2009. Latham et al. (2011a) reported that wolf pack territories overlapped with 17% of caribou range in the 1990's and increased to a 41% overlap in the 2000's. Analysis of wolf scat found that moose had decreased from 64% of annual wolf diet to 18.6% and that deer had increased from 9.4% to 40.8% in the 2000's (as measured by % of occurrence) (Latham et al. 2011a,c). Additionally, wolf density has increased substantially (10.5/1,000 km^2 in the snow season and 11.5/1,000 km^2 in the snow free season) which is likely a numeric response to the increase in white-tailed deer density (Latham 2009). Moose are currently more numerous in fen/bog habitat than in upland habitat and deer, primarily white-tailed deer, numbers have substantially increased in the WSAR (Latham and Boutin 2005). Additionally, wolves appear to be traversing the peatland complex in search of prey, notably beaver in the snow-free season and have become a major factor influencing wolf use of caribou range (Latham 2009; Latham et al. 2013b). Using scat analysis, Latham (2009) found that deer comprised 42.6% of the biomass in a wolf's diet during the snow season and beaver comprised 29.8% of a wolf's diet in the snow free season. Moose were still providing a high proportion of biomass in both seasons (Latham 2009). During the study period, the WSAR and ESAR caribou herds went from stable to declining and caribou were 10 times more common in wolf scat than in the earlier 1990's study period. The results of this study indicate that white-tailed deer should be included as a priority species, in addition to moose, in prey reduction programs. However, the authors suggest that prey harvests should only be increased in the wildlife management units that overlap caribou ranges (Latham et al. 2011a)

- Latham and Boutin (2008) reported an average of 3.9 white-tailed deer per 100 km flown during aerial surveys of the WSAR in the winters of 2004-2007. Of these, 39% were observed in peatland habitat types and 25 white-tailed deer (in nine groups) were observed in March 2007 in tamarack and black-spruce tamarack fens (Latham and Boutin 2008). In March 2007, two white-tailed deer were observed feeding on arboreal lichen (likely *Bryoria* spp. and *Usnea* spp.) (Latham and Boutin 2008). This suggests that white-tailed deer may begin directly competing with caribou for food (Latham and Boutin 2008).

- Latham et al. (2011c) investigated whether proximity to industrial and natural linear features influenced wolf movement (i.e., step selection) on the landscape and to determine if wolves were following industrial and natural linear features as movement corridors in northeastern Alberta. Data were collected on 31 wolves from 11 packs between January 2006 and March 2007. Wolves showed neither avoidance of, nor selection for, movement towards conventional seismic lines during the snow season; however, the opposite was observed during the snow-free season. In the snow season, wolves were more likely to move towards a pipeline if it was less than 6 km away and would more likely move away from a pipeline if it was greater than 6 km away. Pipelines did not influence wolf movement in the snow-free season. Movement (i.e., step selection) was not influenced by distance to roads in the snow season. However, during the snow-free season wolves were less likely to move toward, rather than parallel or away from, the nearest road when that road was less than 20 km away, but were more likely when the road was greater than 20 km away. Wolves were more likely to move in a manner that brings them closer to a minor river or stream, regardless of season. Latham et al. (2011c) reaffirmed that wolf use of seismic lines increases predation risk for caribou close to these features, resulting in caribou avoidance of linear developments and thus functional loss of otherwise suitable habitat.
- Wolf, bear and coyote scat were found in disproportionately high quantities along seismic lines as compared to other habitats within the Little Smoky Herd caribou range. This suggests that seismic lines are utili*zed heav*ily by predators (Neufeld 2006).
- McCutchen (2006) used individual-based movement models for wolves, caribou and moose to determine how linear developments affect wolf movements and consequently predator-prey interactions. Results suggest that the number of predators on the landscape is more important than the number of linear developments when explaining caribou survival (McCutchen 2006). This result suggests that a multi-factor approach to species and landscape management may be required to achieve viable caribou populations.
- Peters (2011) conducted research in west central Alberta to understand the habitat relationships of moose and to estimate moose population densities to guide moose harvest and ultimately the conservation of caribou. Moose and caribou resource selection function models showed similar forage-risk trade-offs, resulting in spatial overlap between the two ungulates.
- Deer habitat selection and occupancy in the boreal forest is being investigated through the use of both satellite collars and remote cameras (Fisher et al. 2014). Deer have been documented to be widespread, annually occupying an estimated 99% of sampling sites. Deer distribution is explained by upland deciduous cover as well as by the percent of anthropogenic disturbance in the landscape. Conversion of conifer stands to deciduous stands is contributing to expansion of deer in the boreal.
- Latham and Latham (2010) completed a study within the CLAWR to assess spatial relationships between black bear and woodland caribou during the caribou calving season (late April to June 30) for five years (2000-2004). Fifteen black bears and 37 caribou were used in the study. At the population level caribou selected for bogs and fens while bears tended to avoid these habitats. However, on an individual level, one of the 15 bears selected for black spruce bogs, one showed neither preference nor avoidance, and six selected for tamarack dominated fens, though this appeared to have been confined to peripheral habitat. One black bear in the study roamed further from uplands into core peatland habitat and may have been a beer specialized on foraging in peatlands, and may have been responsible for at least some of the predation on caribou calves (Latham and Latham 2010, Latham et al. 2011b). No sex-bias was determined

with regard to bears selecting bogs and fens which may suggest that bears who have successfully foraged/hunted within these habitats will return in subsequent years and pass this search image on to their cubs (Latham et al. 2011b). Results suggest that approximately one third of the black bear population within the CLAWR forage in habitat used by caribou during their calving season.

- Latham and Latham (2011) reported coyote expansion into the boreal forest of northern Alberta, likely facilitated by industrial activity. Coyotes were found throughout the study area indicating generalist behaviour. However, some individuals did select for coniferous swamps and bogs (caribou-preferred habitats), others preferred well-drained forests, milled forestry blocks and towns adjacent to caribou range and all were strongly affiliated with rivers and streams throughout the year and lakes during winter months. Caribou accounted for 2% of coyote diet using scat analysis; however, as with other predators (wolves and black bears) incidental predation on caribou could have a significant impact (Latham and Latham 2011; Latham et al. 2013a).
- Musiani and Hebblewhite are conducting research to compare “the influence on caribou mortality of predators and, indirectly, of prey that are favoured by Forestry vs. Oil and Gas development and provide practical recommendations for mitigation (NCASI 2011). Research is ongoing with no anticipated completion date at this time (*as cited within* NCASI 2011).
- Hervieux et al. (2013) reported that wolves have been documented to account for more than 50% of female adult caribou deaths in some populations and are also an important predator of calves.
- Latham et al. (2011) discovered that caribou was found in the diet of wolves 10 times more in the 2000s than documented in the mid-1990’s, thus contributing to their declining population. The sudden decline in the WSAR and ESAR caribou populations was directly related to the massive increase in deer densities, as well as an increased spatial overlap with wolves and therefore, an increased incidental predation risk from wolves on this herd. Reducing primary prey densities through monitoring and harvest regulations seems to be a more suitable option when compared to direst wolf control programs as viewed by the public. Latham et al. (2011) suggest that liberal harvests be allowed in management units that overlap caribou ranges if those areas are to continue to serve as refuges for caribou.
- Latham et al. (2011) also suggested that the increased wolf predation on woodland caribou in peatlands could be caused by global warming since caribou populations are only recently declining and historically, caribou coexisted with wolves in the boreal forest. They argue that ungulate populations might expand due to range amplification caused by relaxed environmental conditions.
- Latham et al. 2013b reported that wolf prey selection changed by season, which impacts the spatial separation between wolves and caribou at important time periods. In the winter, wolf select areas used by deer, whereas in the summer they select areas used by beaver which happens to be overlapping habitat with caribou. The summer is the most vulnerable time for caribou, as calves are born and the highest amount of female mortality occurs during that season. The seasonal pattern of predation is an important factor to consider when assessing the effect of predation on secondary prey (i.e., caribou).
- Dickie (2015 pers. comm. M.Sc. candidate) preliminary results show that wolves significantly select linear features and selection depends on type rather than density of linear features. Wolves selected for linear features with shorter vegetation; in general, wolves changed their movement pattern and speed after

vegetation reached a certain height. When wolves selected for linear features, their daily distance moved increased. In summer, wolf travelling speed on linear features versus travel speed in forest was two times faster on pipelines, conventional seismic, railway and transmission lines, 2.6 times faster on roads, 1.25 times faster on trails, but slower on low-impact seismic. In winter, wolf travel speed was 2 times faster on pipelines and conventional seismic, 2.7 times faster on roads, slower on low-impact seismic, and no faster on trails. Wolves' travelling speed was enabled by linear features in uplands in the summer and in wetlands in the winter. Dickie's M.Sc. thesis publication is expected in spring 2015.

British Columbia

- In BC, caribou declined in the late 1930's and 1940's after moose expanded their range and wolves increased. Following a wolf reduction program from 1949 to 1962, caribou expanded until high population numbers was reached in the late 1960's, after which the herds again diminished as wolf numbers increased and calf recruitment decreased. From 1976 to 1982 an experimental wolf control program was established using two woodland caribou herds as controls, and one population as an experimental unit in northern BC to determine what effect wolf numbers were having on caribou herd growth. Wolves were reduced within the Horseranch caribou range from ten to 1 to 4 wolves/1,000 km^2. Caribou increased at an average rate of 6% per year during the experimental period. The researchers concluded that caribou cannot maintain their numbers when wolves exceed 6.5 wolves/1,000 km^2. Thus, caribou cannot coexist away from refuge habitat when the moose/ungulate biomass allows wolf numbers to increase to high levels (Bergerud and Elliot 1986).

- Wolf populations in northern BC made a considerable recovery by the time they were re-censused the following spring following wolf reductions. In addition, the more wolves that were taken; the more that moved into the vacant area (Bergerud and Elliott 1998).

- Predator management may be necessary to meet Boreal caribou population objectives in northeastern BC. In some situations a short-term predator reduction program may be adequate to allow the local population to recover to a level where it can co-exist with predators, or to allow degraded habitat conditions time to recover. Alternatively, some areas of Boreal caribou critical habitat where permanent changes to habitat have occurred (i.e., agriculture use and corresponding colonization or increased numbers of elk or white-tailed deer), may never be viable over the long term without ongoing predator control (BCTAC 2004).

- In northeastern BC boreal caribou ranges, wolves have been documented to concentrate on moose during the winter, and to be closely associated with beaver activity from spring through fall. A significant decline in the number of caribou calves during the summer was noted, down as low as five calves per 100 cows (reported for 2003). During this neonate period, significant spatial overlap occurred between caribou and wolves (Culling and Culling 2006).

- The Snake-Sahtaneh study area is reported to contain a relatively high density of wolves (minimum estimate 6.3 wolves/1,000 km^2). Wolf packs denned both within and adjacent to the caribou range, with multiple den sites identified within caribou core habitat areas. Analysis of 27 wolf scat samples revealed that beaver constituted the majority of samples. Scat samples also consisted of ungulate calf (moose and caribou) and waterfowl remains. Beaver were highlighted as providing an important alternate prey item for wolves and are hypothesized to be contributing to increased pup survival in the area. Wolf predation was

identified as the likely cause of the high calf mortality observed in the Snake-Sahtaneh caribou herd (Culling and Culling 2006).

- Five adult female caribou mortalities were recorded in the Snake-Sahtaneh study; two confirmed wolf kills (located on seismic lines), one suspected black bear kill and two mortalities of undetermined causes (Culling and Culling 2006).
- Black bears were monitored in the Snake-Sahtaneh study and were strongly associated with upland and riparian deciduous dominated habitats with a preference for early seral communities in cutblocks and along linear developments. Although relative spatial separation between bears and caribou was concluded, bears did make limited trips into adjacent black spruce peatlands during the caribou neonatal period (Culling and Culling 2006).
- Collared boreal (Bearhole/Redwillow) and mountain (Quintette) caribou and reported both ecotypes to be subject to a greater risk of spatial interactions with wolves (Williamson-Ehlers 2012). Caribou and wolves consistently avoided and selected for opposing habitats (e.g. caribou avoid early successional whereas wolves select these habitats). Both caribou and wolves avoided linear features, likely as a means of spatial separation from human activity. Wolves selected for areas with high densities of cutblocks during the non-winter season, perhaps for the increased hunting opportunities of moose and deer (Williamson-Ehlers 2012).
- A four-year collaborative project to evaluate spatial factors influencing predation risk to boreal caribou calves, included space use by wolves and black bears in northeast British Columbia (DeMars and Boutin 2014). Boreal caribou location data was collected from 56 female caribou for three years. During that time period, boreal caribou sustained high rates of neonate mortality. Relatively low rates of parturition were noted. Across all scales, female boreal caribou selected calving habitats that reduced predation risk (e.g., avoided areas with high densities of linear features). At the finest scale, calving sites were predominantly situated in treed bogs and nutrient-poor fens. These habitats continued to be selected when females moved within calving areas. These habitat types are considered to be predator refugia. By comparison, habitat use during the calving period did not differ from winter locations, indicating that forage attributes of calving sites did not differ. At the range scale, females generally moved from winter ranges dominated by treed bogs to calving areas situated in landscapes mosaics with a high proportion of nutrient-poor fen. DeMars and Boutin (2014) suspect this shift may indicate a forage-risk trade off because fens are 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. The presence of a neonate calf intensified selection behaviours associated with reducing predation risk.
- Female caribou during the calving and neonate period generally avoided locations within high densities of linear features and showed weak selection for locations with higher forage productivity (DeMars and Boutin 2014).
- During the calving season, wolf pack territories were tightly spaced and overlapped significantly with boreal caribou range and core areas (DeMars and Boutin 2014). At a fine scale, wolves were closely associated with aquatic areas, showing selection for nutrient-rich fens and being closer to rivers and lakes than expected. This association is consistent with literature that wolves switch to beaver as primary prey during the spring (Latham 2009) and supports previous studies highlighting the importance of water to wolves

during the denning period. Research results identified that in this study, wolves did not select for early seral vegetation and areas of high linear feature density were generally avoided. Wolf response to linear features was further assessed and wolves appeared to be selecting lines that increase movement efficiency and, secondarily, sightability.

- DeMars and Boutin (2014) assessed the influence of spatial factors on the probability of boreal caribou calf survival by evaluating four hypotheses that described impacts from disturbance, refuge effects from lakes and peatlands, and predation risk from bears and wolves. The probability of calf survival was best predicted by a model representing predation risk from bears. Specifically, the model suggested that calf survival depended on the density of high quality bear habitat surrounding locations selected by females within the calving area. Black bears favored landscapes dominated by upland deciduous forest, with bears utilizing habitats that were closer to early seral vegetation and had higher densities of linear features. Across all scales, bear locations were closer to aquatic features than expected and showed strong selection for rich fens when in caribou range. In general, selection patterns by bears suggested a preference for habitats associated with higher grass and forb abundance, which are important food sources for bears in the early spring.

Mountain Ecotype

- Bergerud et al. (1984b) found that female caribou in the Spatsizi caribou herd (northern BC) moved to higher elevations during the calving season to avoid predation by wolves and bears. Dispersion into rugged mountain terrain forces predators to search a greater and more inhospitable area, thereby reducing their capture success. This tactic resulted in females foraging in less quality habitat for the first two to three weeks in June. Despite using this anti-predator technique, approximately 90% of calves died in 1976 and 1977 (during the time of the study). Bears were observed above the timberline in early June when caribou would have been the only prey and upon examination of fresh wolf scat after calving, 89% contained caribou hair (Bergerud et al, 1984b). The limited success of this antipredator technique is a function of the number of predators on the landscape (Bergerud et al. 1984b). The number of wolves is believed to be increasing due to the increased number of moose in northern BC (Bergerud et al. 1984b).

- Kuzyk (2002) reported that in west central Alberta, non-forested clearings and linear corridors were least preferred by wolves and that forest cutblocks were used proportionately more by wolves than both forest and non-forested anthropogenic habitats (e.g., pipelines, clearings). However, there was no evidence that wolves either preferred or avoided cutblock edges.

- Apps et al. (2013) suggest that the majority of mountain caribou predation is mainly incidental since most subpopulations are too small to be the primary prey for any predator species.

- In Jasper National Park, wolves select areas within 25 m of roads and trails, with specific preference for low use roads and trails versus high use sites (Whittington et al. 2005).

- Whittington et al. (2011) conducted research in portions of Banff and Jasper National Parks to develop time-to-event models of wolf-caribou encounters using GPS radio collar data on caribou (35 adult female and 37 adult male) and female wolves (from 11 packs) from 2002 – 2010. An RSF model was developed for wolf travel, where wolves increasingly select for roads and trails with increasing elevation, especially during autumn, winter and spring. Wolves were found to select for higher elevations during the summer and autumn and lower elevations during winter and spring. Eight of the 11 packs collared had home ranges

overlapping with caribou home ranges and 44% of the radio collared caribou encountered a radio collared wolf at least once (encounter numbers ranged from zero to nine), with encounter rates increasing near linear features. Whittington et al. (2011) found that transient wolf packs more frequently encountered caribou than stable packs. Summer and autumn months had the highest number of wolf-caribou encounters; however, the majority of wolf caused mortality of caribou occurred from April to July. However, the risk of mortality for adult female caribou was not directly proportional to their risk of encounter.

- Research conducted on Northern caribou herds in BC (Quintette and Bearhole/Redwillow) showed that caribou overlap with wolves was influenced by both habitat selection and season; the frequency of co-occurrence increased in spring and summer, and in close proximity to cutblocks (Williams-Ehlers 2012). Results obtained from a study of mountain caribou showed the same pattern of caribou-wolf overlap during snow-free months (Steenweg 2011).

- Wittmer et al. (2005a) found when investigating adult mortality of collared adult caribou across seventeen subpopulations of mountain caribou in British Columbia that the major predator differed between the northern and southern caribou populations. Wolves and bears were found to be the major predator of the northern subpopulations while bears, cougar and wolverine were the more prominent predators of the southern subpopulations. The majority of predation deaths occurred in the summer months suggesting that the number of winter deaths may be lower due to bear hibernation and caribou movement into higher elevations resulting in spatial separation. Wittmer et al. (2005a,b) suggest that several of the subpopulations are in “imminent danger of extinction” and that the major proximate cause of the populations decline is predation (which is a result of major environmental changes – alternate prey changing the landscape and altering the predator-prey system). The authors suggest that localized reductions of cougars, wolves, and alternate prey should be considered with the understanding that ongoing predator control may be required to achieve mountain caribou recovery.

- Serrouya et al. (2011) developed an ecologically based population target for moose near Revelstoke, BC where four subpopulations of mountain caribou are found. Moose are found to be positively associated with early seral vegetation created by humans, low elevations and marshes with the most influential being the human created early seral vegetation. Using ungulate biomass (303 moose) to predict wolf numbers, it was determined that there was a density of 8.1 wolves/1,000 km^2 (5.9 to 11.0 / 1000 km^2) in the study area. Wolf numbers are declining in the study area where moose reduction treatments have taken place; however, there is lag between the reduction of moose and subsequent reduction of wolves. The result may be an increase in caribou predation as the search time for their primary prey (moose) is increased. Therefore, any moose reduction treatments should be done concurrently with wolf control to reach historic numbers until early seral habitat can recover completely (Serrouya et al. 2011). The population target for moose (dominant ungulate) will be used in an adaptive management framework to determine if managing for overabundant prey will be successful in the recovery of caribou and whether or not this approach could be applied to other systems involving species endangerment from the apparent competition mechanism (Serrouya et al. 2011; Serrouya 2013).

- The decline of mountain caribou in the Columbia Mountains has been primarily managed through moose reduction, with the goal of reducing wolf numbers (McLellan and Serrouya 2011; Serrouya 2013). Wolf numbers are declining but with a one to two year lag behind moose, which may result in an increased number of alternate prey (caribou) being consumed. Analyzing 81 wolf scat samples, consumption of

moose declined between sample periods from 46% in 2004-2005 (deemed high moose density) to 33% in 2008-2010 (deemed low moose density) with a modest increase of beaver, deer and marmot in all but the Goldstream Valley where moose densities are higher (McLellan and Serrouya 2011). This suggests that the moose population in Goldstream Valley is above a level that would necessitate a shift in wolf foraging behaviour. The results from this study have two implications for management: "predation risk to caribou may increase as wolves seek alternate prey" and "there may not be a proportional decline in wolf numbers relative to the decline in moose abundance" (McLellan and Serrouya 2011).

- Cary Gaynor is conducting research in the South Purcell Mountains in Southeast British Columbia to understand spatial and temporal movements of wolves by using GPS cluster analysis to locate and examine their kill sites, and use the resultant information to assess predation risk to caribou (NCASI 2011). The anticipated completion date for this study is 2014 (*as cited within* NCASI 2011).

6.0 SUMMARY OF IMPACT PATHWAYS

Sorenson et al. (2008)[2] developed a multiple regression correlation model for boreal caribou in Alberta with the intent of providing a tool for managers to identify landscape scale targets for industrial development (also reported as the BCC 2003a equation)[1],[2] Boutin and Arienti (2008) re-examined the Sorenson et al. (2008) model and confirmed that a reasonable relationship exists between caribou population growth and two factors (linear features and young habitat)[3]. However, Boutin and Arienti (2008) also added the following comments on the model:

1) Our certainly about the numerical values of the actual coefficients is not high given the sample size but we have reasonable certainty that the effects are negative.

2) The model can be incorporated into land use models such as ALCES to capture the relationship between linear feature density, young habitat, and population growth of caribou populations.

3) The model should not be used to establish targets of activity to achieve stable caribou population growth.

4) This analysis does not directly test causation.

In 2010, Sleep and Loehle extended the work of Sorensen et al. (2008) by calculating confidence intervals for the model and by attempting to validate the model using independent data from Environment Canada (2009) for 15 herds (of which six were the same herds used by Sorensen et al. (2008)). The data for the six herds used by Sorensen et al. (2008) was more recent for both population dynamics and disturbance (Sleep and Loehle 2010). Differences between the EC (2009) and Sorensen et al. (2008) datasets existed in the way in which anthropogenic disturbance was estimated (Sleep and Loehle 2010). Validation of the Sorensen et al. model occurred in three ways, the first using only Alberta data (n=6), the second using data from the remainder of Canada (n=9) and a combination of both datasets (n=15) (Sleep and Loehle 2010). The explanatory power of

[1] $Y = -0.258a - 0.212b + 1.140$ ($R^2 = 0.8682$, $P<0.05$); Where Y = finite rate of caribou population increase (λ), a = percentage of area of anthropogenic footprint (buffered on all sides by 250 m) within caribou range, and b = percentage area of caribou range burned by recent (50 years or less) wildfire.

[2] $\lambda = 1.192-0.00315*(\%IND)-0.0029(\%BURN)$; $R^2=0.958$, AIC_c weight = 0.920, $F_{2,3}=35.21$, $P=0.008$

[3] $\lambda = 1.0184 – 0.0234*$Linear feature density $– 0.0021*$%Young habitat (<30 years old, Burn plus cut)

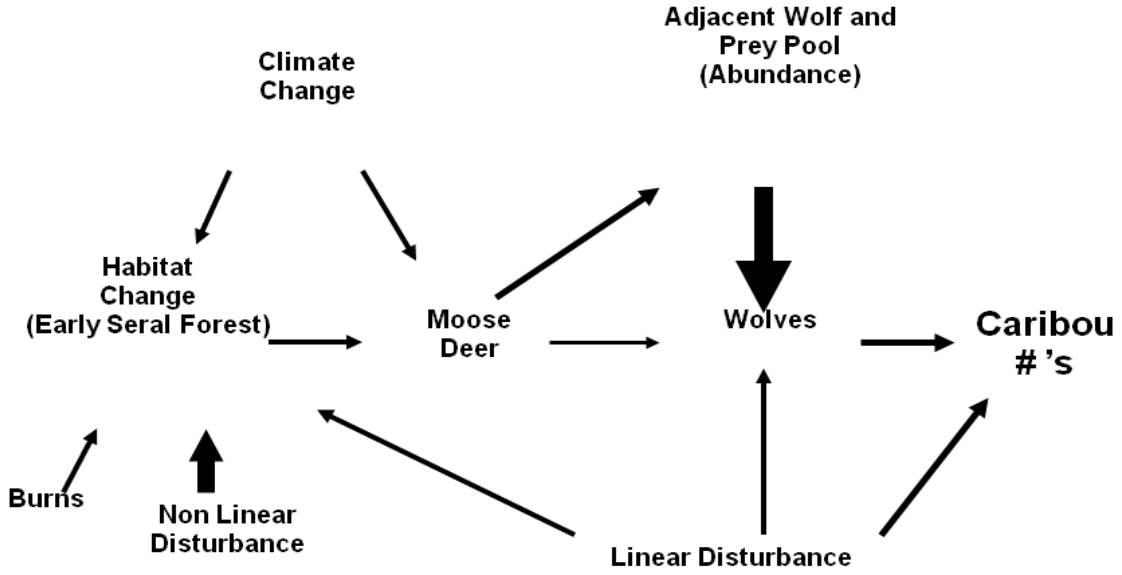
the Sorensen et al. (2008) model decreased from 93% to 40% when the new EC (2009) Canada wide data was applied to the model, the bias was found to be 56.1%, and the model tended to overestimate population growth rate by an average of 9.28% (Sleep and Loehle 2010). When the Sorensen et al. (2008) model was validated for Alberta and the remainder of Canada separately, there was "essentially no detectable explanatory power" (Sleep and Loehle 2010). Sleep and Loehle (2010) found that the Sorensen et al. (2008) model has low predictive ability and limited transferability outside of Alberta and would likely be best used in an adaptive management framework. The Sorensen et al. (2008) model may be improved by the addition of variables as more caribou population information becomes available and will need to be refined before it will be able to accurately predict population growth rates from new data (Sleep and Loehle 2010). Environment Canada (2009) modeled the hypothesized link between landscape disturbance and caribou population dynamics, using recruitment rate as the population metric (Sleep and Loehle 2010). EC (2009) also doubled the distance to anthropogenic disturbance to 500 m and eliminated the overlap between fire and anthropogenic disturbance (Sleep and Loehle 2010). This model also requires validation (Sleep and Loehle 2010).

As these models do not directly test causation, embedded in these relationships are numerous variables, or pathways, which require exploration to help explain why caribou populations are declining in ranges where disturbance conditions exist. These efforts are necessary to develop recovery actions including the identification of effective mitigation. The following five pathways have been identified.

Direct, Pathway 1 – Mortality & Altered Predator-Prey Dynamics: Evidence from Alberta and other regions indicates that predation is a major factor in caribou declines (Bergerud and Elliot 1986; Fuller and Keith 1981; Seip 1992; Dzus 2001; McLoughlin et al. 2003; James et al. 2004). Calf mortality is probably the major factor driving caribou population declines (Mahoney et al. 1990; Rettie and Messier 2001; Whitten et al. 1992; Stuart-Smith et al. 1997; Oakley et al. 2004).

Caribou require spatial separation from alternate prey (moose, deer) and wolves (< 6 per 1,000 km^2) to survive. Increased predator and alternate/primary prey occurrence in caribou range may be the primary mechanism for higher mortality, with the ultimate factor being the condition of caribou range (e.g., decreases in areal extent of caribou habitat, increased fragmentation of remaining caribou habitat, and increases in the areal extent of early seral habitats leading to prey enrichment) (Figure 2). Wolves in particular are causing high rates of predation, but other predators may also be influencing caribou survival (Gustine et al. 2006; Smith and Pittaway 2011; Latham and Latham 2010; Neufeld 2006; Bergerud and Elliott 1998; NCASI 2004). The phenomenon of prey enrichment impacts on caribou populations is referred to as "apparent competition".

Figure 3: Woodland Caribou Pathways Summary. Ultimate cause of Declines Linked to Habitat. Proximate cause of Declines Linked to Predation (ALT 2009).



The implications of increasing primary prey populations as a result of habitat alteration on caribou range, and the associated increase in predators on caribou range, may be adversely affecting caribou mortality rates, specifically during the summer months when predation is greatest (Neufeld 2006; Culling and Culling 2006; Latham 2009; Szkorupa 2002b; DeCesare et al. 2010; Hebblewhite et al. 2010) . Research has been completed using individual-based movement models for wolves, caribou and moose to determine how linear developments affect wolf movements and consequently predator-prey interactions. Results suggest that the number of predators on the landscape is more important than the number of linear developments when explaining caribou survival (McCutchen 2006) and that wolves' travel efficiency is enhanced through linear developments (Dickie 2015).

Direct, Pathway 2 – Habitat Loss (Direct): Direct habitat loss is not considered a major factor in population decline. Habitat alteration however is linked to Pathway 1 and the implications of increasing primary prey habitat and predators within caribou ranges (Dzus 2001; BCC 2003a; Weclaw and Hudson 2004; McLoughlin et al. 2003). It is recognized that habitat loss, as well as reduced habitat effectiveness through avoidance (Pathway 3), are cumulative over the landscape (Smith 2004; Weclaw and Hudson 2004; Wittmer et al. 2008; Sorensen et al. 2008; Boutin and Arienti 2008; Boutin 2010).

Indirect, Pathway 3 – Habitat Loss (Avoidance): Avoidance of disturbance features by caribou is known, although some use does occur within disturbed areas (Bradshaw et al. 1997; Dyer 1999; Neufeld 2006; Smith 2004; Dyer et al. 2001; James 1999; James and Stuart-Smith 2000; Weclaw and Hudson 2004; Oberg 2001). Avoidance may be related to predation and the use of linear disturbances by predators. Both indirect and direct habitat loss are cumulative over the landscape and may be the ultimate cause of caribou population declines when linked to the proximate causes outlined in Pathway 1 (i.e., increased mortality and range overlap with alternate prey populations) (Figure 2). Therefore, identifying management tools to maintain the availability of

large patches of high quality habitat in extensively managed landscapes may be key to reducing caribou predation risk and is a high priority (ALT 2009, Schmiegelow 2005).

Direct, Pathway 4 – Range Abandonment*:* Research indicates that caribou range shifts and contractions have occurred where disturbance levels are high (Dzus 2001; Smith 2004; Hervieux et al. 2013). However, boreal caribou show extremely strong range fidelity which may lead to mortality and predator/prey consequences (as outlined within Pathway 1) if range abandonment does not occur (Tracz 2005).

Indirect, Pathway 5 – Climate Change: The climate change pathway is not considered a priority at this time as fire modeling results do not indicate substantial changes to caribou range as a result of changing fire regimes and because there are a lack of management options available to deal with global warming. However, it is recognized that given the woodland caribou's adaptations to snow, climate change may lead to significant changes in habitat use and lichen availability (Smith 2004; Vors and Boyce 2009; EC 2011). Additionally, it is recognized that implications from climate change may include range expansion of alternate prey (e.g., deer) leading to altered predator/prey dynamics for caribou (Dawe 2011; Dawe et al. 2014). Mountain pine beetle may also impact caribou habitat if expansion is a result of climate change (Cichowski and Williston 2005; ASRD and ACA 2010). Management strategies will need to address reducing the potential risks of climate change impacts to woodland caribou (Schmiegelow 2005).

7.0 RECOVERY

Festa-Bianchet et al*.* (2011) critically reviewed hypotheses to explain caribou declines across Canada. The ultimate cause for the decline of caribou herds across Canada is habitat alteration caused by industrial activities. As a result of habitat alteration, the proximate cause of decline are predation and in some cases overharvest. In order for recovery of caribou populations to be effective, the authors identified that there must 1) be public involvement and improved use of scientific knowledge to influence decision makers; and 2) sustained and intensive management of predators over the short term to increase caribou survival in areas where the habitat has shifted to favour predators and alternate prey, with approximately 80% of wolves being removed in these areas over many years. Without predator control in the short term, it is argued that it is highly unlikely that many caribou populations will persist, even if all industrial activity were to stop and recovery of habitat was accelerated, due to the time lag of forest succession (Festa-Bianchet et al*.* 2011; Apps et al. 2013).

7.1 Environment Canada Recovery Strategies

A Recovery Strategy for Woodland Caribou (Rangifer tarandus caribou), Boreal Population, in Canada was released in 2012 (EC 2012a). Recovery of boreal caribou has been determined to be both biologically and technically achievable across the species' range based on the following criteria:

- Individuals are available now that are capable of successful reproduction to improve local population growth rates and abundance (EC 2011).
- There is sufficient habitat available to support some local boreal caribou populations and other local populations can regain sufficient habitat in the future through efforts to "restore lost, degraded and/or fragmented habitat".
- The primary threat of increased predation (as a result of habitat loss, degradation and fragmentation) can be mitigated through the combination of coordinated land use planning, habitat restoration and management and predator/alternate prey management where necessary.

- Recovery techniques (of which there is some uncertainty with regard to effectiveness) are available to achieve the population and distribution objectives for boreal caribou (EC 2011a).

Critical habitat in the recovery strategy was identified using a threshold of 65% undisturbed habitat in a local population's range. This habitat threshold is required to have a 60% measurable probability that a local population will be self-sustaining. Performance indicators for the recovery of boreal caribou across Canada include maintaining 65% of undisturbed habitat for 14 self-sustaining local populations and ensuring that undisturbed habitat does not fall below existing levels and is increased over the next 50 years for 37 non self-sustaining local populations (EC 2012a). In addition, three indicators will be used:

- where the amount of undisturbed habitat is 65% or more, undisturbed habitat are is maintained at no less than 65% of the total range area;
- local populations are stabilized within five years for those that initially had more than 100 animals; and
- local populations with initial estimates of less than 100 animals have an increasing populations trend (i.e., $\lambda > 1$) within five years (EC 2011).

In order for the objectives of the recovery strategy to be met, connectivity between local populations must be maintained or established to ensure immigration/emigration, maintain genetic diversity, and to allow for the wide ranging populations to adapt to changes in their natural environment (EC 2011). Recovery of the species is considered both biologically and technically feasible but is reliant of a number of parties (including jurisdictions, aboriginal groups, and stakeholder groups) committing to recovery and cooperating with each other to implement the directions set out in the recovery strategy (EC 2011). The Federal government has directed jurisdictions to create Range Plans to identify how they will meet the recovery strategy habitat and population goals for each range within the given timeline. Alberta is currently in the process of developing a range plan for the Little Smoky and A La Peche herds.

A *Recovery Strategy for the Woodland Caribou, Southern Mountain population (Rangifer tarandus caribou) in Canada* was released in 2014 (EC 2014). Similar to the boreal woodland caribou, recovery for the southern mountain population has been deemed biologically and technically feasible using the same criteria as outlined above. The recovery goal is to achieve self-sustaining populations in all local population units. Specifically, i.e., the local population unit demonstrates stable or positive population growth in the short term, can withstand random events and persist in the long term, and populations achieve and/or stay above 100 individuals. Specifically, the recovery strategy specifies the population targets are 4,600 for the Northern group, 2,000 for the Central Group, and 2,500 for the Southern Group.

There are three range components identified for southern mountain caribou, with the most critical requirement of all three being low predation risk:

- high elevation summer and winter ranges;
- low elevation winter range (for Northern and Central groups only); and
- matrix range surrounding summer and winter ranges.

Critical habitat for southern mountain caribou encompasses all the high elevation winter/summer range, and low elevation winter range which has minimum of 65% undisturbed habitat, and matrix range which is managed to allow for a wolf density of less than 3 wolves/1000km^2.

A *Management Plan for the Northern Mountain population of Woodland Caribou (Rangifer tarandus caribou) in Canada* was released in 2012 (EC 2012b). Population trends for the 36 herds indicate that 7 are considered stable, 4 are increasing, 3 are decreasing, and 22 are unknown. The goal of the management plan is to prevent northern mountain caribou from becoming threatened or endangered; to accomplish that, the plan decrees that herds are maintained or recovered, key habitats and ecosystems are maintained, and First Nations and stakeholder groups are meaningfully involved in the stewardship of the Northern Mountain Population and its habitats.

The management plan outlines the following objectives:

- determine herd status and trends over time;
- manage harvest for sustainable use;
- assess health risks and maintain caribou health;
- increase understanding of the dynamics of predator-prey systems and potential competition with other herbivores;
- identify and assess the quality, quantity, and distribution of important habitats;
- mange and conserve important habitats to support healthy caribou herds;
- promote caribou conservation through environmental and cumulative effects assessment; and
- foster opportunities to share knowledge, information and develop education and stewardship programs.

It was recommended that all these actions commence within a 5 year span of the management plan publication.

7.2 Provincial/Other Recovery Strategies and Policies

- In June 2011, the Government of Alberta released a “Woodland Caribou Policy for Alberta”. The Government of Alberta recognizes that “immediate action is required to ensure the long-term presence of naturally thriving woodland caribou populations in Alberta”. The immediate priorities within the policy are to maintain and restore caribou habitat in order to “stabilize, recover and sustain woodland caribou populations” (Government of Alberta 2011). However, a schedule for the planning and implementation of actions has yet to be developed.
- A wolf control program was initiated within the Little Smoky Caribou Range in Alberta, where the pre-removal wolf density was estimated at 21 to 26 wolves/1000 km^2. In total, 104 wolves, 66 wolves and 72 wolves were removed from 2005/2006, 2006/2007 and 2007/2008, respectively. The population trend for this herd has stabilized since the onset of the wolf control program (ASRD and ACA 2010). Adult caribou female survival was 0.73, 0.87 and 0.9 over the 3 years. Calf recruitment from 2005/2006 to 2007/2008 was 11 calves/100 females, 20 calves/100 females (spring following cow/calf penning experiment) and 17 calves/100 females. Average calf recruitment prior to the wolf control and one year penning experiment was 11.4 calves/100 females. (D. Hervieux, pers. comm. 2008).

- Parks Canada released their conservation strategy for southern mountain caribou in Canada's national parks in 2011. Five southern mountain caribou herds exist within the mountain national park region including Columbia South, A La Peche, Tonquin, Maligne and Brazeau. Re-establishment of a sixth herd that was extirpated from Banff in 2009 is included in the conservation strategy. The goals of the conservation strategy are to maintain the Columbia South population and to achieve and maintain herds of 25-40 animals for the remaining 5 herds (including Banff). In order to achieve these goals, Parks Canada has committed 4.5 million dollars over six years to address the five major threats associated with caribou decline including altered predator/prey dynamics, facilitated predator access to caribou, direct disturbance of caribou, direct elimination of caribou habitat and small population effects. Actions identified to address these threats include preventing "elk refuges", discontinuing early season ski tracks that lead to caribou winter habitat, education of park visitors, use of prescribed fire, re-introduction/addition of caribou where extirpated or where herd size is critically low and on-going monitoring (Parks Canada 2011a).
- In NE BC, the Ministry of Environment (MOE) and Ministry of Ministry of Energy, Mines and Petroleum Resources (MEMPR) are developing a strategy that balances future opportunities for Petroleum and Natural Gas (PNG) development with boreal caribou conservation objectives. Wilson et al. (2010) concluded based on analysis that to meet this objective: future population projections and financial impacts are uncertain and model results should be interpreted cautiously; results are highly sensitive to several assumptions in particular, current habitat fragmentation and the effectiveness of restoration; even with a full moratorium on further PNG exploration and development, BC's boreal caribou population is likely to decline and there is a high probability (>40%) that caribou could be extirpated from two ranges; halting all but the development currently committed on previously sold tenures could result in a nearly 50% decline in BC's boreal caribou population and could result in the extirpation of caribou from three ranges; continuing development without significant changes in footprint management or deferring areas from PNG tenure sales will likely result in the extirpation of boreal caribou from all but the Maxhamish range; and, aggressively restoring habitat significantly improves population projections, but the feasibility and predicted outcomes of restoration activities are highly uncertain.
- The Government of British Columbia approved the implementation of management activities for boreal caribou in 2011 which included protecting boreal caribou and their habitat from oil and gas activities and managing the size and mitigating the effects of its' footprint. Government and the oil and gas industry created operating practices (OPs) to help standardize the management of industrial activities so that boreal caribou habitat can be managed. The OPs will be reviewed by First Nations and environmental biologists as the OPs are interim. OPs have been designed for boreal caribou ungulate winter ranges (UWRs) which include limiting activities that reduce terrestrial and boreal lichen forage, enhance predator mobility, increase caribou visibility to predators and cause fragmentation of large areas of caribou range. Other OPS were implemented for protecting calving caribou from predators in areas known as the boreal caribou wildlife habitat areas (WHAs). These include reducing predator mobility, limiting caribou visibility to predators, and reducing production of other prey species (B.C. Ministry of Environment 2011a).
- The Government of British Columbia created a method to equalize habitat protection and management strategies for boreal caribou with petroleum and natural gas (PNG) development outlined in the "Implementation Plan for the Ongoing Management of Boreal Caribou (*Rangifer tarandus caribou* pop. 14) in British Columbia 2011" (BCIP). Some of the recovery actions mentioned in the BCIP include: restoring boreal caribou habitat, managing caribou predators and their primary prey, and conducting research on

boreal caribou and their habitat. The British Columbia Caribou Research and Effectiveness Monitoring Board (REMB) was created in 2011 to carry out the actions in the BCIP. The REMB will submit recommendations focused on conservation efforts to the government within 5 years. Based on this work, caribou populations in the Prophet, Parker, and Chinchaga ranges were reported as likely declining, while populations in the Calendar, Maxhamish and Snake-Sahtaneh ranges may be stable, depending on trends in adult survival. Other research shows that moose populations are currently low but will likely increase in core caribou habitat (REMB Annual Report 2013).

- The current 2013-2014 work plan for the REMB includes things such as incorporating site-level mitigation efforts, updating models to reflect 2012-2013 survey data collections, acquire or develop caribou habitat mapping, evaluate and address gaps in baseline data, and identify research hypotheses (REMB Annual Report 2013).
- The province of British Columbia is beginning to develop management strategies for 7 of their northern caribou herds in the South Peace region. These herds include the Graham, Scott, Kennedy Siding, Moberly, Burnt Pine, Quintette, and Narraway. The Quintette and Graham herds are the only two stable populations. Wilson (2012) used a Bayesian Network model to represent the hypothesis which states that "the density of wolves in the most significant determinant of survival and recruitment of caribou, and the abundance of early seral habitat indirectly influences the density of wolves by influencing the abundance of their primary prey." If future industrial growth continues and no further management efforts are implemented, the northern caribou population in the South Peace will decline to 800 from the current 1,100 in approximately 20 years (Wilson 2012). Wilson (2012) predicts that this could potentially wipe out the Burnt Pine, Moberly and Kennedy Siding herds, as well as drastically reduce populations in three other herds (REMB Annual Report 2013).
- In 2010, the province of BC established 5 Resource Review Areas (RRAs) in boreal caribou ranges and in the Burnt Pine northern caribou ranges. Within a RRA, no oil and gas, mineral, place or coal tenures are allowed for a minimum of 5 years. Performance measures at the range and population levels to monitor the effectiveness of RRAs were recommended in Cichowski et al. 2012, and include evaluating the population rate of increase, adult mortality rate, calf recruitment rate, percentage of area within 500 m of industrial activities, percentage of area in burns <40 years old, undistributed patch size distribution, percentage of area of undisturbed low gradient slope, and predator and alternate-prey density.
- The BC government's Mountain Caribou Recovery Implementation Plan was enacted in 2007 to halt the decline of mountain caribou within 7 years and to recover populations to 1995 levels. The management actions outlined in the plan include:
  - protect 2.2 million hectares of mountain caribou range from logging and road building;
  - manage human recreational activities to minimize disturbance and displacement from their preferred habitat;
  - manage predator populations of wolves and cougars;
  - manage the primary prey of predators of mountain caribou;
  - increase caribou numbers in threatened herds with animals transplanted from elsewhere;

- support adaptive management and research; and
- institute a cross-sector progress board to monitor the effectiveness of recovery actions.

- To date, numerous actions have been taken to address the MCRIP goals: 2.2 million hectares have been protected from logging and road building, and approximately 1 million ha have been excluded from snowmobile use (although monitoring and compliance continue to be a concern). Increased trapping and hunting seasons for wolves and cougars have been enacted to encourage removal of predators, and a wolf-sterilization trial has been occurring since 2001 in the Quesnel Highland region (with limited improvement in caribou populations- see next bullet). Requests have been submitted to conduct aerial wolf removal in specific ranges. Moose reduction pilot projects have occurred with limited success. A caribou transplant to the Purcells South region occurred in 2012 but only 3 out of 19 survived longer than a year. A maternal penning project is currently in development, and discussions with Calgary Zoo about a captive breeding program have occurred (BC MCRIP 2013).
- The BC government have been leading a wolf sterilization project in the Quesnel Highlands to reduce mortality on mountain caribou since 2001. The dominant male and female of each pack were sterilized, and the other members of the pack euthanized. In total, 57 wolves were sterilized and 30 were removed. Sterilized pairs maintained their territories and stopped reproducing, which limited the number of wolves in the area. However, the program did not change caribou recruitment rates in the Quesnel Highland herd relative to comparison herds. An independent review of the program recommended continuing the sterilization for an additional 3 years for a better assessment of calf survival rates (Hayes 2013).
- Predator-prey management is recommended in British Columbia to support mountain caribou recovery efforts. A report by Wilson (2009) suggested that because grizzly bear and black bear predation could not be managed in the same way as wolf and cougar populations, previous reports suggesting densities should be less than 6.5 wolves/1000km^2 and less than 10 cougars/1000km^2 was not sufficient. Wilson instead recommends that in areas where predation would jeopardize the viability of the caribou herd, removal of all resident packs and/or individuals, and/or sterilizing alpha male and females, should be considered. This report also states that hunting and trapping will not be sufficient to meet wolf densities and aerial shooting should be used for wolves; cougars could be managed with changes in hunting regulations.

7.3 Habitat Restoration

The federal Recovery Strategy for boreal caribou identifies coordinated actions to reclaim woodland caribou habitat as a key step to meeting current and future caribou population objectives. Actions include restoring industrial landscape features such as roads, seismic lines, pipelines, cut-lines, and cleared areas in an effort to reduce landscape fragmentation and the changes in caribou population dynamics associated with changing predator-prey dynamics in highly fragmented landscapes. Reliance on habitat restoration as a recovery action within the federal Recovery Strategy is high, identifying 65% undisturbed habitat in a caribou range as the threshold to providing a 60% chance that a local population will be self-sustaining. In alignment with the federal Recovery Strategy, Alberta's Provincial Woodland Caribou Policy identifies habitat restoration as a critical component of long-term caribou habitat management.

Caribou habitat restoration efforts began in the west-central Alberta caribou ranges in 2001 through the Caribou Range Restoration Project (CRRP) (Szkorupa 2002b). At that time, the use of silviculture methods were explored including tree/shrub seedling planting, seeding of tree species, tree/shrub transplanting, mounding and soil de-compaction (CRRP 2007a,b,c). Mapping of current condition of linear features noted that natural regrowth on historical seismic lines had occurred.

Early research on seismic line regrowth reported that seismic lines have very slow reforestation rates (Revel et al. 1984; Osko and MacFarlane 2000), and recovery is strongly influenced by the characteristics of the adjacent forests (e.g., site productivity, tree and shrub species and heights) (Bayne et al. 2011). Conventional seismic lines cleared by bulldozer may take as long as 112 years to reach 95% recovery to woody vegetation in the absence of restoration efforts (Lee and Boutin 2006). Slow tree regeneration has been attributed to root damage from the original disturbance, compaction of the soil in tire ruts, insufficient light reaching the forest floor, maintenance of apical dominance from surrounding stands, introduction of competitive species (i.e., planted seed mixes), drainage of sites (i.e., regeneration slowest on poorly drained sites with low nutrient availability such as bogs) and repeated disturbances (e.g., all-terrain vehicles [ATVs], animal browsing, repeated exploration) on seismic lines (Revel et al. 1984; MacFarlane 1999, 2003; Sherrington 2003; Lee and Boutin 2006; Van Rensen 2014). However, tree regeneration on seismic lines is a key determinant of recovery success (MacFarlane 2003) and, therefore, factors that hinder revegetation efforts should be mitigated.

The ability of linear features to recover to a natural forested state is affected considerably by human use (e.g., Golder 2009; Van Rensen 2014). Oberg (2001) identified that recovery of conventional seismic lines to functioning mountain caribou habitat occurs within 20 years following disturbance in west-central Alberta. Golder (2009) reports that in the Little Smoky caribou area, seismic lines that were allowed to regenerate naturally achieved an average height of 2 m, across all ecosite types, within 20 to 25 years, when lines had not been recently disturbed by human activity (e.g., re-cleared to ground level for winter access or seismic program use). The average age of trees on the control lines was only 10 years, suggesting sites that are continually disturbed or re cleared by human activity take longer to regenerate. Restoration efforts have also failed when ATVs destroyed seedlings after planting (Enbridge 2010; Golder 2011, 2012a).

Implementing practices for new construction projects to reduce the project impact at the construction phase has been identified as critical to reduce the need and/or amount of habitat restoration required at the post-construction phase. Two of the primary practices that can be implemented at the construction phase of a project are minimal disturbance construction and access control (Coupal and Bentham 2014). Pyper and Vinge (2012) identified the importance of managing woody materials such as logs, branches and stumps created from clearing activities. In the past, woody materials were piled and burned or mulched. Currently, whole logs are kept on site because they are valuable for reclamation and biodiversity as they create pockets of shade and moisture which encourage plant growth and help protect seedlings during the winter (Pyper and Vinge 2012). Keeping logs on site allows companies to minimize costs as they can reduce operational footprints and help to regenerate sooner. Past practices of burning woody materials is suggested to only take place in those areas where reduction of fuel loading is the main goal. Wood should be stored on sites where it will be reclaimed quickly or alternatively, logs can be buried beneath soil piles to reduce fire and to preserve woody materials until reclamation can begin. If upland sites receive between 60 m^3/ha and 100 m^3/ha and lowland sites obtain 25 m^3/ha to 50 m^3/ha, than 10% to 25% of sites will be covered (Pyper and Vinge 2012). Rough mulching should only be used when necessary since it reduces operational hazards and preserves microsites.

As caribou habitat restoration initiatives have become more widespread across Alberta in the last decade, there has been much debate regarding what treatment types are appropriate for habitat restoration, and how to measure success. Restored habitat for caribou has not been clearly defined in either provincial or federal caribou recovery strategies. Workshops on caribou habitat restoration began in 2013 and have been attended by caribou, forestry, energy, power, consultants/contractors, and other industry experts where discussions have occurred on defining what the objectives and goals are for habitat restoration (e.g., Golder 2014a; COSIA 2014). In response to research suggesting predators and primary prey are increasing their use of linear features, one focus for restoration treatments has been to establish treatments that will provide an immediate removal of the benefits that linear disturbances provide to predators (e.g., Cody 2013; Cenovus 2013; Saxena 2014). In response to monitoring linear features with natural revegetation, the focus has been on controlling human off road access which compacts soil and inhibits revegetation recovery. Lastly, the focus has been on establishment of coniferous tree species.

The following proposed definition has been endorsed by CAPP:

"Application of techniques on anthropogenic disturbances that deter predation, primary prey and human use in the near term, that supports long term habitat recovery". Although not specific to caribou habitat restoration, the following definition is provided within the Government of Alberta and Alberta Energy Regulator (AER) Enhanced Approval Process guidelines (Government of Alberta and AER 2013):

"Restoration - The process of returning the ecological conditions (i.e., structure, function, and composition) that existed prior to disturbance. As restoration is a function of ecological condition, its determination is largely influenced by the ecological goal (e.g., sage grouse occupancy and utilization) of the habitat."

Based on the above definitions and workshop discussions, the short term objectives of habitat restoration treatments can be summarized as:

- Directly promote the vegetation recovery trajectory along linear disturbances with a focus on conifer abundance and growth, of both naturally occurring and introduced vegetation.
- Access control targeting human and predator access along linear disturbance features (seismic lines, pipelines, cutlines, roads), including during reclamation of recently abandoned dispositions such as lease roads and pipeline ROWs; and legacy features such as seismic lines.

The focus of most initiatives has been on establishing vegetation along pipelines or seismic lines, with the synergistic goals of creating line-of-sight breaks, directly restoring habitat with transplanted vegetation, planting shrub and tree seedlings, sowing native shrub and tree seed, and controlling human access to reclaimed areas to allow undisturbed natural vegetation growth (e.g., Caribou Range Restoration Project [CRRP] 2007a, 2007b; Enbridge 2010; Golder 2010, 2012a; Oil Sands Leadership Initiative [OSLI] 2012a,b; Nexen 2013; Osko and Glasgow 2010). Linear disturbances have been the focus of implementation and learnings to date, due to the prevalence of these linear features within caribou ranges in the boreal and polygonal features such as cutblocks more prevalent adjacent to, or outside of delineated caribou range. Common among many of these initiatives are learnings on site preparation (e.g., on trial sites planted with black spruce and tamarack within forested wetlands, survival and improved height and diameter for surviving seedlings was much higher on mounded sites as compared to non-mounded sites [Iqbal et al. 2014]), use of woody materials (Keim et al. 2014; Vinge and Pyper 2012; Pyper and Vinge 2012), which plant species/shrub species to plant, when and where to plant seedlings

(evolving methods and results for winter seedling planting [e.g., Cody et al. 2014, Vinge 2013]), identification that restoring linear disturbances differ from traditional cutblock methods, development of effective techniques to promote natural revegetation, and a better understanding of methods to control access. A summary of historic and current caribou habitat restoration initiatives has been previously prepared for the British Columbia Ministry of Forests, Lands and Natural Resource Operations (available online at: www.env.gov.bc.ca/wld/speciesconservation/bc/documents/Restoration%20Final%20_BC_Caribou_2012_03_30.pdf) (Golder 2012b).

Key highlights of learnings on restoration tools are reported within the SCEK REMB Restoration Toolkit for boreal ranges in BC (Golder 2014 *draft)*, and have been updated, and summarized, within Appendix B.

The Athabasca Landscape area simulation results indicate that ***coordinated reclamation*** should be the foundation of caribou habitat restoration because it has the greatest influence on functional habitat recovery (ALT 2009). Examples of industry collaboration for coordinated habitat restoration programs include the Algar Caribou Habitat Restoration Program, a 5 year program started in 2012, which has treated over 150 km of linear disturbance as of May 2014 (COSIA 2012a; Reid 2014).

7.4 Other Recovery Management Tools

Translocation/Reintroduction

- Between March 1987 and February 1992, 60 woodland caribou were translocated from BC to the Selkirk Mountains of Idaho (Compton et al. 1995). Caribou were radio collared, released and monitored weekly from fixed-wing aircraft. Twenty seven deaths and seven emigrations of mountain ecotype caribou occurred with 14 active radio collared caribou alive at the end of the reporting period. 53% of deaths occurred during the summer months with seven attributed to predation, seven to emigration, four to other, two to human caused and 14 listed as unknown. Recruitment estimates for the herd in 1991 and 1992 were 0.14 and 0.06 respectively suggesting a declining population. In March 2008, the Idaho Department of Fish and Game conducted a fixed wing survey of the South Selkirk Recovery Area and observed three adult caribou in the Little Smoky Top area of the United States (Idaho Department of Fish and Game 2009).

- Decesare et al. (2011) conducted population viability analysis (PVA) for the Brazeau, Maligne, Tonquin and extirpated Banff populations in Banff and Jasper National Parks to assess the efficacy of translocation-based recovery. Scenarios simulated the translocation of 15 female and 5 male caribou per year over the first three years with post-translocated survival depression modelled at 30, 20 and 10% decreases in annual adult survival probability for the first three years and environmental conditions similar to the past eight years. The Brazeau and Maligne herds were found to be not viable without translocation with median times to extirpation being 14 and eight years, respectively (assuming density-dependent survival). However, the authors reported that translocation efforts alone for these herds, while reducing the short term probability of extirpation, do not appear to be enough to reverse the decline in abundance. The Tonquin herd was stable to increasing over 20 years when mean survival was fixed and appeared to be viable without translocation efforts. A population of re-introduced caribou into Banff may be viable without further translocation efforts if survival probabilities are high. The IUCN recommends that translocation of individuals only take place once sufficient habitat is available and other threats have been removed; this would warrant primary prey and predator control for the Brazeau and Maligne populations. It was also noted

that woodland caribou have locally adapted behaviours which make it difficult to translocate them successfully (Decesare et al. 2011; also see DeCesare 2012).

- In 2011, Parks Canada issued a press release announcing a partnership had formed between themselves, the government of British Columbia and the Calgary Zoo to begin a captive breeding program for southern mountain woodland caribou as a means of providing source animals to herds with critically low numbers (Jasper, Mount Revelstoke and Glacier National Parks) and to reintroduce the species to Banff National Park (Parks Canada 2011b). In 2014, the Calgary Zoo pulled out of the three-year program due to lack of funding (Parks Canada 2011c, Ellis 2014).
- In an effort to augment the Purcells-South mountain caribou herd in southeast BC, 19 caribou were translocated from the Level-Kawdy caribou herd in northwest BC in March 2012. By July 2013, 17 out of the 19 translocated caribou had died from predation, accidents or unknown causes. One of the remaining caribou's status is unknown because of radiocollar failure. The second phase of the project (which was to translocate an additional 21 caribou) has been deferred for the time being (Gordon 2013).

Maternity Pens

- In eastern Alaska-western Yukon, the decline of the Chisana caribou herd has been attributed to high neonatal predation, an aging population and a skewed sex ratio. A maternity pen reduced calf mortality during the first 3 weeks of life and increased calf survival up to 70% (Oakley et al. 2004). This increased calf survival resulted in an overall herd-wide recruitment of 20 calves/100 cows; compared to the herd's average of 6 calves/100 cows (Farnell pers. comm.). However, captive reared calves were on average 15 pounds heavier than free-ranging claves at 5 months of age (Farnell pers. comm.). The effectiveness of predator exclosures on calf recruitment may be confounded by supplementary feeding which occurred in conjunction with penning, and the resultant increase in body condition of cows and calves.
- In 2006 the Little Smoky Caribou Calf Project (LSCCP) was implemented for one year, and coincided with an active wolf control program (wolf numbers were lowered from approximately 30 wolves per 1,000 km^2 to 5 to 8 wolves per 1,000 km^2). Ten pregnant cows were captured in March 2006, radio collared and moved to a four hectare enclosure. Nine of the ten calves born were radio collared with a sex ratio of five female and four male calves. When the youngest calf was 19 days old, the cows and calves were released from the enclosure. Once released, the cows and calves were tracked by air weekly for two weeks and then monthly until the rut, with a final flight to determine survival to 10 months. Of the ten calves born, one died of mycardial degeneration within the enclosure, two were killed by bear near the site of the enclosure, one mortality was unknown and the un-collared calf was found to be not "at heel" by September 2006, resulting in a 50% survival rate for the penned calves. In comparison, there was a 77% survival rate for the wild caribou sample. Should another caribou calf penning project be initiated considerations should include moving the enclosure away from any major rivers (which may be frequented by bears) and ensuring that the penning project is used in conjunction with other positive changes to the landscape (Smith and Pittaway 2011).
- In Revelstoke BC, a maternal pen was established in spring of 2014 by the Revelstoke Caribou Rearing in the Wild (RCRW) community partnership following moose and wolf population management trials. Twelve female caribou (10 cows, including 2 females 10 month old calves) were captured from the Columbia North herd and placed into a 6.4 ha maternity pen pilot project. Nine cows were pregnant, gave birth, and nine

calves were released with their mothers in July 2014. As of November 2014, 6 calves are believed to still be alive with 2 unknown (collar issues). RCRW has confirmed another maternal pen will occur in 2015, with a goal of 18 to 20 cows captured (Revelstoke Caribou Rearing in the Wild, Facebook Page, Accessed December 11, 2014).

- Caribou in the Klinse-Za (Moberly) mountain herd B.C. have declined to under 20 animals. In 2014, the Klinse-Za Maternal Penning Project, coordinated by West Moberly Fist Nations and Saulteau First Nations began with a maternity pen constructed and 10 pregnant female caribou from the Klinse-Za herd were enclosed in late March. Nine calves were released with 10 adult female caribou in early July 2014 (Press Release July 2014: Maternal Penning to Enhance Survival of Cow Caribou and their Calves within the Klinse-Za Caribou Herd).
- Following a 4 year study, DeMars and Boutin (2014) recommend that management actions will need to be conducted at large spatial scales because boreal caribou are at their most dispersed at calving and small-scale actions will likely be ineffective at improving rates of neonate survival. Targeting potential management actions toward large fen complexes may be most effective because of their importance to calving boreal caribou. For rapidly declining populations residing in ranges highly impacted by disturbance, habitat conservation and restoration initiatives may need to be augmented by more intensive actions (e.g. maternal penning, predator management) to improve calf survival rates in the short-term.

Large Scale Fence / Predator Exclosures

- Caribou population enhancement measures will likely be a necessity to sustain caribou in the Athabasca Landscape area given the time lag required to restore the current footprint, and the footprint associated with on-going energy development projections in the Oil Sands Region (Golder 2012d). Through the work commissioned by the OSLI LSWG, the desired outcome of a caribou predator exclosure (i.e., a large fenced and actively managed exclosure) is to establish and maintain a viable caribou population in a natural setting while functional habitat is being recovered (likely 40+ years) so that a self-sustaining caribou population can ultimately be established in the absence of a fence (OSLI LSWG 2012). As summarized within OSLI LSWG 2012, three out of the four feasibility evaluations commissioned by the LSWG concluded that a fenced predator exclosure is technically feasible and worth considering further as part of a caribou management program. These evaluations assume that industrial activities would continue within the fenced area and that a viable caribou population can be maintained in the absence of predators. All feasibility evaluations acknowledge that there will be substantial debate about this option among resource managers, regulators, aboriginal groups, politicians, environmental organizations, and the general public. They also noted that successful implementation would require a long-term, continuous commitment of resources and funds (in the order of $10 million for construction plus annual maintenance/operating costs plus future removal of infrastructure).
- The following potential benefits of a predator exclosure were identified in one or more of the independent evaluations received by the OSLI LSWG (2012):
  - Provides a controlled natural environment to increase the productivity of caribou within the predator exclosure and establish a viable population in a region where one does not currently appear to exist.

- Provides a secure source of boreal-ecotype caribou for regular translocation to augment declining regional/provincial populations. Thus a single fenced area could increase caribou abundance in a multi-herd metapopulation.
- Provides a controlled environment to test the feasibility of habitat restoration and population management options and to undertake research on cause-effect relationships contributing to caribou decline in the absence of predation.
- Offsets impacts of ongoing industrial activities in the oil sands.
- Allows comparison of the effectiveness of this approach with other conservation options and cost/benefit evaluation for application elsewhere in Alberta and Canada.
- Contributes to the Environment Canada Proposed Recovery Strategy (Environment Canada 2011) recommendation to maintain a caribou population in northeast Alberta for national connectivity.
- Reduces the need for annual, large-scale wolf culls over many decades.
- Contributes to the conservation of other species with smaller home range sizes and similar general habitat requirements.
- Would create long-term job opportunities for monitoring, maintenance, and research.
- Release of yearling calves from within the enclosure into the regional woodland caribou population would provide an annual injection of young females, incrementally increasing the pool of young cows at the beginning of their reproductive lives.

- The following potential challenges of a predator exclosure were identified in one or more of the independent evaluations received by the OSLI LSWG (2012):
  - Designing, constructing, and maintaining a fence that is robust enough to keep predators from digging under and climbing over, especially at river crossings.
  - Unintended, detrimental ecological effects to other wildlife and vegetation species as a result of altered predator-prey dynamics.
  - Substantial debate among stakeholders may lead to a lack of public support.
  - Predator exclosure fence may not be warranted if rates of population decline are overstated or if industrial activity is identified as a most important limiting factor than predation.
- An experimental caribou recovery project led by Nexen Energy on behalf of Canada's Oil Sands Innovation Alliance (COSIA) is underway testing a fence design that could support a large scale predator exclosure designed to keep predators out.

Triage

- Some research has suggested a triage approach be warranted when considering caribou recovery in Alberta (Boutin and Boyce 2011, Schneider et al. 2010). Triage's role is to make the most efficient use of resources that are allocated as a result of a societal trade-off decision and is not "simply about picking winners and losers" (Schneider et al. 2010). This approach would call for strategic location of conservation

activities where, for example, 50% of herds may be able to be protected at 5% of the net present value of the energy resources (Boyce and Boutin 2011). The result may be that some caribou populations would be lost, but the remaining herds would receive a greater conservation effort (Boyce and Boutin 2011).

- Rather than focusing on risk of extinction when dealing with conservation efforts in Alberta, Schneider et al. (2010) proposed that people should focus their attention on the probability of success and cost of endangered species. Triage is advisable when three conditions are present. With respect to caribou recovery in Alberta these include, insufficient capacity to adequately treat all herds, herds are in a critical state and cannot wait for additional capacity to become available and the caribou herds differ in the likely outcome and the amount of "treatment" they require. Twelve herds were included in the analysis and were ranked according to relative risk of extirpation, relative likelihood of conservation success, and opportunity costs of protection. Three recovery actions were modeled in combination including habitat restoration (restricted to seismic lines and at a cost of $4,000/km), wolf control (at a cost of $35/km^2) and habitat protection (focusing on opportunity costs of prohibiting new development) to explore the potential differences in cost and response to recovery among herds (Schneider et al. 2010). Of the 12 herds, only the WSAR, A La Peche, and Richardson will maintain a population of greater than 10 individuals for more than 60 years (if current population trends continue and there are no changes in habitat condition or industrial activity) and the Cold Lake and Slave Lake herds will fall below 10 individuals in less than 20 years. The remaining seven herds will fall below 10 individuals in less than 40 years. Five factors were considered when ranking the best and worst herds for recovery including recovery cost per square kilometre, years to decline to 10 individuals, range size, current density of linear disturbance (and proportion of range within young forest) and years to self-sufficiency. Among the five factors, the A La Peche, Caribou Mountains and Redrock-Prairie Creek herds tended to rank high while the Slave Lake, ESAR and Cold Lake herds tended to rank among the worst. The WSAR and Richardson herds were among the most costly to recover but had a high likelihood of success. Based on this study, the authors concluded that a triage approach to caribou recovery in Alberta is warranted; especially if the provincial government finds that the opportunity costs are too high to protect all Alberta caribou ranges (Schneider et al. 2010).

- Schneider et al. (2011) explored the application of optimal resource allocation to coarse-filter reserve design in the context of regional land-use planning in Alberta. By protecting (prohibiting any new industrial development) a representative array of natural ecosystems and their constituent processes, the conservation of the majority of species may be obtained. However, the establishment of environmental reserves will involve a trade-off (in the way of the costs of forgone resource revenues). Schneider et al. (2011) expressed the opportunity cost of protecting an area as a percentage of the total value of the resources in the planning area. This approach resulted in an increase from the current 14.8% of protected areas in Alberta to 30% while maintaining access to 97% of the value of the region's resources. The authors indicate that there were a small number of ecological design elements in their study and while the boreal landscape may have fewer species and less variability than other areas, it is unlikely that the needs of all species are captured in their coarse-filter approach and a complementary fine-filter approach would be required for comprehensive protection.

8.0 CONCLUSION AND RESEARCH GAPS

Based on a review of the science, a review of on-going research and monitoring projects, and a multi-stakeholder workshop with key researchers in Alberta, key wildlife managers and select industry (oil and gas, and forestry) representatives, three priorities for industry funded research were outlined in 2008; the influence of habitat condition on caribou, alternate prey and predator numerical response and the development of restoration as mitigation (Golder 2008).

Since that review of research gaps, academic institutions, industries operating within caribou range, regulatory bodies and consultants have been actively engaged in moving towards adaptive management field research to address these priorities. Although research gaps still exist, collaborative research initiatives are well underway in addition to regional scale implementation and monitoring programs, to clearing understand the influence of mitigation (including removal of predators and moose in an adaptive management approach) on predator mobility, to understand predation risks during calving and on implementing large scale initiatives on the ground to address habitat restoration (e.g., OSLI 2012a), predator success rate (e.g., LIDEA), and population enhancement. Examples are identified below.

- Over the long term, it was identified by the CLMA and FPAC (2007) mitigation audit that caribou and industry managers need to achieve a shift within a relatively large, but defined portion of the landscape from its existing disturbed state (heavily weighted toward an early and mid-seral matrix) into a state more consistent with its natural disturbance regime. Similarly, the ACC Research Subcommittee (N. McCutchen pers. comm.) as well as the West-Central Alberta Caribou Planning Team and the Athabasca Landscape Team have identified restoration, through planning and modelling, as a significant mitigation option for past and ongoing industrial disturbance. To achieve this, clearly defined research programs, which address alternate prey and predator numerical and behavioural response to habitat restoration mitigation practices, not just vegetation response, must be established. One program is underway within the Cold Lake caribou range in northeastern Alberta (Saxena 2014), with pre-treatment wolf data and analysis complete (M. Dickie M.Sc. thesis *in prep*).
- Although some vegetation re-establishment monitoring of treatment plots has occurred, the CRRP was disbanded in late 2007. The Foothills Landscape Management Forum (2008) in west central Alberta includes the commitment to develop a landscape level restoration program designed to manage the historical industrial footprint to support enhancement of caribou habitat in the short and long term. This restoration program was to build on the CRRP work with an established government/FLMF task team, as there are provincial implications. However, formal approval of the Integrated Industrial Access Plan (IIAP) by ESRD is required to move forward with this reclamation plan (Golder 2012d). Through the Foothills Research Institute, restoration research projects should aim to address the following questions (Finnegan 2014):
  - How soon after disturbance and recovery do caribou start to use an area again? How soon do caribou start to use regenerated forests?
  - When is a line restored from a caribou perspective (and to meet the Federal recovery strategy?)?
  - Does increased predator access, as a result of disturbance corridors, affect predation success on caribou calves and females? Can increased predator access, and presumed increased predation success, be mitigated along industrial disturbances? If so, how (linear deactivation)?

Given the Recovery Strategy goals, current status of caribou in Alberta and BC, provincial regulations, and policies and pending release of Provincial Range Plans, research into identifying land use practices built off of long-term science-based solutions to caribou herd declines continues to be a priority. Once identified, these practices need to be implemented without delay.

9.0 CLOSURE

This report was prepared by Golder Associates Ltd. (Golder) for the Canadian Association of Petroleum Producers. This report was originally prepared in 2004 by Paula Bentham and reviewed by Martin Jalkotzy and Jim O'Neil. Updates have occurred in 2005 (Paula Bentham, reviewed by Corey De La Mare), 2011 (Brandi Hall and Paula Bentham, reviewed by Martin Jalkotzy) and 2014 (Michelle Bacon with review by Paula Bentham). This report focuses on woodland caribou research which are reflective of studies or programs within areas of overlap of oil and gas activities and caribou ranges in Western Canada. Select literature from other regions of Canada have been included to support hypotheses or trends. This report is therefore not a complete compilation of all research work conducted on woodland caribou within Canada.

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We trust the information contained in this report is sufficient for your present needs. Should you have any questions regarding the project, please do not hesitate to contact the undersigned at (780) 483-3499.

GOLDER ASSOCIATES LTD.

Michelle Bacon, M.Sc.
Wildlife Biologist

Paula Bentham, M.Sc., P.Biol.
Principal, Senior Ecologist

MB/PB/

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APPENDIX A

West Central Alberta and Athabasca Landscape Area Management Options

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Golder Associates

APPENDIX A
West Central Alberta and Athabasca Landscape Area Management Options

The Alberta Caribou Committee Governance Board (ACCGB) has formed Landscape Teams for West Central Alberta and the Athabasca Landscape Area and tasked these teams with developing management options for woodland caribou within their subsequent regions. Management options have been developed and recommended to the Deputy Minister of SRD, for implementation to recover and sustain woodland caribou in all populations consistent with the provincial woodland recovery plan (2004/5 – 2013/14) (ACCGB 2008, 2009). Technical, political and economic challenges were not considered.

Similarities exist between both the Athabasca Landscape Planning Team (ALT) and the West Central Alberta Planning Team (WCCLP) recommendations. Both planning teams suggest predator and alternate prey control, with a heavy emphasis on habitat protection, reclamation and restoration (ALT 2009; ACCGB 2008).

Management options identified by the Athabasca Landscape Planning Team focus on decreasing predation risk and restoring functional caribou habitat (ALT 2009) which include:

- establishing large (1,000's of km^2) Zone 1 areas (where caribou recovery is the priority) in portions of each planning area where functional habitat is recovered and predators/alternate prey are controlled;
- predator and alternate prey control for 100+ years, coordinated reclamation, and implemented enhanced best practices in Zone 2 areas (where all management options including footprint restrictions are implemented); and
- implementing cow-calf penning/predator/prey exclosures within only the Richardson Caribou Range.

Landscape plan recommendations from the West Central Alberta Planning Team (ACCGB 2008) are similar to those recommended by the ALT and include:

- policy alignment to effectively manage cumulative effects; acknowledging that caribou conservation and recovery should be considered at the outset of planning and not as a condition on approvals;
- adopting a concept of habitat intactness and establishing measures to reduce and manage industrial and other human caused footprint in intact areas;
- managing habitat and industrial/human footprint outside of the identified primary intact areas but within caribou range areas;
- reducing predation rates and managing alternate prey;
- adapting, realigning and/or developing government policy, regulations and procedures to reduce human and industrial footprint and to manage cumulative effects of all activities that impact caribou;
- developing detailed implementation plans for each population and range area; and
- implementing an adaptive management process.

Based on the above recommendations, implementation strategies were developed which include (ACCGB 2008):

- Conserving habitat intactness where it already exists and facilitating development of more contiguous primary intact areas while managing/reducing the industrial footprint in each range to a level that will not compromise caribou recovery. However, if a reduction in industrial footprint is absolutely necessary to achieve caribou conservation, the Alberta government, industry and the public must be aware of the socio-economic implications (ACCGB 2008). Alternatively, should species recovery and conservation goals not be met, a new host of socio-economic implications will emerge (ACCGB 2008).
- A long term predator/prey control program within and potentially adjacent to caribou range.
- Policy Alignment between the different ministries.

The ALT recognized that moving forward with the above management options will face challenges (ALT 2009) including:

- establishing legislated boundaries and management guidelines for Zone 1 areas;
- conducting landscape scale reclamation programs which must be coordinated among multiple stakeholders;
- aggregating the decision making process from individual government departments into one integrated cross government strategy;
- the consultation and engagement of stakeholders; and
- building the awareness of the decision makers, land users and general public to maintain social and financial support for the required management actions, research, and monitoring over the long term.

Finally, the ALT concluded that tough choices need to be made between the management, social/economic and intergovernmental imperatives to recover and conserve boreal caribou and plans for ongoing bitumen development and industrial land-use. A comprehensive suite of management strategies (as outlined above) will need to be applied together to achieve desired caribou conservation objectives.

APPENDIX B

Restoration Table

Table B-1: Habitat Restoration Methods Best Suited for Caribou Areas (modified from Golder 2014b)

Type of Mitigation Prescription	Objective(s)	Specifications	Comments	References
Minimum disturbance construction	• erosion control • reduce line-of-sight • facilitate rapid natural revegetation of native vegetation • maintain natural drainage	• Grubbing on the right-of-way (RoW) is restricted to the trench width, allowing the integrity of the root layer to be maintained on the majority of the RoW, and allowing rapid recovery of herbaceous and deciduous woody vegetation species. Snow padding or matting on work areas of the right-of-way can be used to avoid the need for grubbing, and protect shrubs and small trees.	• Construction during winter conditions reduces the need for soil salvage and grading, and the width of grubbing is limited to the trench area. • Reduced disturbance to vegetation and root systems by cutting, mowing or walking down shrubs and small diameter trees at ground level facilitates rapid regeneration of vegetation. • Use of snow padding or matting in select locations limits the need for cutting or mowing shrubs and small trees, and facilitates regeneratioin of native vegetation.	NGTL 2014
Mechanical site preparation: Mounding and/or ripping using an excavator	• Create microsites in areas where it is deemed to be effective for enhanced survival and growth of planted seed and seedlings, and natural regrowth of woody species • Access control	• For access control purposes, mounds should be created using an excavator. Mounds should generally be approx. 0.75 m deep, if feasible. The excavated material is positioned right beside the hole. • Ripping should focus on moist to dry sites and areas were soil compaction is a concern. • Troughs created by ripping should be positioned to reduce erosion potential. • Target density of mounding for access control and/or microsite creation purposes can vary from 1,200 to 2,000 mounds / hectare (ha). • Seedlings are planted near the hinge of the mound: o Slightly higher up from the hinge for lowland and transitional sites o At or slightly lower than the hinge for upland sites	• For the purposes of enhancing microsites for planted seedlings, mounding is a well-researched and popular site preparation technique in the silviculture industry. It is commonly used in wetter, low-lying areas to create higher, better-drained microsites for seedlings. • Mounding treed fen and bog areas can enhance a site to promote natural revegetation over time, as higher, drier spots are created that seed can eventually settle into and germinate. • Mounding has been used as an access control measure on decommissioned roads and seismic lines to discourage off-road vehicle activity. It is effective immediately following implementation. • Ripping is a standard site preparation method that has been modified for tighter workspaces. • Mounding rakes or buckets can be used. Mounds will settle and may fracture, plant seedlings deeper to account for fracturing. • Compress mounds to eliminate air space.	• Macadam and Bedford 1998 • Roy *et al.* 1999 • MacIsaac *et al.* 2004 • Golder 2010 • OSLI 2012a, 2012b • Nexen 2013 • CRRP 2007c • Archuleta and Baxter 2008 • USDA 2009 • BC Ministry of Forests and Range 2014 • BC Forest Service 1998 • BC Ministry of Forests 2000 • BC Ministry of Forests and Range 1998 • COSIA 2014
Tree/shrub seedling planting	• access control • erosion control • reduce line-of-sight • restore habitat	• Tree/shrub species are determined based on site conditions, the adjacent forest stand and restoration objectives (e.g., low palatability for ungulates). Coniferous tree species are recommended to meet caribou habitat needs. Considerations for the use of shrubs: • Alder is generally planted because it forms an effective access control and line of sight break in a relatively quick period of time; • Alder has a similar palatability rating for ungulates as conifer species (CRRP 2007c) • Willow is avoided due to the high palatability rating for ungulates (CRRP 2007c) • Shrub and tree seedlings are often planted together, depending on site conditions and anticipated natural revegetation of both species. • Seedlings are generally planted after July 15, which is after the end of the Restricted Activity Period for caribou • Seedlings can be planted frozen at lowland sites in the winter (OSLI 2012b)	• Seedling planting is considered a long-term restoration treatment due to the length of time it takes to establish effective hiding cover and access deterrents. • Seedlings are ideally sourced at least six months prior to planned planting dates. • Seedlings and/or seed for growing seedlings may not be available for every species prescribed and therefore seed may need to be collected and grown in the nursery. • Seedling planting during winter is generally restricted to lowland sites with organic soil that have been treated with mechanical site preparation. • Need to consider planting temperatures and storage conditions/temperatures. • Pine roots hardy to -15^{0}C, stems hardy to -40^{0}C. • Black spruce seedlings have been successfully planted in February at -25^{0}C on mounds (95% survival)	• AENV 2010, 2011 • CRRP 2007c • DES 2004 • Golder 2005, 2010, 2012a, 2012c • OSLI 2012a, 2012b • Nexen 2013 • Vinge 2013b • Smit-Spinks et al. 1985 • Sutinen et al. 1998
Spreading of woody debris	• control of human access during snow free periods • erosion control, particularly along steep slopes • protect planted seedlings from extreme weather, wildlife trampling, and damage from ATVs (human access) • provide site nutrients when the debris decomposes • provide microsites for natural seed ingress	• Spread debris evenly across the entire corridor or polygon feature. • Ensure debris is consistently dense enough on the ground to discourage ATV use. • Osko and Glasgow (2010) recommend loads do not exceed 400 tonnes/ha. • Vinge and Pyper recommend to apply between 60 to 100 m^3/ha of woody material to reclaimed sites to mimic the natural range of variability for woody debris in the forest. • Locations where spreading woody debris is considered effective include on each side of an intersection with a linear feature that is currently in use. • Implement at sites left for natural recovery when debris is available as well as sites that are planted with seedlings.	• The length of a treated segment is dependent on sufficient quantities of debris available. Longer segments are a more effective treatment at controlling human access since ATV riders will be less inclined to try to ride through the debris or traverse around it in adjacent forest stands if the debris continues for an extended distance. • Woody debris can also conserve soil moisture, moderate soil temperatures, provide nutrients after it decomposes, prevent soil erosion, provide a source of seed for natural revegetation, provide microsites for seed germination and protection for introduced tree seedlings, and protect seedlings from wildlife trampling and browsing. • Spreading of woody debris is effective as an access control immediately following implementation. • Woody debris can be brought to a site from another location that has identical tree species.	• CRRP 2007c • Enbridge 2010 • Osko and Glasgow 2010 • Golder 2010, 2012a • CEMA 2012 • Government of Alberta and Alberta Regulator 2013 • OSLI 2012a, 2012b • Nexen 2013 • Pyper and Vinge 2012 • Vinge and Pyper 2012

Table B-1: Habitat Restoration Methods Best Suited for Caribou Areas (modified from Golder 2014b)

Type of Mitigation Prescription	Objective(s)	Specifications	Comments	References
Berms	• access control • reduce line-of-sight • create microsites and protection for natural seed ingress and vegetation growth	• Berms may be constructed of slash and timbers, or a combination of slash and earth. Supported berms are constructed using timber cleared from the RoW. • Construct berms to an approximate height of 2 m. • Promote rapid shrub/tree regeneration at ends of berms (e.g., bio-engineering, seedling planting) to increase effectiveness as access control.	• Feasibility of slash/timber berms is dependent on approval from provincial authorities to retain and pile slash onsite, and retention of sufficient quantities of slash onsite during construction. • Availability of source material is unlikely sufficient for earth berm construction in areas where minimal disturbance construction techniques are employed. • Earth berms should not be located in peatlands to avoid potential for settling and alteration of surface hydrology. Berms are effective immediately following implementation.	• TERA 2011 • Westland Resource Group 2011
Bending or felling trees	• access control • reduce line-of-sight • reduce shade effect	• Bend mature trees partially across the line with the excavator while treating the features for woody debris or mounding purposes. • Fell mature trees across the line on upland and transitional sites by hand-cutting with a chainsaw or pushing over with an excavator. • Can be done every 25 m or in patches on lowland sites. • Two or more trees can be cut at one spot, from opposite sides of the corridor, to create an access control and line of site break on upland sites • Can be implemented every 25 m along the corridor, where sufficient sized timber is present.	• Hinging and felling trees across the line is mimicking natural processes that occur in the forest. • Felling trees across the corridor can reduce the shade effect, leading to more sunlight and warmer soils, creating an enhanced environment for plant growth.	• Cody 2013 • CRRP 2007b • Neufeld 2006 • Cenovus 2013 • Golder 2014a
Installing wooden fences	• access control • reduce line-of-sight	• Fences can be installed at intersections with linear corridors and/or along a corridor where line-of-sight breaks are required. • Create fences from untreated timber that will decompose overtime.	• Fences could also be established using poles and geotextile matting. Regulator approval would be necessary. • Consideration needs to be taken for fence location, accessibility, installment.	• CRRP 2007a • Golder 2014a

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For more information, visit golder.com

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 44 1628 851851
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Ltd.
102, 2535 - 3rd Avenue S.E.
Calgary, Alberta, T2A 7W5
Canada
T: +1 (403) 299 5600

Golder Associates