Expert report on woodland caribou [*Rangifer tarandus caribou*] in the Traditional Territory of the Beaver Lake Cree Nation

July 5, 2010

Dr. Stan Boutin PhD, FRSC

Acronyms

ACC – Alberta Caribou Committee

ALT – Athabasca Landscape Team

ASRD – Alberta Sustainable Resource Development

CLAWR – Cold Lake Air Weapons Range

COSEWIC – Committee on the Status of Endangered Wildlife in Canada. URL: http://www.cosewic.gc.ca [Updated April 2006].

EC – Environment Canada

ESAR – East Side of Athabasca River

RE – Red Earth

SARA – Species at Risk Act, Statutes of Canada 2002, chapter 29

TT – Beaver Lake Cree Nation's Traditional Territory in Alberta, as taken from the map included in Figure 1 of this report

WSAR – West Side of the Athabasca River

Definitions

Critical Habitat*:* The resources and conditions required for persistence of local populations of boreal caribou throughout their current distribution in Canada. The quantity, quality and spatial configuration of resources and conditions may be influenced by both natural and human-induced conditions (from EC 2008).

Ecotypes*:* forms of a given species with characteristic adaptations.

Habitat: The suite of resources (food, shelter) and environmental conditions (abiotic variables such as temperature and biotic variables such as competitors and predators) that determine the presence, survival and reproduction of a population (Caughley and Gunn 1996). (from EC 2008).

Home range*:* The area covered by an individual during its reproductive life-time.

Local Population: A group of caribou occupying a defined area that can be distinguished spatially from areas occupied by other groups of caribou. Local populations experience limited exchange of individuals with other groups, such that population dynamics are driven by local factors affecting birth and death rates, rather than immigration or emigration among groups (from EC 2008).

Lambda*:* Population growth expressed as population recruitment/survival expressed on a yearly basis. Values <1 signify the population has decreased from one year to the next while values >1 signify population increase. Details of calculations can be found in Appendix 1.

Range: A geographic area occupied by individuals of a local population that are subjected to the same influences affecting vital rates over a defined time frame (see Appendix 4.2: Delineating Units of Analysis for Boreal Caribou Critical Habitat Identification, EC 2008).

Realized Population Growth*:* Changes in population size determined by multiplying year lambda values together. Details of calculations can be found in Appendix 1.

Assumptions

I have assumed that the Traditional Territory of the Beaver Lake Cree Nation in Alberta is the area set out in the map included in Figure 1 of this report (I do not render any opinion about whether this map accurately reflects the Beaver Lake Cree Nation's Traditional Territory in Alberta).

Author's statement

The opinions in this report are my own. While some portions of the report involving GIS mapping and data summaries (Appendix 3) were prepared by others under my supervision, I am responsible for the entire contents of the report as the sole author.

I certify that I am aware of my duty as an expert witness to assist the court and not be an advocate for any party. I further certify that I have made this report in conformity with this duty and will, if called on to give oral or written testimony, give that testimony in conformity with this duty.

Dr. Stan Boutin PhD, FRSC

Summary

Caribou inhabiting the TT are classified as the boreal ecotype of the woodland subspecies (*Rangifer tarandus caribou).* All woodland caribou in Alberta have been designated as *Threatened* by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2007), and also listed as *Threatened* under Canada's *Species at Risk Act* (SARA). Under the Government of Alberta general wildlife status process, woodland caribou have been determined to be an *At Risk* species in the province (Alberta Sustainable Resource Development 2007). The provincial wildlife status review process resulted in woodland caribou receiving legal status as a *Threatened* species under Alberta's *Wildlife Act* in 2001.

Woodland caribou in the TT are estimated to number between 175 and 275. This is down 10-fold from historical numbers. Recent systematic monitoring indicates that numbers have been declining. The ESAR herd has declined by 71% since 1996 while the CLAWR has declined 74% since 1998. This level of decline is dramatic and it is a strong signal that drastic immediate management action is required to keep caribou from disappearing completely in the TT. If current rates of decline continue, this population will drop below 50 individuals (the number of individuals below which small populations are vulnerable to extinction events and at extreme risk of extirpation) by 2025-2030. The current rate of population decline is likely to increase over the next decade if human-caused habitat change continues to increase, further reducing the time to extirpation.

The ultimate cause of the decline is human-caused changes in vegetation and the creation of linear features such as seismic lines, pipelines, and roads. These changes can result in physical loss of habitat, avoidance of areas by woodland caribou, and increased caribou mortality as a result of population increases of moose and deer and wolves. The primary changes that have occurred in the TT on or near caribou range include agricultural development to the south of caribou range, forest harvesting (107,998 ha cut or 2.8% of the range in TT), energy sector development (34,773 wells, 66,489 km of seismic lines, 11,591 km of pipelines), and 12,283 km of roads associated with this activity. Given that the creation of linear features due to energy sector development is the most prominent human-caused habitat change in caribou range in the TT, it is likely that these changes are the primary contributor to the declines in caribou seen in the TT. Extensive oil and gas deposits underlie most caribou ranges in Alberta and very high levels of petroleum and natural gas exploration and development have taken place on most of Alberta's caribou ranges including the caribou range within the TT. The majority of the well sites, seismic lines, and pipelines created by the energy sector remain in place on caribou range because of continued industrial use, slow forest regeneration, and/or high levels of recreational vehicle use. All of these human-caused changes have decreased the quality and quantity of caribou habitat in the TT by reducing lichen cover, enhancing habitat for moose and deer which

has led to increased numbers of predators, and increasing access to caribou habitat by predators. There are 20,005 km of linear features on caribou range in the TT. Caribou are known to avoid habitat within 250m of these features. If all linear features are buffered within caribou range in the TT, 51% of CLAWR and 66% of ESAR caribou ranges in the TT would be functionally lost.

There is clear evidence that the human-caused changes in vegetation on caribou range in the TT are well above any threshold that could support viable caribou populations. Population declines in recent years have been drastic and recovery of caribou in the TT requires immediate action involving restoration of linear features, well sites, and cut blocks to natural vegetation, no further habitat change caused by human land use (full protection of caribou range), and caribou mortality management. It is clear that the history of planning and mitigation of activities at local project scales has not worked to protect caribou. The cumulative effects of many individual projects have led to total industrial activity exceeding the levels that can support viable caribou herds in the TT and surrounding area.

The information necessary to act to conserve caribou has been available for the past 3-5 years but there has been no action undertaken on the ground to date. The identification of critical habitat and development of a recovery strategy are fundamental steps in the conservation of any species, including caribou (see also the Federal SARA). No National Recovery Strategy has been produced for caribou, partially due to a purported claim that Critical Habitat has not yet been identified (EC 2008). In my opinion, the scientific information provided in EC (2008) was fully adequate to identify caribou Critical Habitat. This opinion was also held by the Scientific Advisory Group (of which I was a member) involved in drafting of the document.

Any delays in the implementation of conservation actions for caribou greatly increase the risk of failure (ALT 2009). Given the rapid rates of decline that are now well-documented for the herds in the TT, the number of animals left is fast approaching levels where management actions are less and less likely to be effective. It is my opinion that caribou will be extirpated from the TT, most of northeastern Alberta, and in many other parts of Canada if the conservation actions outlined in this report are not implemented immediately.

Table of Contents

Woodland caribou in the TT

All woodland caribou in Alberta belong to either the nationally defined Boreal or Southern Mountain populations, both of which have been designated as *Threatened* by the COSEWIC (COSEWIC 2007), and also listed as *Threatened* under Canada's *Species at Risk Act* (SARA).

Under the Government of Alberta general wildlife status process, woodland caribou have been determined to be an *At Risk* species in the province (Alberta Sustainable Resource Development 2007). The provincial wildlife status review process resulted in woodland caribou receiving legal status as a *Threatened* species under Alberta's *Wildlife Act* in 2001.

Ecotypes (forms of a given species with characteristic adaptations) are frequently used in the description of caribou (Edmonds 1991, Thomas and Gray 2002). Woodland caribou that live year-round in forested habitat are of the boreal ecotype.

Caribou inhabiting the TT are classified as the boreal ecotype of the woodland subspecies (*Rangifer tarandus caribou).* Throughout this document this ecotype will simply be referred to as "caribou".

General habitat needs

The basic habitat of caribou must provide adequate food and protection from predation. Lichen is the major winter food source and it is considered to be the food most influential to caribou habitat delineation. Caribou require large tracts of low productivity mature to old coniferous forests or forested peatlands that contain lichens. These tracts must be large (caribou herd ranges are 3,000-18,000 km^2 and individual caribou home ranges are 700 km^2) and there must be relatively low productivity of ground vegetation (shrubs, herbs, and grasses) to prevent their use by other ungulate species such as moose and white-tailed deer. The latter is important because abundant deer and moose support higher numbers of wolves. High wolf densities make areas uninhabitable for caribou because predator-caused mortality becomes too high. The current suggested threshold for wolf densities is 6.5 wolves/1000 km^2 with wolf densities above this target meaning that caribou populations will decline because caribou productivity cannot match the mortality rates caused by predators (Bergerud and Elliot 1986).

There are three recent comprehensive reviews of caribou habitat requirements and all have produced similar conclusions to the above. The most thorough review can be found in EC (2008) which states:

> In general, suitable boreal caribou habitat is characterized by large tracts of mature to old conifer forests with abundant lichens, or peatlands intermixed with uplands

> dominated by mature to old conifers (Darby and Pruitt 1984; Brown *et al.* 1986; Bradshaw *et al.* 1995; Stuart-Smith *et al.* 1997; Rettie and Messier 2000; Courtois 2003). However, there is variability among regions in vegetation types used.
>
> Boreal caribou have distinct habitat requirements at different spatial and temporal scales (Rettie and Messier 2000, Johnson *et al.* 2001, O'Brien and Manseau 2003).... Coarser scales encompass large areas (e.g. ranges) and broad time frames (e.g. seasons, years and decades), whereas finer scales cover small areas (e.g. forest stands or habitat patches) and narrow time frames (e.g. hours and days). Boreal caribou [appear to] select habitat to avoid predation at coarser scales (Bergerud 1988; Johnson *et al.* 2001) and then select habitat to meet forage requirements at finer scales (Schaefer and Pruitt 1991; Rettie and Messier 2000).
>
> At coarser scales, boreal caribou local populations require large range areas that contain sufficient suitable habitat and reduce predation by allowing caribou to avoid areas of high predation risk (Rettie and Messier 2001; Brown *et al.* 2003). At finer scales, boreal caribou select individual habitat patches (within ranges) that provide food, particularly ground and tree lichens during late winter and early spring, and they avoid early stage seral forests and recently disturbed areas (Schaefer and Pruitt 1991; Stuart-Smith *et al.* 1997; Rettie and Messier 2000). Although forest fire destroys lichens and other vegetation in the short term, it is an important factor in regenerating caribou forage over long time scales (Dunford 2003)....
>
> In general, boreal caribou require habitats that provide necessary functional attributes (the conditions and resources which provide for all of their life requirements), including physiological health, dispersal of cows during calving and post-calving periods, and refuge from predation.

EC (2008) defined woodland caribou critical habitat as: "the resources and environmental conditions required for persistence of local populations of woodland caribou throughout their current distribution in Canada", and added:

> local population range is the relevant spatial scale for identification of critical habitat conditions that includes the habitat conditions (quantity, quality, spatial configuration) required for caribou.

Similar statements can be found in ALT (2009) and in ASRD (2010). For example, ASRD (2010) states that:

> Woodland caribou require large tracts of relatively low-productivity mature to old coniferous forests and forested peat lands, which contain lichens, the primary winter food source for caribou. Under natural conditions, the forests used by woodland caribou typically contain relatively few other ungulates and as a result contain few wolves; predation by wolves is the primary cause of woodland caribou death. Through

their adaptation to these types of habitats, under natural conditions woodland caribou are able to spatially separate themselves from other prey species and thereby reduce the risk of predation by wolves.

Although the proximate cause of caribou mortality has always likely been predation, under historical conditions, predator-caused mortality was sufficiently low to allow cows to produce enough calves that survived to adulthood to allow for replacement of adults, thus leading to stable populations.

There have been no published studies of habitat use by caribou occupying the TT but there have been numerous studies on adjacent herds (WSAR and RE). These include Bradshaw *et al.* 1995, Stuart-Smith *et al.* 1997, Anderson 1999, James *et al.* 2004, Dunford *et al.* 2006, Latham 2009). These studies were conducted in areas that have very similar conditions to those found in the TT and they reinforce the general finding that caribou are found in mature to old conifer or forested peatlands and they avoid shrub-rich habitats (often termed uplands in the woodland caribou literature) that support higher densities of moose and deer.

Caribou habitat and ranges in the TT

The TT contains important caribou habitat as delineated by Provincial Government caribou range maps (Fig. 1, boundaries provided by ASRD staff 19 January, 2010). As outlined in EC (2008), the herd range is the accepted unit of analysis for caribou population viability and conservation.

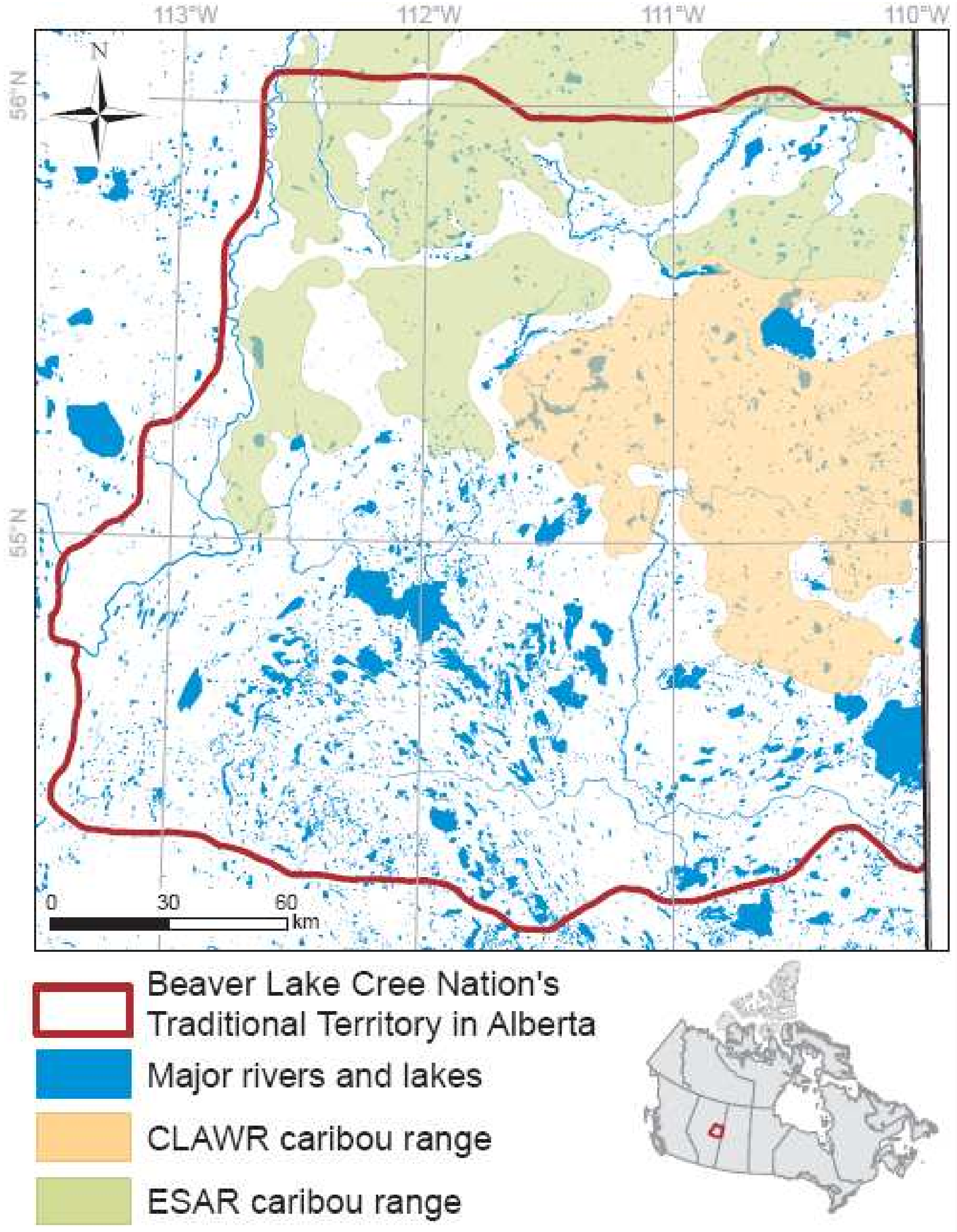

Figure 1. Caribou ranges within the Beaver Lake Cree Nation's Traditional Territory in Alberta (boundaries of Traditional Territory are taken from Schedule 1 to the Amended Statement of Claim, filed 23 October 2009, for Alberta Court of Queen's Bench Action No. 0803 06718). Caribou range boundaries provided by ASRD staff 19 January 2010.

Two (ESAR, CLAWR) of the 12 designated boreal ecotype woodland caribou herds in Alberta have 52% and 100% respectively, of their current ranges within the TT. ESAR extends north of the TT while the northern CLAWR boundary is jurisdictional (Federal Cold Lake Air Weapons Range) rather than biological and there is likely exchange of animals between the ESAR and CLAWR herds. Both ESAR and CLAWR are bounded on the east by the Alberta-Saskatchewan border and there is likely exchange of animals across this border.

The range occurring within the TT represents 11% of the total boreal caribou range in the Province (13,294 of 115,608 km^2). The caribou range within the TT is important because it supports a significant proportion of the estimated total number of boreal caribou in Alberta (8-10% of the roughly 2265-2725 caribou thought to be currently present in the Province (ASRD 2010)); it comprises the southeastern boundary of caribou range in the province, and if compromised, would greatly increase the risk of extinction for the ESAR and CLAWR herds.

The current ESAR and CLAWR boundaries are based on caribou habitat (as defined above), telemetry locations of radio-collared animals, and sightings of caribou. These boundaries represent the best estimates by Provincial Government biologists and are those accepted by federal agencies and caribou researchers. The exact range boundaries are regularly updated as new information is obtained. Historical ranges are more difficult to determine, but Thomas and Gray (1992) show the historical southern distribution of caribou to be well south of their current distribution. There is widespread agreement that the southern distribution of caribou has moved northward in the last 30-50 years. Hummel and Ray (2008) suggest that as much as 60% of historical woodland caribou range in Alberta has disappeared. ASRD (2010) states:

> The current distribution of woodland caribou in Alberta has declined relative to its historical distribution. Although a detailed description of historical caribou distribution in northern Alberta is not available, Soper (1964) described the former range of woodland caribou in the northern part of the province as the "whole of northern Alberta south to the lower limits of mixed-wood forest (approximately Cold Lake; Lac la Biche; Barrhead) and south in comparable, western environment to about the latitude of Sundre; now absent in the major part of that region.

Although one cannot be certain of the exact amount of range contraction, I support the conclusion that caribou range contraction has taken place in the TT.

Changes in habitat condition in recent times

Quoting from ASRD (2010):

> Habitat change as a result of human activities can result in both physical loss of habitat and avoidance of areas by woodland caribou (e.g., Smith *et al*. 2000, Dyer *et al*. 2001, Oberg 2002). It can also cause increased caribou mortality as a result of population increases in other ungulate prey species and wolves (Bowman *et al.* 2010), and increased predator travel efficiency and hunting success (James 1999, James and Stuart-Smith 2000).The primary anthropogenic disturbances to woodland caribou habitat in Alberta are due to oil and gas exploration and development, forest harvesting, peat mining, agricultural development, and the development of linear features (e.g., roads, pipelines, seismic lines) associated with these activities.

Based on the above and similar conclusions in EC (2008) and ALT (2009), I conclude that the quality of the ESAR and CLAWR caribou range in and around the TT has declined relative to historical conditions. Any human-caused vegetation change which is favourable for moose or deer is detrimental to caribou. The primary changes that have occurred in the TT on or near caribou range include:

1) agricultural development to the south of caribou range
2) forest harvesting (107,998 ha cut or 2.8% of the range in TT)
3) energy sector development (34,773 wells, 66,489 km of seismic lines, 11,591 km of pipelines), and
4) 12,283 km of roads associated with this activity.

Data sources for these figures can be found in Appendix 3. All of these changes have decreased the quality and quantity of caribou habitat in the TT by reducing lichen cover and enhancing habitat for moose and deer which has led to increased predator densities. These habitat changes are the root cause of a proximate increase in predation risk to caribou. Each of these aspects will be discussed in detail when limiting factors are considered.

Historical and current caribou densities

Most density estimates of boreal woodland caribou are considered "best guesses" because methods to count caribou accurately are unproven and costly. Estimates from ASRD (2010) include values of 150-250 for ESAR and 100-150 for CLAWR. Given that all of the CLAWR and roughly half of the ESAR are in the TT, the current estimate of caribou within the TT is 175-275 animals.

Historical estimates of population size do not exist but estimates based on a range capacity of 3.3 caribou per 100 km^2 (Thomas and Gray 1992, ALT 2009) would put the potential number of caribou in the TT at 1286 animals, roughly 10 times higher than current values. The difference between current and historic numbers of caribou in the TT is likely to be greater than outlined above, given that the actual area occupied by caribou in the TT has shrunk relative to historical conditions.

Population trend and risk of extirpation

Although it is not possible to get accurate estimates of population size it is possible to measure population trend (lambda and realized population growth) through systematic monitoring. Details of the methods employed can be found in Appendix 1. In general, the technique involves assessing adult female survival through the use of radio telemetry and measuring calf recruitment through the ratio of calves per cow as obtained through aerial surveys in February-March. This methodology has been used for the ESAR herd since 1996 and for the CLAWR herd since 1998. Adult survival and calf recruitment are combined to determine the finite rate of increase (termed lambda). A lambda of 1 means the population is stable from one year to the next whereas <1 means the population is declining and >1 means the population is increasing. When yearly estimates of lambda are multiplied together one can calculate the realized population change (Fig 2a,b). By these calculations the ESAR herd has declined by 71% since 1996 while the CLAWR has declined 74% since 1998. Given the sample data used in the calculation, it is possible that the population declines could be as low as 50% or as high as 90%. Although there is uncertainty around the exact rate of population decline given the available data, there is high certainty that both the ESAR and CLAWR herds have declined since detailed monitoring began in 1996 and 1998. This level of decline is dramatic and it is a strong signal that drastic immediate management action is required to keep caribou from disappearing completely in the TT.

Figure. 2a.

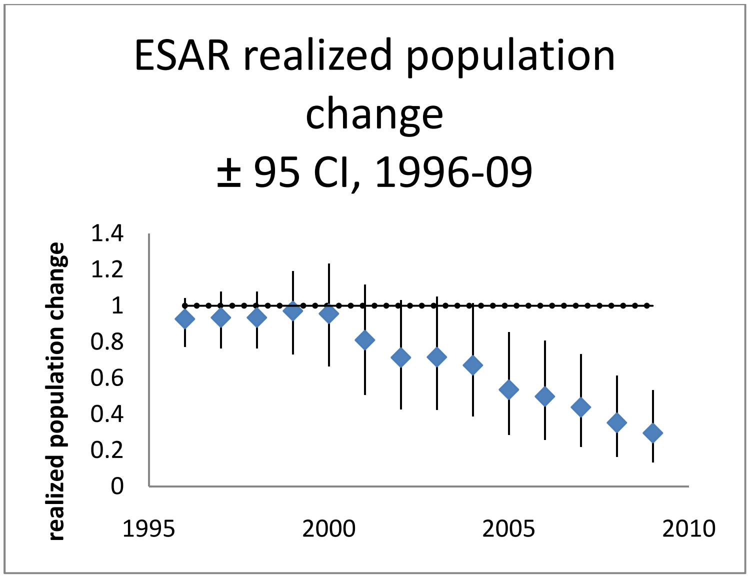

Figure 2b.

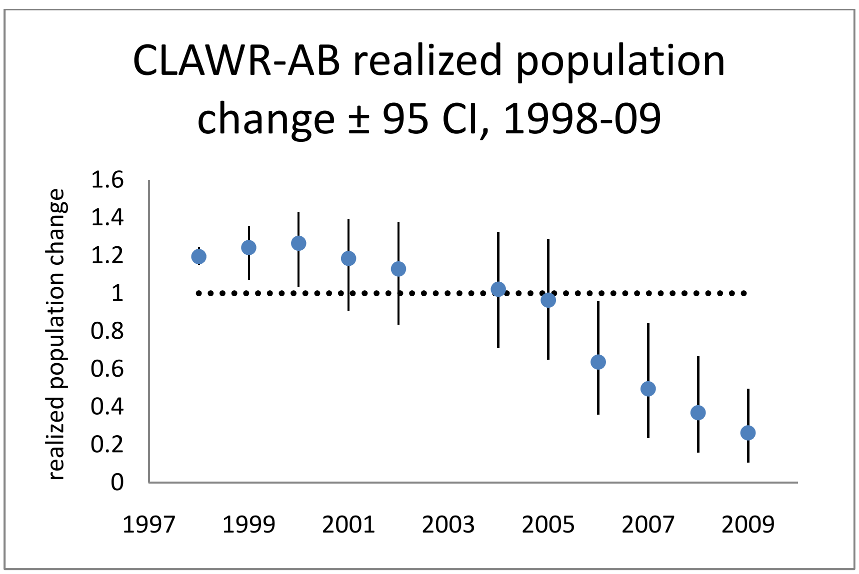

Figure 2. Realized population change for ESAR (a) and CLAWR (b). See Appendix 1 for methods and definitions.

Caribou herds immediately adjacent to the TT show similar population trends. WSAR, directly west of the TT has declined by 66% since 1996 levels while RE (northwest of TT) has declined by 74% from 1995 levels. The Richardson herd, located north of the TT, is considered stable at present but monitoring has been done for the past 3 years only.

It is difficult to determine the actual time to extinction for a population because small populations (<50 individuals) are subject to potential rapid extinction due to chance events. As a guideline for calculating when populations are at high risk of extinction EC (2008) states:

> Therefore, the population assessment component of critical habitat identification recognizes that very small populations (<50) are vulnerable to stochastic events and phenomena, resulting in an especially low probability of persistence, whereas local populations of >50 but <300 caribou are less vulnerable but still face risks, and populations greater than 300 can persist indefinitely when range conditions support average adult female and calf survival.

Two independent assessments of the risk of extirpation for the caribou in ESAR and CLAWR (EC 2008, ALT 2009) rated these herds as having a high risk of extirpation in the absence of management intervention; I support these assessments. If the populations in the TT were to continue to decline at the rates seen since systematic monitoring began and current population size is taken as 175-275 individuals, the population would reach 50 individuals by 2025-30 and 10 individuals by 2041-46. The current rate of population decline is likely to increase over the next decade if human-caused habitat change continues to increase, further reducing the time to extirpation.

Causes of population decline

Early studies suggested that the direct loss of habitat could be a major limiting factor for caribou populations (Edwards 1954, Bloomfield 1980), but Bergerud (1974) proposed that it was not the loss or alteration of habitat that caused the decline and range recession of caribou in many areas of North America, but rather the secondary effects associated with increased predation. This latter view is now embodied in the concept that human-caused habitat changes ultimately affect caribou populations by affecting habitat use, movements and the abundance of predators and alternate prey. This results in increased predation on caribou which becomes the proximate factor for declining caribou populations in the presence of industrial activity (McLoughlin *et al*. 2003, Bowman *et al.* 2010). I strongly support this view, as do many other scientists (EC 2008, ALT 2009, ASRD 2010, Festa-Bianchet *et al.* 2010).

Human-caused habitat change can affect the vulnerability of caribou to predation in the following ways:

1) by altering vegetation through agriculture, forest cutting, and the creation of well-sites and linear features leading to an increase in the density of other prey species which in turn, increases wolf density

2) by creating linear features (seismic lines, pipelines, roads) that increase hunting efficiency and penetration by wolves into caribou range, and

3) by both of the above, leading to a reduction in large, intact patches of habitat where caribou can space themselves out and away from other ungulates and wolves.

Predation (primarily by wolves) is the main proximate limiting factor for woodland caribou throughout Alberta and Canada (Bergerud 1974, 1988, 1992, Bergerud and Elliot 1986, Rettie and Messier 1998, Schaefer *et al*. 1999, Thomas and Gray 2002, McLoughlin *et al*. 2003, Wittmer *et al*. 2005a, 2005b, Courtois *et al*. 2007, Festa-Bianchet *et al.* 2010). Woodland caribou that are able to spatially separate themselves from other ungulates and wolves are less susceptible to predation (Bergerud and Page 1987, Seip 1992, James *et al.* 2004, Latham 2009). Boreal caribou normally exist at low densities in very large range areas that contain lower densities of alternate prey and hence lower densities of predators. Boreal caribou in and around the TT select fen/bog complexes whereas moose, deer and wolves select well-drained habitat, resulting in spatial separation (James *et al*. 2004, Latham 2009). In winter, predation pressure and risk were found to be higher in well-drained upland habitat than in fen/bog complexes in the WSAR (McLoughlin *et al*. 2005, James *et al*. 2004).

Small changes in predation pressure can trigger caribou population declines (e.g., Wittmer *et al*. 2005b, 2007) and the availability of other prey species means that wolves have the potential to extirpate caribou herds because there is no negative feedback effect on their own populations (i.e., apparent competition; Edmonds 1988, Holt and Lawton 1994, Messier 1994, Cumming *et al*. 1996, Rettie and Messier 2000, Mech and Boitani 2003, James *et al*. 2004, Wittmer *et al*. 2005b, Hebblewhite *et al*. 2007).

If wolves reach a density of >6.5 wolves/1000 km^2, caribou populations are expected to decline (Bergerud and Elliot 1986). Recent surveys suggest that the wolf density estimates are now 10-11/1000 km^2 in the ESAR and CLAWR (Latham 2009, ALT 2009).

I will now address the potential effects of the human activities that are the ultimate cause of changes in caribou numbers in the TT.

Agriculture

The amount of agriculture in the TT is 7891.66 km^2 which is roughly 20% of the TT (based on the 2001 Agricultural census of Alberta). Forested areas near agriculture can be highly productive deer and moose habitat because wolf numbers are reduced in agricultural areas (predator refuge) and food supply is abundant (ALT 2009). These productive populations, in turn, increase populations in adjacent habitat which leads to higher wolf densities. Aerial surveys of moose and deer by Provincial Government personnel in Wildlife Management Units in the TT that contain agriculture suggest relatively high moose and deer densities (up to 36 moose and 203 deer per 100km^2, ALT 2009). Although wolf densities have not been measured in these areas it is likely that their densities are also high and this could increase predation pressure on caribou in adjacent caribou range.

Forest cutting

Habitat created following forest cutting tends to favour moose and deer and this effect can last up to 30 years (Rempel *et al.* 1997, Festa-Bianchet *et al.* 2010). Timber harvesting in black spruce/larch forests (caribou habitat) is generally not currently cost effective in Alberta. However, as with agriculture, cutting adjacent to or in uplands within peatlands, can increase moose, deer, and wolf densities. Although the magnitude of change will vary among caribou ranges, there is a strong theoretical and empirical basis for the relationship between timber harvesting in or near caribou range and its subsequent effects on predator-caribou dynamics (e.g. Seip 1992, Messier 1994, Cumming *et al*. 1996, James 1999, Vors *et al.* 2007, Bowman *et al.* 2010). In Ontario, Schaefer (2003) hypothesized that the northward recession of caribou was driven by the northward advancement of timber harvesting. This was supported by Vors *et al*. (2007), who determined that the probability of caribou persistence was negatively related to the presence of timber harvesting and Smith *et al.* (2000) found that caribou avoided cutblocks for up to 1 km away in west central Alberta.

The amount of forest cut in the last 30 years in the TT is 1080 km^2 which is roughly 3% of the TT. This is a relatively small change suggesting that forest harvesting has played a small role to date in the caribou population decline in the TT. Forest harvesting also creates roads, and this potentially negative effect will be addressed below.

Energy sector activities

Extensive oil and gas deposits underlie most caribou ranges in Alberta and very high levels of petroleum and natural gas exploration and development have taken place on most of Alberta's caribou ranges including the caribou range within the TT. The majority of the well sites, seismic lines, and pipelines created by the energy sector remain in place on caribou range because of continued industrial use, slow forest regeneration, and/or high levels of recreational vehicle use (Lee and Boutin 2006). Linear features may affect caribou populations by altering the movements and distribution of both predators and prey, and by providing easier access for predators to travel into caribou habitats and prey on caribou (James and Stuart-Smith 2000). Wolves have been found to occur closer to linear features than expected by chance and to use linear features as travel routes (Musiani *et al*. 1998, James 1999, James and Stuart-Smith 2000, Whittington *et al*. 2005, Neufeld 2006). These features may give wolves greater access into caribou range, especially to areas that weren't previously accessible. It also means that linear features are associated with high predation risk for caribou as a result of increased wolf-caribou encounters. James and Stuart-Smith (2000) found that caribou killed by wolves were closer to linear features than were locations of live caribou. Furthermore, wolf use of lines is associated with faster travel (James 1999), which could lead to increased wolf hunting efficiency and kill rates.

Boreal caribou in Alberta have also been documented to avoid roads, pipelines, seismic lines, and well sites. Caribou avoidance distances depend on season, and the type and age of the disturbance, but range from 0.1 to 1.2 km (Smith *et al*. 2000, Dyer *et al*. 2001, Oberg 2001). Dyer *et al*. (2002) determined that seismic lines were not barriers to caribou movements while roads with moderate vehicle traffic acted as semi-permeable barriers.

In the case of energy sector activities, functional habitat loss (as a result of caribou avoidance behaviours) is estimated to be much greater than direct habitat loss. For example, Dyer *et al*. (2001) estimated that during late winter in the WSAR, 1% of habitat was directly lost to anthropogenic disturbance (predominantly seismic lines) and 48% was functionally lost as a result of avoidance behaviour by caribou. This major increase in functional habitat loss arises when avoidance buffers are applied to each linear feature. Dyer *et al.* (2001) used a 250m buffer (caribou avoided habitat within 250m of a linear feature) and as a consequence, linear features that were only 5-8 m wide become 500m wide (see Fig. 3 for an example). The total km of linear features (seismic, pipelines) on caribou range in the TT is 20,005 km. If the 250m buffer suggested by Dyer *et al.* (2001) is implemented, 51% of CLAWR and 66% of ESAR in the TT would be functionally lost to caribou.

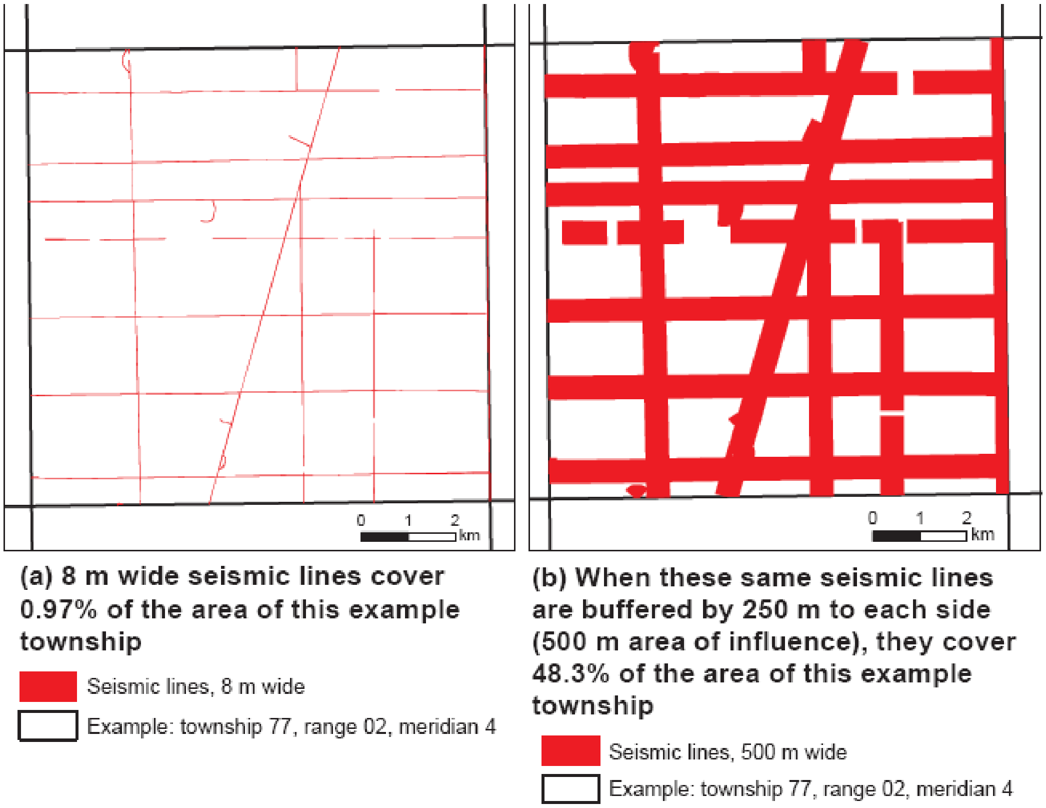

Figure 3. An example of how buffering of linear features can have large effects on the proportion of habitat affected.

The consequence of direct and indirect habitat loss is that caribou have less available habitat to space themselves away from other prey species and wolves, possibly resulting in effective increases in caribou density and predictability of distribution, and contributing to population declines because of increased susceptibility to predation. Compression of caribou populations into higher densities (e.g., Nellemann and Cameron 1998, Vistnes and Nellemann 2001, Nellemann *et al*. 2001) may make individual caribou easier for wolves to find (Smith *et al*. 2000, Dyer *et al*. 2001, 2002, Kuzyk *et al*. 2004). Studies to date for boreal caribou in northern Alberta have failed to demonstrate decreased home range size in response to anthropogenic disturbance (Tracz 2005, Tracz *et al*., in prep.; also see Dalerum *et al*. 2007).

Although the majority of pipelines are buried, some above-ground pipelines are constructed when Steam Assisted Gravity Drainage (SAGD) is the mode of oil extraction. Above-ground pipelines tend to be <0.8 m above ground and such lines act as barriers to caribou movement (Dunn and Quinn 2009). There is some scientific evidence that caribou will cross under piplelines >2.0 m above ground and above-ground pipeline crossings are also constructed at variable intervals as a mitigation technique. Although there are records (photographs) of caribou using these crossings, there is no evidence to indicate that such structures fully mitigate the barrier effect of above-ground pipelines. At present there are relatively few above-ground pipelines (< 50 km) in the TT but this amount will grow as SAGD extraction systems develop.

Sensory disturbance (e.g., noise and activity associated with industrial or recreational activities) may affect caribou by increased energetic expenditure and/or habitat avoidance. Caribou in northern Alberta that were exposed to simulated elements of seismic activity showed higher mean movement rates and linear displacement relative to control animals, but feeding patterns were not affected by the disturbance (Bradshaw *et al*. 1997, Bradshaw *et al*. 1998). Caribou behavioural responses (displacement/avoidance) have been demonstrated in oilfields in Alaska (Dau and Cameron 1986, Murphy and Curatolo 1987, Nellemann and Cameron 1996) but not in Alberta. Sensory disturbance is likely to have a much smaller effect on caribou survival and productivity compared to the effects of predation.

The number of well sites within caribou range in the TT is 11,111 with each well site being roughly 1 ha in size. Well sites represent a loss of habitat for caribou in winter because these sites would have no lichen present. In addition, Dyer *et al.* (2001) reported functional habitat loss around well sites (250m radius).

Roads

Although roads were found to act as semi-permeable barriers to caribou (Dyer *et al.* 2002) and they can lead to mortality through collisions, the greatest effect is likely to occur through the increased access they create for hunters. Licensed harvest of caribou has not been allowed in Alberta since 1981 but hunting by First Nations can still occur. Available data for some boreal ecotype caribou populations indicates that human hunting may account for at least 15% to 20% of mortality on radio collared adult caribou (ACC unpubl.). Improved access into caribou range as a result of an expanding network of linear corridors could lead to increased First Nations and illegal hunting of caribou.

Caribou range in the TT contains 948.31 km of roads. Although not insignificant, seismic lines and pipelines are likely more important in providing human and predator access to caribou range.

Hunting

There is no opportunity for a harvestable surplus of caribou in the TT given the low numbers of caribou currently present. In addition, reproductive rates of caribou are much lower than moose or deer, meaning that any harvest by humans would result in a population decline unless other sources of mortality (predator) were greatly reduced. Any level of hunting is not advisable until recovery has taken place.

Fire

Fire is the dominant natural factor shaping the boreal forest of Alberta (Rowe and Scotter 1973) and has important implications for caribou populations. In the short term, fire is detrimental to caribou habitat by removing lichens; however, in the long term, fire may be beneficial in some situations by removing competing vegetation and rejuvenating growing conditions for lichens that are declining in productivity (Scotter 1970, Klein 1982, Schaefer and Pruitt 1991, Thomas 1998). Terrestrial lichen abundance recovered 40 years after fire disturbance in peatlands in northern Alberta (Dunford *et al*. 2006), although caribou winter use of burned areas 60 years post-fire is generally low (Schaefer and Pruitt 1991, Thomas *et al*. 1998, Dalerum *et al*. 2007). In northern Alberta, boreal caribou did not change home range size or shift home ranges following fire, probably since initial home range sizes were large enough to provide adequate habitat and space for caribou even with fire disturbance (Dalerum *et al*. 2007). In general, woodland caribou have evolved in the presence of forest fires and have persisted in the boreal forest with the occurrence of this natural disturbance. However, I and several of my colleagues have raised concerns for the persistence of woodland caribou in relation to the combined effects of forest fire and the human-caused habitat changes listed above (e.g. Sorenson *et al*. 2008).

Twenty-nine to 35 percent of the caribou range within the TT has burned in the last 50 years.

Cumulative effects

It is difficult to apportion components of the caribou decline to different human land use changes and it may not be necessary to do so since the energy sector, forest cutting and roads tend to develop together. In other words, it is the combined disturbances that create the potential negative effects on caribou. Using data from Alberta woodland caribou populations, both Boutin and Arienti (2008) and Sorenson *et al*. (2008) demonstrated a negative relationship between the amount of linear features and young forest and caribou population growth rate. Sorenson *et al*. (2008) developed a 2 variable model which showed that the percentage of the caribou range within 250m of any linear feature and the percentage of the caribou range burned (burns in the last 50 years) had negative effects on lambda (rate of population change – described above). Similarly, Boutin and Arienti (2008), using updated information, determined that the density of linear features and the proportion of range covered by young forest (burns plus cut blocks in the last 30 years) were negatively correlated with caribou population growth (see Appendix 2). Both studies developed equations to describe the negative relationship between lambda and habitat alteration. According to these equations, given the linear feature density, percentage of young forest and percentage burned, the predicted lambda in the ranges is 0.88-0.89 for ESAR and 0.92-0.95 for CLAWR.

Given that the creation of linear features due to energy sector development is the most prominent human-caused habitat change in caribou range in the TT, it is likely that these changes are the primary contributor to the declines in caribou seen in the TT.

In other studies, female adult caribou survival was negatively associated with linear feature density in northern boreal caribou ranges (Dunford 2003) and with cut block and road density in west-central caribou ranges (Smith 2004). These results are consistent with research findings in other provinces. For example, in Québec, Courtois *et al*. (2007) found that caribou were more likely to die as the amount of disturbed habitat, from timber harvest and fire, increased in their range. In British Columbia, Wittmer *et al*. (2007) established that survival of female mountain caribou declined with the proportion of early and mid-seral stage forests within the home range; higher survival was associated with increasing proportion of older forests. Kinley and Apps (2001) also determined that adult survival was lower in British Columbia ranges with more young forest as a result of timber harvesting, higher road densities, and more fragmentation. More generally, Apps and McLellan (2006) suggested that the persistence of mountain caribou in British Columbia was linked to the presence of old forest and to their isolation from human presence, areas of high road density and motorized access.

It is difficult to tease apart the potential causes of decline in the TT but all indications are that human-caused habitat change is playing a significant role. The changes to habitat created by human activity predict a population lambda of 0.88-0.89 for ESAR and 0.92-0.95 for CLAWR. Observed average lambdas are .9135 for ESAR and .8935 for CLAWR. These values would suggest that population size will drop by half every 8-10 years.

Disease and parasites

There is no evidence that caribou declines in Alberta are linked to disease or parasites.

Weather and climate warming

There are some arguments in the literature that weather can affect caribou population dynamics by reducing energy intake through deep snow or icing limiting access to lichens or by increasing calf mortality through wet, cold conditions during calving. These situations have been documented for migratory and Peary caribou but not for woodland caribou (Festa-Bianchet *et al.* 2010). In most years, winter conditions in Alberta are not likely to negatively affect caribou condition, survival or reproduction. However, it is possible that in winters with above average snowfall and/or severe crusting, caribou condition, reproduction and survival might be compromised. There is no information to my knowledge to suggest that weather in recent years has been more severe for caribou in Alberta or in the TT.

Warming associated with global climate change may alter caribou population dynamics through increased frequency/severity of forest fires and forest insect outbreaks (such as mountain pine beetle although this is not applicable to the TT), changes to forage type/quality/abundance, changes in conditions that may favour caribou diseases and parasites, and altered predator-prey dynamics. For climate warming to affect caribou in the TT, the effects have to be immediate, given that human-caused habitat changes are likely to lead to extirpation in the next 20-40 years. Given this, the most likely effects of warming climate would involve an increase in fire frequency and most importantly, an increase in deer abundance. Latham (2009) and Charest (2005) showed that deer are expanding northward in northeastern Alberta to the point that they have reached densities capable of supporting wolf populations. The cause of the northward expansion remains unknown but there is growing support for both habitat change (discussed above) and less severe winters (Dawe unpubl.) being contributing factors.

There is no evidence to suggest that winter weather or climate conditions have made the TT less suitable for caribou.

Recommendations for restoration and maintenance of caribou in the TT

The ALT (2009) report summarizes the recommended actions for recovery of caribou in the ESAR and CLAWR. The report is based on extensive modeling work using the best available information for the region. I fully support their recommendations which include:

1. The time for management action is now.
2. A suite of management actions requiring hundreds of millions of dollars is necessary to recover caribou.
3. The suite of management actions must include: aggressive restoration of seismic lines, well pads and pipelines; no further increase in industrial activity (no further habitat change caused by human land use; full protection of caribou range); and reduction of caribou mortality risk.

The ALT (2009) recommends that caribou management be conducted at a landscape scale. Tough choices need to be made between caribou conservation and industrial development of oil reserves. It is clear that the history of planning and mitigation of activities at local project scales has not worked to protect caribou. The cumulative effects of many individual projects have led to total industrial activity exceeding the levels that can support viable caribou herds in the TT and surrounding area. Restoration, protection, and caribou mortality management need to be part of a broad land use planning framework that recognizes the trade-off between caribou conservation and industrial development. The ALT (2009) recommends that zones within caribou range be created where caribou mortality management, restoration, and protection are implemented. However, the smaller the proportion of the ranges that receives these management actions the lesser the effect will be on caribou population increase. It is more likely that recovery would be successful if the entire caribou range within the TT received all three management actions. Finally, long-term risk to caribou will be minimized if habitat restoration in the entire caribou range within the TT begins as soon as possible (ALT 2009).

Is there enough information available to act to conserve caribou?

Scientific knowledge concerning caribou habitat requirements, caribou status, and appropriate conservation actions has become available in the last 10 years and there was fully adequate knowledge to act in the last 3-5 years. This holds for the herds residing in the TT, northeastern Alberta, and the rest of Canada. Dzus (2001) reported most of the population trends and management concerns outlined here. Boreal caribou in Alberta were listed as Threatened under SARA in 2002 and a recovery plan was tabled in 2005 (ASRD 2005). Although the Provincial government developed a recovery strategy in 2004, no on the ground actions have been implemented to date with the exception of the Little Smoky Range in west-central Alberta.

The identification of critical habitat and development of a recovery strategy are fundamental steps in the conservation of any species, including caribou (see also the Federal SARA). No National Recovery Strategy has been produced for caribou, partially due to a purported claim that Critical Habitat has not yet been identified (EC 2008). In my opinion, the scientific information provided in EC (2008) was fully adequate to identify caribou Critical Habitat. This opinion was also held by the Scientific Advisory Group (of which I was a member) involved in drafting of the document. A 'preface' to the recent assessment EC (2008) hints at continued delay of the recovery strategy until 2011.

Neither the Provincial or Federal Governments have implemented any conservation-based land-use plans in the TT. The Lower Athabasca Regional Plan is currently under development but there are no explicit conservation strategies for woodland caribou. Recommendations made by ALT (2009) included the establishment of zone 1 areas within each caribou range that have caribou conservation as a priority. The management elements included caribou mortality management, restoration of current energy sector footprint and establishment of areas with no further industrial development. The location and size of these zones were not made explicit and to date, the Provincial Government has not acted to implement the ALT (2009) recommendations.

There is ample evidence to support the claim that any delays in the implementation of conservation actions for caribou greatly increase the risk of failure (ALT 2009). Given the rapid rates of decline that are now well-documented for the herds in the TT, the number of animals left is fast approaching levels where management actions are less and less likely to be effective. It is my opinion that caribou will be extirpated from the TT, most of northeastern Alberta, and in many other parts of Canada if the conservation actions outlined in this report are not implemented immediately.

Literature cited

ALT. 2009. Athabasca caribou landscape management options report. Prepared for the Alberta Caribou Committee, Edmonton, AB. 94pp.

ASRD. 2010. Alberta Sustainable Resource Development and Alberta Conservation Association. In prep. Status of the Woodland Caribou (*Rangifer tarandus caribou*) in Alberta: Update 2010. Alberta Sustainable Resource Development, Wildlife Status Report No. 30 (Update 2010), Edmonton, AB.

Alberta Sustainable Resource Development. 2007. The General Status of Alberta Wild Species 2005. URL: http://www.srd.gov.ab.ca/fishwildlife/wildspecies/index.htm [Updated January 2007].

Alberta Sustainable Resource Development (Alberta Woodland Caribou Recovery Team). 2005. Alberta woodland caribou recovery plan 2004/05 – 2013/14. Alberta Sustainable Resource development, Fish and Wildlife Division, Alberta Species at Risk Recovery Plan No. 4. Edmonton, AB. 48pp.

Anderson, R. B. 1999. Peatland habitat use and selection by woodland caribou (Rangifer tarandus caribou) in northern Alberta. M.Sc. Thesis, University of Alberta, Edmonton, AB. 59 pp.

Apps, C.D., and B.N. McLellan. 2006. Factors influencing the dispersion and fragmentation of endangered mountain caribou populations. Biological Conservation 130:84-97.

Bergerud, A. T. 1974. Decline of caribou in North America following settlement. J. Wildl. Manage. 38:757-70.

Bergerud, A. T. 1983. The natural population control of caribou. Pp. 14-61 in Symposium on natural regulation of wildlife populations. Proceedings of the northwest section, the Wildlife Society (F. L. Bunnell, D. S. Eastman, and J. M. Peek, eds.). Forest, Wildlife and Range Experiment Station, University of Idaho, Moscow, ID.

Bergerud, A. T. 1988. Caribou, wolves and man. Trends Ecol. Evol. 3:68-72.

Bergerud, A. T. 1992. Rareness as an antipredator strategy to reduce predation risk for moose and caribou. Pp. 1008-21 in Wildlife 2001: populations. (D. R. McCullough and R. B. Barrett, eds.) Elsevier, London.

Bergerud, A. T., and J. Elliot. 1986. Dynamics of caribou and wolves in northern British Columbia. Can. J. Zool. 64:1515-1529.

Bergerud, A. T., and R. E. Page. 1987. Displacement and dispersion of parturient caribou at calving as antipredator tactics. Can. J. Zool. 65:1597-1606.

Bjorge, R. R. 1984. Winter habitat use by woodland caribou in west-central Alberta, with implications for management. Pp. 335-342 in Fish and wildlife relationships in old-growth forests. Proceedings of a symposium (W. R. Meehan, T. R. Merrel Jr., and T. A. Hanley, eds.). American Institute of Fishery Research Biologists, Juneau, AK. 425 pp.

Bloomfield, M. 1980a. Closure of the caribou hunting season in Alberta: management of a threatened species. Alberta Energy and Natural Resources, Fish and Wildlife Division, Edmonton, AB. 39 pp.

Boutin, S., and C. Arienti. 2008. BCC equation reanalysis – final report. Unpublished report prepared for the Alberta Caribou Committee, Edmonton, AB. 19 pp.

Bowman, J., Ray, J.C., Magoun, A.J., Johnson, D., and Dawson, F.N. 2010. Roads, logging, and the large-mammal community of an eastern Canadian boreal forest. Can. J. Zool. **88**:454-467.

Bradshaw, C. J. A., S. Boutin, and D. M. Hebert. 1997. Effects of petroleum exploration on woodland caribou in northeastern Alberta. J. Wildl. Manage. 61:1127-1133.

Bradshaw, C. J. A., S. Boutin, and D. M. Hebert. 1998. Energetic implications of disturbance caused by petroleum exploration to woodland caribou. Can. J. Zool. 76:1319-1324.

Bradshaw, C. J. A., D. M. Hebert, A. B. Rippin, and S. Boutin. 1995. Winter peatland habitat selection by woodland caribou in northeastern Alberta. Can. J. Zool. 73:1567-1574.

Brown, W. K., and J. B. Theberge. 1990. The effect of extreme snowcover on feeding-site selection by woodland caribou. J. Wildl. Manage. 54:161-168.

Brown, G.S., F.F. Mallory, and W.J. Rettie. 2003. Range size and seasonal movement for female woodland caribou in the boreal forest of Ontario. Rangifer 14:227-233.

Caughley, G. and A.Gunn. 1996. Conservation biology in theory and practice. Blackwell Science, Cambridge, Massachusetts, USA. 459pp.

Charest, K. S. 2005. Changes in moose and white-tailed deer abundance in northeastern Alberta and the relationship to cumulative impacts. M.Sc. Thesis, University of Alberta, Edmonton, Alberta.

COSEWIC. 2002. COSEWIC assessment and update status report on the woodland caribou *Rangifer tarandus caribou* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 98 pp.

COSEWIC. 2007. Database of species assessed by COSEWIC. Committee on the Status of Endangered Wildlife in Canada. URL: http://www.cosepac.gc.ca/eng/sct1/searchform_e.cfm [Updated 4 October 2007]

Courtois, R., J.P Ouellet, L. Breton, A. Gingras, and C. Dussault. 2007. Effects of forest disturbance on density, space use, and mortality of woodland caribou. Ecoscience 14:491-498.

Cumming, H. G., D. B. Beange, and G. Lavoie. 1996. Habitat partitioning between woodland caribou and Moose in Ontario: the potential role of shared predation. Rangifer Special Issue No. 9:81-94.

Dalerum, F., S. Boutin and J. S. Dunford. 2007. Wildfire effects on home range size and fidelity of boreal caribou in Alberta, Canada. Can. J. Zool. 85:26-32.

Darby, W. R., and W. O. Pruitt Jr. 1984. Habitat use, movements and grouping behaviour of woodland caribou Rangifer tarandus caribou, in southeastern Manitoba. Can. Field-Natur. 98:184-90.

Dau, J. R., and R. D. Cameron. 1986. Effects of a road system on caribou distribution during calving. Rangifer Special Issue No.1:95-101.

Dunford, J. S. 2003. Woodland caribou-wildfire relationships in northern Alberta. M.Sc. Thesis, University of Alberta, Edmonton, AB.

Dunford, J. S., P. D. McLoughlin, F. Dalerum, and S. Boutin. 2006. Lichen abundance in the peatlands of northern Alberta: Implications for boreal caribou. Ecoscience 13(4):469-474.

Dunn B. M. and M. S. Quinn. 2009. Effectiveness of above-ground pipeline mitigation for moose (Alces alces) and other large mammals. Biological Conservation 142: 332-343.

Dyer, S. J., J. P. O'Neill, S. M. Wasel, and S. Boutin. 2001. Avoidance of industrial development by woodland caribou. Journal of Wildlife Management 65:531-542.

Dyer, S. J., J. P. O'Neill, S. M. Wasel, and S. Boutin. 2002. Quantifying barrier effects of roads and seismic lines on movements of female woodland caribou in northeastern Alberta. Canadian Journal of Zoology 80:839-845.

Dzus, E. 2001. Status of the woodland caribou (*Rangifer tarandus caribou*) in Alberta. Alberta Environment, Fisheries and Wildlife Division, and Alberta Conservation Association, Wildlife Status Report No. 30, Edmonton, AB. 47pp.

Edmonds, E. J. 1988. Population status, distribution, and movements of woodland caribou in west-central Alberta. Can. J. Zool. 66:817-826.

Edmonds, E. J. 1991. Status of woodland caribou in western North America. Rangifer Special Issue No.7:91-107.

Edwards, R. Y. 1954. Fire and the decline of a mountain caribou herd. J. Wildl. Manage. 18:521-596.

EC . 2008. Scientific review for the identification of critical habitat for woodland caribou (Rangifer tarandus caribou), boreal population, in Canada. August 2008. Ottawa: Environment Canada. 72 pp. plus 180 pp Appendices.

Festa-Bianchet, M., J. C. Ray, S. Boutin, S. D. Côté and A. Gunn (in press). Caribou conservation in Canada: an uncertain future. Can. J. Zool.

Hebblewhite, M., Whittington, J., Bradley, M., Skinner, G., Dibb, A., and C. White. 2007. Conditions for caribou persistence in the wolf-elk-caribou systems of the Canadian Rockies. Rangifer Special Issue no. 17:79-91.

Holt, R.D., and J.H. Lawton. 1994. The ecological consequences of shared natural enemies. Annual Review of Ecology and Systematics 25:495-520.

Hummel, M., and Ray, J.C. 2008. Caribou and the North. Dundurn Press, Toronto.

James, A. R. C. 1999. Effects of industrial development on the predator-prey relationship between wolves and caribou in northeastern Alberta. Ph. D. Dissertation, University of Alberta, Edmonton, AB. 77 pp.

James, A. R. C., S. Boutin, D. M. Hebert, and A. B. Rippin. 2004. Spatial separation of caribou from moose and its relation to predation by wolves. Jour. Wildl. Manage. 68:799-809.

James, A. R. C., and A. K. Stuart-Smith. 2000. Distribution of caribou and wolves in relation to linear corridors. Jour. Wildl. Manage. 64:154-159.

Johnson, E. A. 1978. Fire recurrence in the subarctic and its implications for vegetation composition. Can. J. Bot. 57:1374-1379.

Johnson, C. J., K.L. Parker, and D.C. Heard. 2001. Foraging across a variable landscape: behavioural decisions made by woodland caribou at multiple spatial scales. Oecologia 127:590-602.

Kelsall, J. P. 1984. Status report on woodland caribou, Rangifer tarandus dawsonii and Rangifer tarandus caribou, in Canada, in 1982. Committee on the Status of the Endangered Wildlife in Canada, Canadian Wildlife Service, Ottawa, ON. 103 pp.

Kelsall, J. P., E. S. Telfer, and Wright Thomas D. 1977. The effects of fire on the ecology of the boreal forest, with particular reference to the Canadian north: a review and selected bibliography. Occasional Paper Number 32, Canadian Wildlife Service, Edmonton, AB. 56 pp.

Kinley, T. A., and C.D. Apps. 2001. Mortality patterns in a subpopulation of endangered mountain caribou. Wildl. Soc. Bull. 29:158-164.

Klein, D. R. 1982. Fire, lichens, and caribou. J. Range Manage. 35:390-395.

Kuzyk, G. W., J. Kneteman, and F. K. A. Schmiegelow. 2004. Winter habitat use by Wolves, *Canis lupus*, in relation to forest harvesting in west-central Alberta. Canadian Field Naturalist 118:368-375.

Latham, A.D.M. 2009. Wolf ecology and caribou-primary prey-wolf spatial relationships in low productivity peatland complexes in northeastern Alberta. Ph. D. Dissertation, University of Alberta, Edmonton, AB. 194 pp.

Lee, P., and S. Boutin. 2006. Persistence and developmental transition of wide seismic lines in the western Boreal Plains of Canada. Journal of Environmental Management **78:**240-250.

McLoughlin, P. D., J. S. Dunford, and S. Boutin. 2005. Relating predation mortality to broad-scale habitat selection. Journal of Animal Ecology 74:701-707.

McLoughlin, P. D., E. Dzus, B. Wynes, and S. Boutin. 2003. Declines in populations of woodland caribou. Journal of Wildlife Management 67:755-761.

Mech, L.D., and L. Boitani. 2003. Wolf social ecology. In Wolves: Behavior, Ecology, and Conservation. Edited by L.D. Mech and L. Boitani. The University of Chicago Press, Chicago. pp. 1-34

Messier, F. 1994. Ungulate population models with predation: a case study with the North American Moose. Ecology 75:478-488.

Murphy, S. M., and J. A. Curatolo. 1987. Acitvity budgets and movement rates of caribou encountering pipelines, roads, and traffic in northern Alaska. Can. J. Zool. 65:2483-2490.

Musiani, M., H. Okarma, and W. Jedrzejewski. 1998. Speed and actual distances traveled by radiocollared wolves in Bialowieza Primeval Forest (Poland). Acta Theriolgica 43:409-416.

Nellemann, C., and R. D. Cameron. 1996. Effects of petroleum development on terrain preferences of calving caribou. Arctic 49:23-28.

Nellemann, C. and R.D. Cameron. 1998. Cumulative impacts of an evolving oil-field complex on the distribution of calving caribou. Can. J. Zool. 76: 1425-1430.

Nellemann, C., I. Vistnes, P. Jordhoy, and O. Strand. 2001. Winter distribution of wild reindeer in relation to power lines, roads, and resorts. Biological Conservation 101:351-360.

Neufeld, L. M. 2006. Spatial dynamics of wolves and woodland caribou in an industrial forest landscape in West-Central Alberta. M.Sc. Thesis, University of Alberta, Edmonton, AB.

Oberg, P. R. 2001. Responses of mountain caribou to linear features in a west-central Alberta landscape. M.Sc. Thesis, University of Alberta, Edmonton, AB.

O' Brien D., M. Manseau, A Fall, and M.J. Fortin. 2006. Testing the importance of spatial configuration of winter habitat for woodland caribou: An application of graph theory. Biological Conservation 130:70-83.

Rempel, R.S., Elkie, P.C., Rodgers, A.R., and Gluck, M.J. 1997. Timber management and natural-disturbance effects on moose habitat: landscape evaluation. J. Wildl. Manag. **61**: 517-524.

Rettie, W. J., and F. Messier. 1998. Dynamics of woodland caribou populations at the southern limit of their range in Saskatchewan. Can. J. Zool. 76: 251-259.

Rettie, W. J., and F. Messier. 2000. Hierarchical habitat selection by woodland caribou: its relationship to limiting factors. Ecography 23: 466-478.

Rowe, J. S., and G. W. Scotter. 1973. Fire in the boreal forest. Quatern. Res. 3:444-464.

Saher, D. J. 2005. Woodland caribou habitat selection during winter and along migratory routes in West-Central Alberta, M.Sc. Thesis, University of Alberta, Edmonton, AB.

Schaefer, J.A. 2003. Long-term range recession and the persistence of caribou in the taiga. Conservation Biol. 17:1435-1439.

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

Scotter, G.W. 1970. Wildfires in relation to the habitat of Barren-ground Caribou in the taiga of northern Canada. Pp. 85-105 in Proceedings of the tenth annual tall timbers fire ecology conference. Florida State University, Tallahassee, FL.

Seip, D. R. 1992. Factors limiting woodland caribou populations and their interrelationships with wolves and moose in southeastern British Columbia. Can. J. Zool. 20:1494-1503.

Smith, K. G. 2004 Woodland caribou demography and persistence relative to landscape change in west-central Alberta. M.Sc. thesis, University of Alberta. Edmonton, AB.

Smith, K. G., E. Janet Ficht, D. Hobson, T. Sorensen, and D. Hervieux. 2000. Winter distribution of woodland caribou in relation to clear-cut logging in west-central Alberta. Can. J. Zool.78:1433-1440.

Soper, J. D. 1964. The mammals of Alberta. The Hamly Press Ltd., Edmonton, AB. 410 pp.

Sorenson, T., P.D. McLoughlin, D. Hervieux, E. Dzus, J. Nolan., B. Wynes., and S. Boutin. 2008. Determining sustainable levels of cumulative effects for boreal caribou. Jour. Wildl. Manage. 72:900-905.

Stuart-Smith, A. K., C. J. A. Bradshaw, S. Boutin, D. M. Hebert, and A. B. Rippin. 1997. Woodland caribou relative to landscape patterns in northeastern Alberta. J. Wildl. Manage. 61:622-633.

Telfer, E. S., and J. P. Kelsall. 1984. Adaption of some large North American mammals for survival in snow. Ecology 65:1828-1834.

Thomas, D. C. 1998. Fire-caribou relationships: the Beverly herd. Canadian Wildlife Service, Edmonton, AB. 912 pp.

Thomas, D.C., and D.R. Gray. 2002. Update COSEWIC status report on the woodland caribou *Rangifer tarandus caribou* in Canada, *in* COSEWIC assessment and update status report on the woodland caribou *Rangifer tarandus caribou* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-98pp.

Tracz, B. V. 2005. Woodland caribou (*Rangifer tarandus caribou*) home range and habitat-use relationships to industrial activity in northeastern Alberta. MSc. Thesis. University of Alberta. 99p.

Tracz, B.V., E.M. Bayne, J.M. LaMontange, and S. Boutin. *in prep*. Site fidelity of female boreal caribou in response to petroleum development.

Vistnes, I., and C. Nellemann. 2001. Avoidance of cabins, roads and power lines by reindeer during calving. J. Wildl. Manage. 65:915-925.

Vistnes, I., and C. Nellemann. 2008. The matter of spatial and temporal scales: a review of reindeer and caribou response to human activity. Polar Biology 31:399-407.

Vors, L.S., J.A. Schaefer, B.A. Pond, A.R. Rodgers, and B.R. Patterson. 2007. Woodland caribou extirpation and anthropogenic landscape disturbance in Ontario. Jour. Wildl. Manage. 71:1249-1256.

Whittington, J., C. Cassady St. Clair, and G. Mercer. 2005. Spatial response of wolves to roads and trail in mountain valleys. Ecol. Applications 15:543-553.

Wittmer, H.U., B.N. McLellan, D.R. Seip, J.A. Young, T.A. Kinley, G.S. Watts, and D. Hamilton. 2005a. Population dynamics of the endangered mountain ecotype of woodland caribou (*Rangifer tarandus caribou*) in British Columbia, Canada. Can. J. Zool. 83:407-418.

Wittmer, H.U., A.R.E. Sinclair, and B.N. McLellan. 2005b. The role of predation in the decline and extirpation of woodland caribou. Oecologia 144:257-267.

Wittmer H.U., B.N. McLellan, R. Serrouya, and C.D. Apps. 2007. Changes in landscape composition influence the decline of a threatened woodland caribou population. Jour. of Animal Ecology 76:568-579.

Appendix 1. Calculation of lambda and realized population change, from Latham *et al.* (in press): Invading white-tailed deer change wolf-caribou dynamics in northeastern Alberta. Journal of Wildlife Management (please see original for references).

A. DAVID M. LATHAM, M. CECILIA LATHAM, NICOLE A. MCCUTCHEN, STAN BOUTIN

The finite rate of population increase, lambda (λ), for caribou herds was based on a long term provincial monitoring program that tracked the survival and recruitment rates of collared caribou in northeastern Alberta. We typically maintained a sample size of 23 to 44 female caribou per range each year.

Caribou survival rates were determined by relocating radiocollared adult female caribou 3 to 12 times per year to check if they were alive, dead, or censored (i.e., the collar signal was lost). Annual survival rates and variance for each 'year' (May to April) were calculated using the Kaplan-Meier program in Krebs (1999), which is based on Pollock *et al.*'s (1989) staggered entry modification of Kaplan-Meier's (1958) survivorship model. Calf:cow ratios (calves per 100 cows) were used to estimate recruitment rates. Ratios were determined after recruitment surveys were flown in February or March of each year (i.e., when calves were 10 or 11 months old). We counted the number of calves and females in each group of caribou encountered during the survey. We predominantly used radiocollar signals to find groups of caribou; however, we also classified any groups encountered opportunistically during the survey. The mean calf:cow ratio and its variance was calculated for the entire survey with the means of ratio program in Krebs (1999), which is based on Cochran (1977).

Annual estimates of λ from 1996 to 2009 were calculated using a stochastic version of Hatter and Bergerud's (1991) equation, in which $\lambda = S/(1-R)$, S = female adult survival, and R = female calf recruitment (also see Patterson *et al*. 2002). We calculated female calf recruitment as $(Y/2)/(100 + Y/2)$, in which Y = number of calves per 100 cows. We generated error estimates around λ by randomly drawing from annual survival and recruitment distributions (i.e., means and standard deviations) 10,000 times using the Monte Carlo PopTools extension for Excel (Hood 2009). Survival rates were drawn from a beta distribution (which truncates values at 0 and 1) and calf:cow rates were drawn from a lognormal distribution (which truncates values at 0) (see Morris and Doak 2002). Annual estimates of λ prior to 1996 were calculated using the original deterministic version of Hatter and Bergerud's (1991) equation because the raw recruitment data were not available.

Realized population change was calculated as the successive product of λ calculated from the first year of monitoring up to and including the 2009 λ calculation following Anthony *et al.* (2003). For example, if λ for 1996, 1997, and 1998 was 0.97, 1.01, and 0.98 respectively, then realized population change would be calculated as (0.97)(1.01)(0.98) = 0.96. When λ was estimated stochastically, we generated error estimates around realized population change by drawing randomly from annual λ distributions (i.e., mean and standard deviation) 10,000 times using the Monte Carlo PopTools extension for Excel (Hood 2009). Lambda was drawn from a lognormal distribution.

Appendix 2. Calculation of the relationship between linear feature density, young forest and caribou population growth (lambda).

Adapted from Boutin, S., and C. Arienti. 2008. BCC equation reanalysis – final report. Unpublished report prepared for the Alberta Caribou Committee, Edmonton, AB. 19 pp.

Sorensen *et al.* (2008) derived a linear regression equation relating caribou population growth rate (λ) to the proportion of each range within 250m of a linear feature and the Proportion of range burned in the last 30 years. The Sorensen *et al.* (2008) model was:

$$\lambda = 1.192 - 0.00315 * (\% \text{ within 250m of Industrial features}) - 0.0029(\%\text{Burned}).$$

We performed a similar analysis but used additional years of caribou demographic information and more herds to derive an updated equation. The objectives were to examine potential statistical relationships between woodland caribou population growth and various disturbance variables (fires and human-caused). Selected variables for consideration were meant to assess the proposed relationship between human activities and the creation of primary prey habitat (young forest) and improved predator access (linear features).

Methods

We used nine herds in the analysis (WSAR, ESAR, Cold Lake Air Weapons Range (CLAWR), Chinchaga (CH), Red Earth (RE), Caribou Mountains (CM), Little Smoky (LS), Red Rock Prairie Creek (RRPC), and A La Peche (ALP); Table 1).

We calculated the geometric mean of annual λ for each herd as described in McLoughlin *et al.* (2003) over the period 1993-2006. For the Little Smoky herd, geometrical mean and variance were calculated over the period 1993-2005, discarding the population data from years after wolf control and calf penning were implemented.

We obtained range boundaries for each herd from the ACC website. The Base Features 2006 dataset was used as a source for all linear feature information. From it we calculated:

<u>Linear feature density (LF):</u> Road, Pipeline and Seismic line polyline shapefiles were intersected with the range to obtain the total length, in km, of each type of linear feature per range. The total length was then divided by the area of the range to obtain densities of roads, pipelines and seismic lines in km/km^2. These were also summed to provide the total density of all linear features.

Linear feature area (ha) + buffers: The Road, Pipeline and Seismic line polygonal shapefiles described above (where each polyline was buffered to represent their actual on-the-ground area) were each buffered by applying a 25m buffer to each side (50 m buffer in total), with flat ends, and then completely dissolved in order to remove any overlaps. Buffer sizes of 100m (50m to each side) and 200m (100m to each side) were also applied. Once buffered, each linear feature type was intersected with the range shapefiles in order to obtain the total area, in ha, of each type of linear features plus its buffer. This was then used to calculate the % of each range within a designated buffer.

We also calculated a number of variables that attempted to capture the potential of each range to support other ungulates as indicated by the % of recently disturbed habitat. These variables included:

Burns: Fire polygons were obtained from the Alberta fire database. All fires that occurred between 01/01/1976 and 01/01/2006 were included in the analysis (i.e. fires less than 30 yrs old). Polygons with burncode = I (unburnt islands) were discarded, however, polygons with burncode = PB (partial burns) were retained. All fire polygons were dissolved together in order to remove any overlap. The fire shapefile was then intersected with the range and buffered range shapefiles in order to obtain the total area, in ha, and the percent area of burns less than 30 yrs old.

Harvested: Because we couldn't get recent cutblock shapefiles for all of the ranges, we used a tabular database (provided by the Alberta Sustainable Resource Develeopment Forest Branch) containing information on forestry cutblocks (location (see below), area and harvest date) that were harvested between 01/01/1976 to 01/01/2006. Many of the cutblock records in the tabular database had information on the township, range, meridian and section (TTRRMMSS) in which the cutblock is located; however, some of the records only had information on township, range, meridian (TTRRMM) so this was the only spatial reference that could be used. Each TTRRMMSS and TTRRMM was intersected with the range shapefiles, and the proportion of each one of these cells falling within each range/buffered range was calculated. Once this was known, each cutblock was matched to a range or buffered range based on the TTRRMMSS or TTRRMM where it is located. For those TTRRMMSS/TTRRMM that fell only partially within a certain range, the known area of the cutblock was multiplied by the proportion of the corresponding TTRRMMSS or TTRRMM that fell within the range or buffered range. We did this to avoid counting the totality of a large cutblock for a certain range if only part of the corresponding TTRRMMSS/TTRRMM fell within the range/buffered range. Once each cutblock was matched to a range and its area within the range proportionally adjusted, we added them in order to obtain the total area as well as the % of the range consisting of cutblocks less than 30 yrs old.

Young: This variable was calculated by adding the area of young burns and young cutblocks and then dividing this by the total area of the range. Additionally, we calculated the proportion of the range that had been disturbed; this variable included the area of young burns, young cutblocks, well sites (1 ha each), roads (10-30m), pipelines (30m) and seismic lines (5m).

Dependent and independent variables

Table 1 summarizes the values used in our statistical analysis. Road, pipeline, seismic, LF (linear features) values are expressed as km/km^2. Burn is the % of each range that has burned in the last 30 years and Harvested is the % of each range that has been harvested in the past 30 years. Young is the sum of Burn plus Harvested.

We used total linear feature density in our regression analyses. Linear features were dominated by seismic lines (75-99% of all linear features). Also, linear feature density and the % of range within buffers (25, 50, and 100m) of linear features were highly correlated ($R > 0.98$) so we did not include any buffer measures in the analysis.

The % of range in young habitat was highly correlated with the % of range that had been burned in the last 30 years ($r = 0.974$). The % of range that had burned in the last 30 years was not strongly correlated with the proportion that had been harvested ($r=-0.364$).

Linear features were not correlated with the % of young forest ($r=-0.082$).

Table 1. Values used in the statistical analyses.

HERD	Lambda	Range size (ha)	Road	Pipeline	Seismic	LF	Burn	Harvested	Young
ALP	1.02324	568717	0.08505	0.02137	0.50524	0.61167	0.00154	2.60203	2.60358
CM	0.89807	1863867	0.00492	0.00174	0.85822	0.86488	35.71134	0.96317	36.67450
CH	0.92613	894560	0.06655	0.12457	3.16567	3.35678	2.63241	0.15569	2.78810
CL	0.93344	267948	0.01821	0.24428	0.88927	1.15176	30.02471	0.02938	30.05409
ESAR	0.94522	1469081	0.05298	0.23616	1.49452	1.78366	22.70601	1.91660	24.62261
LS	0.90841	292706	0.21450	0.16892	3.36415	3.74757	0.09608	10.16583	10.26191
RE	0.92158	1597686	0.04959	0.06526	1.98245	2.09729	25.48671	1.60477	27.09148
RRPC	0.95995	451338	0.14688	0.06229	0.63225	0.84141	0.38400	5.42790	5.81190
WSAR	0.97512	1500989	0.05173	0.13034	0.99694	1.17901	2.78638	0.53021	3.31658

Table 1 summarizes the values used in our statistical analysis. Road, pipeline, seismic, LF (linear features) values are expressed as km/km^2. Burn is the % of each range that has burned in the last 30 years and Harvested is the % of each range that has been harvested in the past 30 years. Young is the sum of Burn plus Harvested. We used total linear feature density in our regression analyses. Linear features were dominated by seismic lines (75-99% of all linear features). Also, linear feature density and the % of range within buffers (25, 50, and 100m) of linear features were highly correlated ($R > 0.98$) so we did not include any buffer measures in the analysis.

The % of range in young habitat was highly correlated with the % of range that had been burned in the last 30 years ($r = 0.974$). The % of range that had burned in the last 30 years was not strongly correlated with the proportion that had been harvested ($r=-0.364$).

Linear features were not correlated with the % of young forest ($r=-0.082$).

Statistical analysis

To conduct regression analysis, we followed the methods used by Sorensen *et al.* (2008) and used a weighted least squares linear regression. The inverse of the geometric variance for each herd was used to weight the data. We produced the following set of candidate models for comparison using an AIC approach.

lambda=LF + Harvested + Burn

= LF

=Burn

=Harvested

=LF + Burn

=LF + Harvested

=Harvested + Burn

= Young

=LF + Young

Note that a model including both Burn and Young was not part of the candidate set because these two variables were highly correlated.

Table 2. Summary of AIC analyses for regression models listed above.

model	AIC	k	AICc	Delta AICc	likelihood	wi
LF+Young	-40.272	2	-38.272	0	1	0.590622
LF+Burn	-38.958	2	-36.958	1.3139675	0.5184126	0.306186
LF+Burn+Harvested	-38.3337	3	-33.5337	4.7382674	0.0935617	0.05526
Young	-31.727	1	-31.1556	7.1164286	0.0284897	0.016827
LF	-30.882	1	-30.3106	7.9614307	0.0186723	0.011028
Burn	-30.5501	1	-29.9787	8.293342	0.015817	0.009342
Burn+Harvested	-31.1397	2	-29.1397	9.1323423	0.0103977	0.006141
Harvested	-27.863	1	-27.2916	10.980436	0.0041269	0.002437
LF+Harvested	-29.0466	2	-27.0466	11.225409	0.0036512	0.002156

The model receiving greatest support was Lambda = LF + Young. However, the model, Lambda = LF + Burn ranked second and had similar support. All other models had much weaker support.

The adjusted r^2 on the best model was 0.74 and coefficients for LF and Young were negative and statistically significant (see Table 3).

Table 3. Summary statistics for the regression model, Lambda = LF +Young.

Coefficients:	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	1.018402	0.016543	61.559	1.24E-09
LF	-0.023373	0.006393	-3.656	0.01063
Young	-0.002104	0.000538	-3.908	0.00791

Multiple R-squared: 0.802, Adjusted R-squared: 0.736

F-statistic: 12.15 on 2 and 6 DF **p-value: 0.007759**

Based on the above analyses we adopted the following empirical model to describe the relationship between caribou population growth and changes in linear feature density arising from energy exploration and restoration:

Lambda=1.0184-0.0234*Linear feature density-0.0021*%Young

Where linear feature density is expressed as km/km^2 and Young is the % of a caribou range that has been burned or harvested in the last 30 years.

Literature Cited

McLoughlin, P. D., E. Dzus, B. Wynes, and S. Boutin. 2003. Declines in populations of woodland caribou. Journal of Wildlife Management **67:**755-761.

Sorensen, T., P. McLoughlin, D. Hervieux, E. Dzus, J. Nolan, B. Wynes, and S. Boutin. 2008. Determining sustainable levels of cumulative effects for boreal caribou. Journal of Wildlife Management **72:**900-905.

Appendix 3. Summary of land use change as determined by GIS-based calculations.

Area of Ranges

Cold Lake = 6,719.01 km2 = 671,901.24 ha
ESAR = 13,150.35 km2 = 1,315,034.79 ha
WSAR = 15,720.64 km2 = 1,572,063.88 ha

Given the small proportion of WSAR in the TT we did not include it in the report but it is included this appendix.

1- What proportion of ESAR and Cold Lake ranges are in the TT?

CLAWR = 1
ESAR = 0.516

Note: calculated using the latest available delineated caribou ranges for Alberta (ASRD 2010)

2- What proportion of the TT is covered by caribou habitat? What proportion of the TT is covered by delineated ranges?

Proportion of TT covered by caribou habitat (peatland) = 0.3116

Upland/Peatland Habitat in the TT			
Habitat type	Area (ha)	Area (km^2)	Proportion of TT
Peatland	1,214,425.17	12,144.25	0.3116
Upland	2,682,764.33	26,827.64	0.6884
Total	3,897,189.50	38,971.90	

Upland/Peatland Habitat inside of Caribou ranges in the TT			
Range	Habitat	Area (ha)	Area (km^2)
Cold Lake	Peatland	354,211.43	3,542.11
	Upland	317,689.81	3,176.90
ESAR	Peatland	330,319.09	3,303.19
	Upland	348,747.57	3,487.48
WSAR	Peatland	9,268.81	92.69
	Upland	2,929.86	29.30
Total Peatland in Caribou ranges		693,799.34	6,937.99
Total Upland in Caribou ranges		669,367.23	6,693.67
Total in Caribou ranges		1,363,166.57	13,631.67

Upland/Peatland Habitat Outside of Caribou ranges in the TT		
Total Peatland outside Caribou ranges	520,625.83	5,206.26
Total Upland outside Caribou ranges	2,013,397.10	20,133.97
Total	2,534,022.93	25,340.23

Note: Caribou habitat was calculated using the Alberta Peatland Inventory (Vitt *et al.* 1998). Caribou habitat was considered to be peatland habitat identified as those polygons with more than 50% of peatland types (e.g. bogs, fens, etc.)

Proportion of TT covered by delineated ranges = 0.34978 (includes ESAR, CLAWR and a bit of WSAR)

Proportion of TT covered by ESAR = 0.17425
Proportion of TT covered by WSAR = 0.00313
Proportion of TT covered by CLAWR = 0.17241

Note: calculated using the latest available delineated caribou ranges for Alberta (ASRD 2010).

3- What is the linear feature density in the TT? Total km?

Linear feature type	Length (km)	density (km/km^2)
Roads	12,283.98	0.3152
Pipelines	11,591.21	0.2974
Seismic	66,489.19	1.7061
Total	90,364.38	2.3187

Based on a Total Area for the TT = 38,971.90 km^2

Note: Calculated using all roads, pipelines and seismic lines from the Provincial Digital Base Map Data (ASRD 2006).

4- What is the number of well sites in the TT?

	Number	Density ($\#/km^2$)
Oil and gas wells (as of June 2007)	31,036	0.7964
Oil and gas wells (as of January 2010)	34,773	0.8923

In caribou range within the TT

CLAWR 7484
ESAR 3603
WSAR 24

Total number of wells in caribou ranges within the TT = 11,111 (as of January 2010)

Note: Calculated using all oil and gas wells, surface hole locations, from the dataset by IHS Energy (2007, 2010).

5- What percentage of the ranges in TT are covered by young forest?

Proportion of TT covered by fires < 30 yrs old = 0.1619

Fires <30 yrs old inside of Caribou ranges in TT		
Range	Area (ha)	Area (km2)
Fires in Cold Lake	180,762.34	1,807.62
Fires in ESAR	230,029.71	2,300.30
Fires in WSAR	193.02	1.93
Total Fires in Caribou Ranges in TT	410,985.07	4,109.85
Fires <30 yrs old outside of Caribou ranges in TT		
Fires outside of caribou ranges in TT	219,971.47	2,199.71
Total area of fires in TT	**630,956.54**	**6,309.57**
Total area of TT	**3,897,189.50**	**38,971.90**

Note: Calculated using fire polygons from the provincial fire database (ASRD 2010). All fires that occurred between 30/04/1978 and 30/04/2008 were included in the analysis (i.e. fires less than 30 yrs old). These dates were selected based on the harvesting data available, which was current to 30/04/2008. Polygons with burncode = I (unburnt islands) were discarded, however, polygons with burncode = PB (partial burns) were retained. All fire polygons were dissolved together in order to remove any overlap.

Note: Calculated using the Alberta Provincial Fire Database (ASRD 2010).

Proportion of TT covered by cutblock < 30 yrs old = 0.0277
Area of cutblocks in the TT = 107,998.10 ha.

Note: To calculate area harvested, we used tabular data from the ARIS database (ASRD 2008) containing information on forestry cutblocks (area (ha) and harvesting date) harvested between 30/04/1978 to 30/04/2008 (i.e. cutblocks less than 30 yrs old). Many of the cutblock records in the tabular database had information on the section (TTRRMMSS) in which the cutblock is located; however, some of the records only had information on the township (TTRRMM); this was the only spatial reference information that could be used to spatially locate the cutblocks across the province. Township and Section shapefiles were spatially intersected with the TT shapefile, and the proportion of each one of these cells falling within the TT was calculated. Once this was known, each cutblock in the tabular database was retained if the TTRRMMSS or TTRRMM where it was located was itself located within the TT. For those TTRRMMSS/TTRRMM that fell only partially within the TT, the known area of the cutblock was multiplied by the proportion of the corresponding TTRRMMSS or TTRRMM that fell within the TT. We did this to avoid counting the totality of a large cutblock if only part of the corresponding TTRRMMSS/TTRRMM fell within the BLCN TT (and because we didn`t know exactly where in the TTRRMMSS or TTRRMM the cutblock was located). Once the cutblocks within the TT were identified, and their area within the TT proportionally adjusted, we added them in order to obtain the total area as well as the proportional area of cutblocks less than 30 yrs old within the traditional territory.

6- Linear feature density for the ESAR and CLAWR caribou ranges in the TT.

Range	Area within the TT (km^2)	Pipeline length (km)	Road length (km)	Seismic length (km)	Pipeline density (km/km^2)	Road density (km/km^2)	Seismic density (km/km^2)	All LF density (km/km^2)
CLAWR	6,719.01	2,014.88	394.16	9,198.68	0.300	0.059	1.369	**1.73**
ESAR	6,790.67	2,000.95	554.15	12,326.72	0.295	0.082	1.815	**2.19**
WSAR	121.99	11.90	-	174.14	0.098	0.000	1.428	**1.53**

So the density of linear features within ESAR and CLAWR in the TT is 2.19 km/km^2 and 1.73 km/km^2, respectively.

Note: Calculated using all roads, pipelines and seismic lines from the Provincial Digital Base Map Data (ASRD 2006).

7- Proportion of the ranges in the TT that are within 250m of a linear feature.

Range	Area of range within the TT (km^2)	Area of LF with 250m buffer (km^2)	Proportion of the range in the TT within 250m of a LF
CLAWR	6,719.01	3,436.60	**0.511**
ESAR	6,790.67	4,457.19	**0.656**
WSAR	121.99	62.91	**0.516**

Note: Calculated using all roads, pipelines and seismic lines from the Provincial Digital Base Map Data (ARSD 2006).

8- Proportion of young forest (burns and cuts < 30 yrs old) in caribou range within the TT for ESAR and CLAWR

Range	Area of range within TT (ha)	Area (ha) of fires ≤30 yrs within TT portion of the range	Area (ha) of CC ≤30 yrs within TT portion of the range	Area (ha) of young habitat (burns + cuts ≤30 yrs old) within the TT portion of the range	Proportion of young habitat (burns + CCs ≤ 30 yrs old) within the TT portion of the range
CLAWR	671,901.25	180,762.34	4,170.64	184,932.98	**0.2752**
ESAR	679,066.65	230,029.71	25,221.37	255,251.07	**0.3759**
WSAR	12,198.59	193.02	190.95	383.97	**0.0315**

Note: Calculated using the Alberta Provincial Fire Database (ASRD 2010) and the ARIS database (ASRD 2008).

9- The % burn in caribou range within the TT for ESAR and CLAWR (to use in Sorensen equation). The Sorensen equation considers recent fires (≤ 50 yrs old).

Range	Area of range within TT (km^2)	Area of fires ≤50 yrs within the TT portion of the range (ha)	Area of fires ≤50 yrs within the TT portion of the range (km^2)	Proportion of the TT portion of the range in ≤50yrs old fires	Percentage of the TT portion of the range in ≤50yrs old fires
CLAWR	6,719.01	198,222.54	1,982.23	**0.295**	**29.5017**
ESAR	6,790.67	237,360.94	2,373.61	**0.350**	**34.9540**
WSAR	121.99	276.78	2.77	**0.023**	**2.2689**

Note: Calculated using the Alberta Provincial Fire Database (ASRD 2010) and the ARIS database (ASRD 2008).

10- Agriculture

We used the Census of Agriculture for Alberta (AARD 2001) which provides tabular data on the number of farms of a given acreage by county/municipal district (table attached). We calculated the area of farms within the TT based on the counties/MDs that fall within the TT (and for those counties/MDs that do not fall completely within the TT we adjusted the area proportionally). We used a mean size for each acreage category. After doing all these calculations, it comes out to a proportion of 0.20250 of the TT under agriculture (789,166.07 ha = 7,891.66 km^2).

Data sources:

- Alberta Agriculture and Rural Development (AARD). 2001. 2001 Census of Agriculture for Alberta. Available from http://www1.agric.gov.ab.ca.login.ezproxy.library.ualberta.ca/$department/deptdocs.nsf/all/sdd5726?opendocument

- Alberta Sustainable Resource Development (ASRD). 2008. Alberta Reforestation Information System (ARIS). Maintained by the Forestry Branch, Alberta Sustainable Resource Development, Edmonton, Alberta.

- Alberta Sustainable Resource Development (ASRD). 2010. Delineated Caribou ranges for Alberta. Fish and Wildlife Division.

- Alberta Sustainable Resource Development (ASRD). 2010. Fire history database. Available at http://www3.gov.ab.ca/srd/wildfires/ [Verified 01 June 2010]

- Alberta Sustainable Resource Development (ASRD). 2006. Provincial Digital Base Map Data. Resource Management Branch, Edmonton, Alberta. Available from ALTALIS (http://www.altalis.com/)

- IHS Energy. 2007. Wells, Surface Hole. Shapefile, current to June 2006. Calgary, Alberta.

- IHS Energy. 2010. Wells, Surface Hole. Shapefile, current to January 2010. Calgary, Alberta.

- Vitt, D.H., L.A. Halsey, M.N. Thormann, and T. Martin. 1998. Peatland Inventory of Alberta. Prepared for Alberta Peat Task Force, fall 1996. Sustainable Forest Management Network of Centres of Excellence, University of Alberta, Edmonton, Alberta, Canada.

Curriculum Vitae

STAN BOUTIN, PhD

DEGREES

PhD (Zoology)	University of British Columbia	June 1983
MSc (Zoology)	University of British Columbia	June 1980
BSc (Honours)	University of Alberta	June 1977

APPOINTMENTS

Department of Biological Sciences, University of Alberta

- NSERC Industrial Research Chair (Integrated Landscape Management) — Feb 2001-present
- Professor — July 1995-present
- Associate Professor — July 1990-June 1995
- Assistant Professor — July 1986-June 1990

Alberta-Pacific Forest Industries Inc.

- Director of Science and Technology — June 1998-July 1999
- Research Program Leader — Mar 1997-June 1998
- Research Ecologist — July 1994-June 1995

Department of Zoology, University of Guelph

- Assistant Professor — Feb 1983-June 1986

AWARDS

- William Rowan Award, Alberta Chapter of the Wildlife Society, 2010
- Royal Society of Canada's Miroslaw Romanowski Medal 2009
- Elected Fellow Royal Society of Canada June 2006
- McCalla Professorship 2003-04
- Killam Annual Professorship 2002-03
- Al-Pac/ASTECH (Alberta Science and Technology) Innovation in Integrated Landscape Management Prize 2001
- NSERC Industry Synergy Award (Alberta Pacific Forest Industries and University of Alberta) 1999
- McMaster Fellowship, CSIRO Australia 2000
- Outstanding Publication of the Year in Wildlife Ecology and Management (Wildlife Society) 1996 (co-recipient)
- H.R. MacMillan Scholarship 1981-82
- NSERC Postgraduate Scholarship 1977-81

RELEVANT PROFESSIONAL ACTIVITIES

International

- Co-organizer, 11th North American Caribou Conference (2006)
- External Reviewer Finnish Centres of Excellence (2005)
- Co-organizer of Predator Prey Symposium Wildlife Society meeting (2004)
- External Reviewer, Kanuti National Wildlife Refuge, Biological review (2002)
- Chair (2002) and Research Expert (2000), Academy of Finland, Research Council for Biosciences and Environment
- BORNET Advisory Committee (2001-2003)
- Reviewer, Royal Society of New Zealand, Marsden Fund (2001)
- Reviewer, Natural Environment Research Council (United Kingdom) (2001)
- Visiting Scientist, CSIRO, Australia (2000)
- World Bank CEO Forum on Forestry (Forestry Expert on behalf of Mitsubishi Corporation) (1998-1999)
- External Reviewer for Associate Professor Position, University of Turku, Finland (1998)
- External Reviewer for Associate Professor Position, University of Oulu, Finland (1997)
- Visiting Scientist, Large Animal Research Group, University of Cambridge (1990)
- Visiting Scientist, Serengeti Research Institute, Tanzania (1986,1990)
- Wildlife Society Special Service Committee (1997-98)
- Co-organizer, International Theriological Conference, Predator-prey symposium (1997)

National

- Federal Woodland Caribou Critical Habitat Science Advisory Committee (2008-09)
- NSERC Polyanyi Award Committee (2008)
- NSERC Northern Supplements Review Panel (2004-05)
- Canada Research Chairs College of Reviewers (2000-present)
- National Integrated Landscape Coalition (2004-present)
- National Round Table on the Environment and Economy Taskforce (2004)
- External evaluation for Simon Fraser University Tenure and Promotions Committee (2002)
- Reviewer, Fonds pour la Formation de Chercheurs et l'Aide à la Recherche (2001)
- Management Team, Sustainable Forest Management Network Centre of Excellence (1996-2004)
- Research Area Leader, Sustainable Forest Management Network Centre of Excellence (2000-2004)
- NSERC GSC-18 Ecology and Evolution Grant Selection Committee (1998-2001)
- NSERC Scholarships Earth Sciences and Ecology Selection Committee (1997)
- Deputy Scientific Leader and Ecological Basis of Sustainability Theme Co-Leader, Sustainable Forest Management Network of Center of Excellence (1995-1996)

Provincial

- Director of the Science Centre, Alberta Biodiversity Monitoring Institute (2007-present)
- Alberta Landuse Framework Planning Working Group (2007)
- Governance Board for the Alberta Caribou Committee (2005-present)
- Alberta Environmental Protection Advisory Committee (2002-2009)

- Science Advisory Committee for the G8 Legacy Chair in Wildlife Ecology (2004-present)
- Alberta Biodiversity Monitoring Institute Senior Advisory Committee (2002-present)
- Alberta Biodiversity Monitoring Institute Secretariat Working Group (2002-present)
- Alberta Chamber of Resources Integrated Landscape Management Steering Committee (2001-present)
- *Provincial Endangered Species Conservation Committee (1998-1999)*
- Alberta Forest Biodiversity Monitoring Program Steering and Technical Committees (1998-present)
- Alberta Boreal Caribou Research Committee (1996-present)
- Alberta Forest Conservation Strategy Round Table Discussions (1993-95)
- Special Advisory Committee -Yukon Game Branch Aishihik Caribou Recovery Program (1992-95)

University

- Alberta Cooperative Conservation Unit (ACCRU)
- Killam Annual Award Selection Committee (2006)
- Alberta Conservation Association Chair Renewal Committee (2005)
- Martha Piper Research Prize Nomination Committee (2002)
- Petro Canada Young Innovator Award Selection Committee (2002)
- Graduate Student and Postdoctoral Fellows Award Committee, Biological Sciences (2001-2004)
- Reviewer, Canadian Circumpolar Institute Grants Adjudication Committee (2001)
- Adjunct Professor, Canadian Circumpolar Institute (March 1989-present)
- Canadian Circumpolar Institute Grants Adjudication Committee (1989-92)

EDITORIAL BOARDS

Guest Editor Special Section Biological Conservation, 2010

Wildlife Research Editor (2009-present)

Wildlife Research Editorial Board (2006-2009)

OIKOS Editorial Board (2007-present)

Journal of Animal Ecology 1992-2004, Associate Editor (2004-present)

Journal of Wildlife Management, Associate Editor, (1999-2002)

External PhD Examiner:

- Patrick Leighton, McGill University, 2009
- Scott Wilson, University of British Columbia, 2008
- Fredrik Dalerum, Stockholm University, Sweden, 2005
- David Hayward, University of New South Wales, Australia, 2002
- Anthony Dean Arthur, University of Sydney, Sydney, 2001
- David Huggard, University of British Columbia, Vancouver, 2000
- Paul Mahon, University of Sydney, Sydney, 1999
- Peter Banks, University of Sydney, Sydney, 1997
- David Choquenot, University of Sydney, Sydney, 1994
- Luigi Marinelli*, University of Saskatchewan, Saskatoon, 1993*

External MSc Examiner

- Carrie-Lee Hutchinson, Lakehead, 1997
- Thomas Hossie, Trent, 2009

GRADUATE SUPERVISION

Name	Degree	Year	Final Degree	Position	Organization
Julian Caley	MSc	1986	PhD	Research Group Leader	*Australian Inst. of Marine Science*
Mark Simpson	MSc	1987	PhD		
Dennis Murray	MSc	1990	PhD	Canada Research Chair	Trent University
Mark Williams	MSc	1990	MSc	Biologist	BC Government
Andrew Derocher	PhD	1991	PhD	Professor	University of Alberta
Sabine Schweiger	MSc	1992	MSc	Environmental Coordinator	City of Whitehorse
Karl Larsen	PhD	1992	PhD	Professor	UCC Kamloops
Constance Becker	PhD	1992	PhD	Professor	Kansas State University
Dean Cluff	MSc	1992	MSc	Wolf biologist	GNWT
Jean-Pierre Ouellet	PhD	1992	PhD	Professor and Chair	Université du Québec à Rimouski
Kari Stuart Smith	MSc	1993	PhD	Forest Scientist	Tembec Industries, Cranbrook
Garth Mowat	MSc	1993	MSc	Senior Wildlife Biologist	BC Government
John Nishi	MSc	1993	MSc	Bison biologist	GNWT
John Krebs	MSc	1994	MSc	Biologist	BC Hydro
Corey Bradshaw	MSc	1994	PhD	Professor	University of Adelaide, AUS
Yves Pinsonneault	MSc	1995	MSc	Senior Director	Conservation International
Douglas Clark	MSc	1996	PhD	PDF	University of Alberta
Ainsley Sykes	MSc	1996	MSc	Research Associate	University of Alberta
Murray Humphries	MSc	1996	PhD	Canada Research Chair	McGill University
Lisa McDonald (Verbisky)	MSc	1996	MSc	Instructor	Northern Lights College

Robin Weaver (Tizzard)	MSc	1996	MSc	Instructor	Portage College
Jason Marshal	MSc	1997	PhD	Senior lecturer of ecology	University of Witwaterstand
Carl Burgess	MSc	1997	MSc	Senior Science Advisor	Yukon Government
Adam James	PhD	1999	PhD		
Matt Wheatley	MSc	1999	PhD	Park Ecologist	Alberta Parks
Jake Fisher	MSc	1999	PhD	research scientist	Alberta Innovates-Technology Futures
Liz Anderson	MSc	1999	MSc	Consultant	Rocky Mtn House
Rob Anderson	MSc	1999	MSc	senior biologist	Alberta Conservation Association
Cristine Corkum (Carnine)	MSc	1999	MSc	coordinator	Nebraska Prairie Partner
Simon Dyer	MSc	1999	MSc	Program Director	Pembina Institute
Sue Peters	MSc	2000	MSc	Species at Risk Biologist	Alberta Conservation Association
Jordan DeGroot	MSc	2002	MSc		
Andrew McAdam	PhD	2003	PhD	Professor	University of Guelph
Jess Dunford	MSc	2003	MSc	Environmental Specialist	National Energy Board
Arin McFarlane	MSc	2005	MSc	Consultant	Maternity Leave
Boyan Tracz	MSc	2005	MSc	Biologist	GNWT - Norman Wells
Kerri Charest	MSc	2005	MSc	director ASPB	Spencer Environmental
Nicole McCutchen	PhD	2006	PhD	Manager	Government of Northwest Territory
Lucas Habib	MSc	2006	MSc	Park Warden	Parks Canada/Jasper
Troy Pretzlaw	MSc	2006	MSc	Regional Biologist	Yukon
Cecilia Arienti	MSc	2006	MSc	spatial ecologist	Fiera Consulting
Jalene LaMontagne	PhD	2007	PhD	Professor	Asian University for Women
Adi Boon	MSc	2007	MSc	med student	
Jeff Lane	PhD	2008	PhD	PDF	University of Edinburgh
Dave Latham	PhD	2008	PhD	biologist	Fiera Consulting
Rafael Avila-Flores	PhD	2009	PhD	PDF	Mexico City
Meghan Larivee	MSc	2009	MSc	Contractor	Yukon Government
Neil Darlow	PhD			Program manager	Yellowstone to Yukon
Mark Andruskiw	PhD			student	UofA
Shawna Pelech	PhD			student	UofA
Diane Haughland	PhD			student	UofA
Todd Mahon	PhD			student	UofA
Quinn Fletcher	PhD			student	McGill
Kim Dawe	PhD			student	UofA
Jamie Gorrell	PhD			student	UofA
Jenna Donald	MSc			student	UofA
Stephen Mayor	PhD			student	UofA
Jesse Tigner	MSc			student	UofA
Rob Serrouya	PhD			student	UofA
Corey De La Mare	MSc				
Vilis Nams	PDF	1990		Professor	Nova Scotia Agricultural College
Richard Moses	PDF	1994		Lecturer	University of Alberta
Karl Larsen	PDF	1995		Professor	Thompson Rivers University
David Choquenot	PDF	1996		General Manager	Landcare New Zealand
Elston Dzus	PDF	1998		Ecologist	Alberta Pacific Forest Industries

Dominique Berteaux	PDF	1999	Canada Research Chair	Rimouski
Erin Bayne	PDF	2002	Associate Professor	University of Alberta
Murray Humphries	PDF	2002	Canada Research Chair	McGill
Philip McLoughlin	PDF	2003	Assistant Professor	University of Saskatoon
Michael Clinchy	PDF	2003	Adjunct Professor	Victoria
Craig Aumann	PDF	2006	Manager	Sustainable Ecosystems ARC
Frederik Dalerum	PDF	2006	PDF	University of Pretoria
Scott Nielsen	PDF	2006	Assistant Professor	University of Alberta
Marta Labocha	PDF	2009	PDF	University of Alberta
Nicole McCutchen	PDF/RA	2008	Manager	GNWT

INVITED PRESENTATIONS

I have given over 100 invited presentations since 1986 including 7 Plenary Lectures (selected list provided below with plenaries in bold). In addition, members of my lab have given 45 presentations or posters on our work in 2009. This is typical of yearly output since 2000.

Selected List

1. **Lakehead University Northern Studies Conference, Thunder Bay (2009)**
2. Canadian Institute, Edmonton (2009)
3. International Union of Forest Research, Thompson Rivers University, Kamloops (2008)
4. International Congress on a Global Vision of Forestry in the 21st Century, Ottawa (2007)
5. International Felid Biology and Conservation Conference, Oxford (2007)
6. **11th North American Caribou Workshop, Jasper (2006)**
7. **Restoration Workshop, Cooperative Freshwater Ecology Unit, Laurentian University (2006)**
8. University of Oslo, Oslo, Norway (2006)
9. University of Oslo, Norway (2005)
10. Stockholm University (2005)
11. University of Uppsala, Sweden (2005)
12. **2nd World Lagomorph Conference, Vairão, Portugal (2004)**
13. Department of Applied Conservation Biology, UBC (2004)
14. **International Arctic Ungulate Conference, Finland (2003)**
15. University of Oslo, Norway (2003)
16. Wildlife Conservation Society, Carnivore Conservation Workshop, Florida, one of 15 invited experts (2003)
17. Society for Conservation Biology, Minnesota (2003)
18. University of Regina (2003)
19. Northwest Section of the Wildlife Society, Oregon (2003)
20. BORNET International Conference on Biodiversity Conservation in Boreal Forests, Uppsala, Sweden (2002)
21. Ontario Forest Research Institute, Emulating Natural Forest Landscape Disturbances International Symposium, Natural Disturbance Patterns and Forest Harvesting in the Western Boreal: From Concept to Practice, Sault Ste. Marie (2002)
22. Faculty of Science Visiting Committee, (2002)

23. Université de Moncton, Adaptive Management and Sustainable Forestry, Moncton (2002)
24. University of Orebro, Sweden (2001)
25. Environmental Studies and Ecology/Evolution Group, University of Oregon (2001)
26. Department of Zoology, University of British Columbia (2000)
27. Australian National University (2000)
28. James Cook University (2000)
29. University of Queensland, Brisbane (2000)
30. Wildlife and Ecology CSIRO, Canberra (2000)
31. International Association of Landscape Ecology, Snowmass, Colorado (1999)
32. Ecological Society of America, Spokane, Washington (1999)
33. Grimso Wildlife Station, Sweden (1999)
34. **7th Polish Theriological Congress, Bialewieza National Forest, Poland (1998)**
35. Department of Wildlife Biology, University of Idaho, Moscow, Idaho (1998)
36. Canadian Society of Zoologists, Kamloops, British Columbia (1998)
37. International Theriological Congress, Acapulco, Mexico (1997)
38. Small Mammal Symposium, Oslo, Norway (1996)
39. British Ecological Society, Nottingham, UK (1996)
40. Terje Skogland Memorial Symposium, Norway (1995)
41. International Colloquium Ecology of Tree Squirrels, Carnegie Museum of Natural History, Rector Pennsylvania, Pennsylvania (1994)
42. International Theriological Congress, Sydney, Australia (1993)
43. Department of Zoology, University of Cambridge (1991)
44. University of Ottawa (1990)
45. **Quebec Ethology and Ecology Conference (1988)**

LIST OF PUBLICATIONS

Refereed Journal Publications (Mentored students in bold)

153. **Haughland, D.L**., J-M. Hero, J. Schieck, J.G. Castley, S. Boutin, P. Sólymos, B. E. Lawson, G. Holloway and W.E. Magnusson. 2010. Why resist real solutions for biodiversity monitoring and research? Trends in Ecology & Evolution 125:199-200.

152. McLellan**, R. Serrouya**, H. Wittmer and S.A. Boutin. 2010. Predator-mediated Allee effects in multi-prey systems. Ecology 91:286-292.

151. **Lane, J.E**., S.A. Boutin, J.R. Speakman and M.M. Humphries. 2010. Energetic costs of male reproduction in a scramble competition mating system. Journal of Animal Ecology 79: 27-34.

150. **Latham, A.D.M.** and S.A. Boutin. *In Press.* Possible evidence of arboreal lichen use in peatlands by White-tailed Deer, *Odocoileus virginianus*, in northeastern Alberta. Canadian Field-Naturalist 122

149. **Latham, A.D.M**. and S.A. Boutin. *In Press.* Evidence of Raccoon, *Procyon lotor,* range extension in northern Alberta. Canadian Field-Naturalist 122

---

148. Schneider, R.R, A. Hamann, D. Farr, X. Wang and S.A. Boutin. 2009. Potential effects of climate change on ecosystem distribution in Alberta. Canadian Journal of Forest Research.39:1001-1010

147. Lamb, E., E. Bayne, S. Boutin, J. Schieck, J. Herbers, G. Holloway, and **D. Haughland**. 2009. Indices for monitoring biodiversity change: are some more effective than others? Ecological Indicators 9:432-444

146. LaMontagne**, J.M**. and S.A. Boutin. 2009. Quantitative methods for defining mast-seeding years across species and studies. Journal of Vegetation Science 20: 745-753.

145. **Lane, J.E**., S.A. Boutin, M.R. Gunn and D.W. Coltman. 2009. Sexually selected behaviour: red squirrel males search for reproductive success" Journal of Animal Ecology 78: 296-304.

144. **Descamps, S**., S.A. Boutin, A.G. McAdam, D. Berteaux and J-M. Gaillard. 2009. Survival costs of reproduction vary with age in North American red squirrels. Proceedings of the Royal Society B-Biological Sciences 276: 1129-1135.

143. Guillemette, C.U., **Q.E. Fletcher**, S.A. Boutin, R.M. Hodges, A.G. McAdam and M.M. Humphries. 2009. Lactating red squirrels experiencing high heat load occupy less insulated nests. Biology Letters 5 166-168.

---

142. **Descamps, S**., S.A. Boutin, D. Berteaux, A.G. McAdam and J-M. Gaillard. 2008. Cohort effects in red squirrels: the influence of density, food abundance and temperature on future survival and reproductive success. Journal of Animal Ecology 77: 305-314.

141. Sheriff, M.J., L Kuchel, S.A. Boutin and M.M. Humphries. 2008. Seasonal metabolic acclimatization in a northern population of free-ranging snowshow hares, *Lepus Americanus*. Journal of Mammalogy 90: 761-767.

140. Bayne, E.M., **L. Habib**, and S.A. Boutin. 2008. Impacts of chronic anthropogenic noise from energy-sector activity on abundance of songbirds in the boreal forest. Conservation Biology

22:1186-1193.
139. Vik, J.O., C.N. Brinch, S.A. Boutin and N.C. Stenseth. 2008. Interlinking hare and lynx dynamics using a century's worth of annual data. Population Ecology 50: 267-274.
137. Krebs, C., P. Carrier, S. Boutin, R. Boonstra, and E. Hofer. 2008. Mushroom crops in relation to weather in the southwestern Yukon. Botany 86: 1497-1502.
136. **Descamps, S**., S. Boutin, D. Berteaux, and J.-M. Gaillard. 2008. Age-specific variation in survival, reproductive success and offspring quality in red squirrels: evidence of senescence. Oikos 117:1406-1416.
135. Bayne, E., S.A. Boutin and R. Moses. 2008. Ecological factors influencing the spatial pattern of Canada Lynx relative to its southern range edge in Alberta, Canada. Canadian Journal of Zoology 86: 1189-1197
134. **Boon, A**., D. Réale and S.A. Boutin. 2008. Personality, habitat use, and their consequences for survival in North American red squirrels *Tamiasciurus hudsonicus*. Oikos 117: 1321-1328.
133. **Lane, J.E**., S.A. Boutin, M.R. Gunn, J. Slate and D.W. Coltman. 2008. Female multiple mating and paternity in free-ranging North American red squirrels. Animal Behaviour 75: 1927-1937.
132. Sorensen, T., **P. McLoughlin**, D. Hervieux, E. Dzus, J. Nolan, B. Wynes and S.A. Boutin. 2008. Determining sustainable levels of cumulative effects for boreal caribou. Journal of Wildlife Management 72: 900-905.
131. **Boonstra**, R., **J. Lane**, S.A. Boutin, A. Bradley, L. Desantis, A. Newman and K. Soma. 2008. Plasma DHEA levels in wild, territrial red squirrels: Seasonal variation and effect of ACTH. General and Comparative Endocrinology 158: 61-67.

---

130. Hone, J., C. Krebs, M. O'Donoghue, S. Boutin. 2007. Evaluation of predator numerical responses. Wildlife Research 34: 335-341.
129. **Descamps**, S., S. Boutin, D. Berteaux, and J.-M. Gaillard. 2007. Female red squirrels fit Williams' hypothesis of increasing reproductive effort with increasing age. Journal of Animal Ecology 76:1192-1201.
128. **Aumann, C**., D. Farr, and S. Boutin. 2007. Multiple use, overlapping tenures and the challenge of sustainable forestry in Alberta. Forestry Chronicle 83:642-650
127. McAdam, A., S. Boutin, A. Sykes, and M. Humphries. 2007. Life histories of female red squirrels and their contributions to population growth and lifetime fitness. EcoScience 14:362-369
126. **Boon, A. K**., D. Reale, and S. Boutin. 2007. The interaction between personality, offspring fitness and food abundance in North American red squirrels. Ecology Letters 10:1094-1104
125. **Lane, J.E**., S. Boutin, M.R. Gunn, J. Slate, and D.W. Coltman. 2007. Genetic relatedness of mates does not predict patterns of parentage in North American red squirrels. Animal Behaviour 74:611-619
124. **LaMontagne, J. L**., and S. Boutin. 2007. Local-scale variability and synchrony in mast seed production patterns of *Picea glauca*. Journal of Ecology 95:991-1000
123. **Dalerum, F**., S. Boutin, and **J. Dunford**. 2007. Wildfire effects on home range size and fidelity of boreal caribou in Alberta, Canada. Canadian Journal of Zoology 85:26-32

122. Gunn, M.R., K. Hartnup, S. Boutin. J. Slate, and D. Coltman. 2007. A test of the efficacy of whole-genome amplification on DNA obtained from low-yield samples. Molecular Ecology Notes. 7:393-399
121. Kerr, T.D., S. Boutin, **J. LaMontagne**, A. McAdam, and M. Humphries. 2007. Persistent maternal effects on juvenile survival in North American red squirrels. Biology Letters 3:289-291
120. **Nielson, S.E**., E. Bayne, J. Schieck, J. Herbers, and S. Boutin. 2007. A new method to estimate species and biodiversity intactness using empirically derived reference conditions. Biological Conservation 137:403-414
119. **Habib, L**., E.M. Bayne, and S. Boutin. 2007. Chronic industrial noise affects pairing success and age structure of ovenbirds Seiurus aurocapilla. Journal of Applied Ecology 44:176-184

---

118. **Arienti, M.C**., S. Cumming, and S. Boutin. 2006. Empirical models of forest fire initial attack success probabilities: the effects of fuels, anthropogenic linear features, fire weather, and management. Canadian Journal of Forest Research 36:3155-3166
117. Boutin, S., L. Wauters, A. McAdam, M. Humphries, G. Tosi, and A. Dhondt. 2006. Anticipatory reproduction and population growth in seed predators. Science 314:1928-1930
116. **Pretzlaw, T., C. Trudeau**, M.M. Humphries, **J.M. LaMontagne**, and S. Boutin. 2006. Red squirrel (*Tamiasciurus hudsonicus*) feeding on spruce bark beetles (*Dendroctonus rufipennis*): energetic and ecological implications. Journal of Mammalogy 87:909-914
115. **Dunford, J.S, F. Dalerum, P.D. McLoughlin and S. Boutin. 2006. Lichen abundance in the peatlands** of northern Alberta: implications for boreal caribou. EcoScience 13:469-474
114. **Descamps, S**., S. Boutin, D. Berteaux and J-M Gaillard. 2006. Best squirrels trade a long life for an early reproduction. Proceedings of the Royal Society B 273:2369-2374
113. Lee, P and S. Boutin. 2006. Persistence and developmental transition of wide seismic lines in the western Boreal Plains of Canada. Journal of Environmental Management 78:240-250
112. Macdonald, S.E., B. Eaton, C.S. Machtans, C. Paszkowski, S. Hannon, and S. Boutin. 2006. Is forest close to lakes ecologically unique? Analysis of vegetation, small mammals, amphibians, and songbirds. Forest Ecology and Management 223:1-17

---

111. **LaMontagne, J.M., S. Peters**, and S. Boutin. 2005. A visual index for estimating cone production for individual white spruce trees. Canadian Journal of Forest Research 35:3020-3026
110. Humphries. M.M., S. Boutin, D.W. Thomas, J.D. Ryan, C. Selman, A.G. McAdam, D. Berteaux, and J.R. Speakman. 2005. Expenditure freeze: the metabolic response of small mammals to cold environments. Ecology Letters 8:1326-1333
109. **McLoughlin, P.D., J.D. Dunford**, and S. Boutin. 2005. Relating predation mortality to broad scale habitat selection. Journal of Animal Ecology 74:701-707
108. **Bayne, E.M**., S. Boutin, **B. Tracz, and K. Charest**. 2005. Functional and numerical responses of Ovenbirds (*Seiurus aurocapilla*) to changing seismic exploration practices in Alberta's boreal forest. EcoScience 12:216-222
107. **Fisher, J.T**, S. Boutin, and S.J. Hannon. 2005. The protean relationship between boreal forest landscape structure and red squirrel distribution at multiple spatial scales. Landscape Ecology 20:73-82

106. **Wheatley, M**., J.T. Fisher, K. Larsen, J. Litke, and S. Boutin. 2005. Using GIS to relate small mammal abundance and landscape structure at multiple spatial extents: Northern flying squirrels in Alberta, Canada. Journal of Applied Ecology 42:577-586
105. Smyth, C., J. Schieck, S. Boutin, and S. Wasel. 2005. Influence of stand size on pattern of live trees in mixed wood stands following wildfire. The Forestry Chronicle 81:125-132
104. Bayne, E.M., S.L. Van Wilgenburg, S. Boutin, and K.A. Hobson. 2005. Modeling and field- testing of Ovenbirds (*Seiurus aurocapillus*) responses to boreal forest dissection by energy sector development at multiple spatial scales. Landscape Ecology 20:203-216

---

103. **James, A**., S. Boutin, D. Hebert, A.B. Rippin, and A. Blair. 2004. Spatial separation of caribou from moose and its relation to predation by wolves. Journal of Wildlife Management 68(4):799-809
102. Angelstam, P., S. Boutin, F. Schmiegelow, M-A. Villard, P. Drapeau, G. Host, J. Innes, G. Isachenko, T. Kuuluvainen, M. Mönkkönen, J. Niemelä, G. Niemi, J-M. Roberge, J. Spence, and D. Stone. 2004. Targets for boreal forest biodiversity conservation - a rationale for macroecological research and adaptive management. Ecological Bulletins 51:487-509
101. N.C. Stenseth, A. Shabbar, K-S. Chan, S. Boutin, E. K. Rueness, D. Ehrich, J.W. Hurrell, O.C. Lingjaerde, and K. S. Jakobsen. 2004. Snow conditions may create an invisible lynx-barrier. Proceedings of the National Academy of Sciences 101(29):10632-10634
100. D. Berteaux, D. Réale, A.G. McAdam, and S. Boutin. 2004. "Keeping pace with fast climate change: can Arctic life count on evolution?" Integrative and Comparative Biology 44:140-151
99. Lee, P., C. Smyth and S. Boutin. 2004. Quantitative review of riparian buffer width guidelines from Canada and the United States. Journal of Environmental Management 70:165-180
98. Macdonald, E., **C.J. Burgess**, G.J. Scrimgeour, S. Boutin, S. Reedyk, and B. Kotak. 2004. Should riparian buffers be part of forest management based on emulation of natural disturbance? Forest Ecology and Management 187:185-196.
97. **McAdam, A.G.** and S. Boutin. 2004. Maternal effects and the response to selection in red squirrels. Proceedings of the Royal Society of London, Series B 271:75-79
96. **McLoughlin, P.D**., D. Paetkau, M. Duda, and S. Boutin. 2004. Genetic diversity and relatedness of boreal caribou populations in western Canada. Biological Conservation 118:593-598
95. **Peters, S.H**., S.E. MacDonald, S. Boutin, and **R.A. Moses**. 2004. Post-dispersal seed predation of white spruce in cutblocks in the boreal mixedwoods. Canadian Journal of Forest Research 34:907-915
94. Stenseth, N.C., D. Ehrich, E. K. Rueness, O. C. Lingaerde, K. Chan, S. Boutin, M. O'Donoghue, D. Robinson, H. Viljugrein, and K. S. Jakobsen. 2004. The effect of climatic forcing on population synchrony and genetic structuring of the Canadian lynx. Proceedings of the National Academy of Sciences 101:6056-6061

---

93. **McAdam, A.G**. and S. Boutin. 2003. Variation in viability selection among cohorts of juvenile red squirrels (*Tamiasciurus hudsonicus*). Evolution 57:1689-1697
92. **McAdam, A.,** and S. Boutin. 2003. Effects of food abundance on genetic and maternal variation in the growth rate of juvenile red squirrels. Journal of Evolutionary Biology 16(6):1249-1256

91. **McLoughlin, P**., E. Dzus, B. Wynes, and S. Boutin. 2003. Declines in populations of woodland caribou. Journal of Wildlife Management 67:755-761
90. **Peters, S.H**., S. Boutin, and S.E. Macdonald. 2003. Pre-dispersal seed predation of white spruce cones in logged boreal mixedwood forest. Canadian Journal of Forest Research 33:33-40
89. Réale, D., **A.G. McAdam**, S. Boutin, and D. Berteaux. 2003. Genetic and plastic responses of a northern mammal to climate change. Proceedings of the Royal Society London B 270:591-596
88. Réale, D., D. Berteaux, **A.G. McAdam**, and S. Boutin. 2003. Lifetime selection heritable life-history traits in a natural population of red squirrels. Evolution 57:2416-2423
87. Rueness, E.K., N.C. Stenseth, M. O'Donoghue, S. Boutin, H. Ellegren, and K. Jakobsen. 2003. Ecological and genetic spatial structuring in the Canadian lynx. Nature 425:69-72.
86. Schneider, R.R., J.B. Stelfox, and S. Boutin. 2003. Managing the cumulative impacts in the Western Canadian Sedimentary Basin: a modeling approach. Conservation Ecology 71(1):8

---

85. **McLoughlin, P**., M. Taylor, H.D. Cluff, R.J. Gau, R. Mulders, R.L. Case, S. Boutin, and F. Messier. 2002. Demography of barren-ground grizzly bears. Canadian Journal of Zoology 81: 294-301
84. Hannon, S. J., C. A. Paszkowski, S. Boutin, **J. DeGroot**, S. E. Macdonald, M. Wheatley and B. R. Eaton. 2002. Abundance and species composition of amphibians, small mammals and songbirds in riparian forest buffer strips of varying widths in the boreal mixedwood of Alberta. Canadian Journal of Forest Research 32(10):1784-1800
83. **Dyer, S.J**., J.P. O'Neill, S.M. Wasel, and S. Boutin. 2002. Quantifying barrier effects of roads and seismic lines on movements of female woodland caribou in northeastern Alberta. Canadian Journal of Zoology 80:839-845
82. **Wheatley, M.T**., Larsen K.W. and S. Boutin. 2002. Does density reflect habitat quality for North American red squirrels during a spruce-cone failure? Journal of Mammalogy 83(3):716-727
81. **Anderson, E. M.** and S. Boutin. 2002. Edge effects on survival and behaviour of juvenile red squirrels (*Tamiasciurus hudsonicus).* Canadian Journal of Zoology 80(6):1038-1046
80. **McAdam, A.G**., S. Boutin, D. Réale, and D. Berteaux. 2002. Maternal effects and the potential for evolution in a natural population of animals. Evolution 56(4):846-851
79. Boutin, S. and D. Hebert. 2002. Landscape ecology and forest management: developing an effective partnership. Ecological Applications 12(2):390-397

---

78. Moses, R.A. and S. Boutin. 2001. The influence of clear-cut logging and residual leave material on small mammal populations in aspen-dominated boreal mixedwoods. Canadian Journal of Forest Research 31:483-495
77. **Dyer, S.J**., J.P. O'Neill, S.M. Wasel, and S. Boutin. 2001. Avoidance of industrial development by woodland caribou. Journal of Wildlife Management 65(3):531-542
76. Krebs, C. J., R. Boonstra, S. Boutin, and A.R.E. Sinclair. 2001. What drives the ten-year cycle of snowshoe hares? BioScience 51(1):25-36
75. Krebs, C.J., R. Boonstra, V. Nams, M. O'Donoghue, K.E. Hodges, and S. Boutin. 2001. Estimation of snowshoe hare population density from pellet plots – a further evaluation. Canadian Journal of Zoology 79:1-4

---

74. Boutin, S., **K.W. Larsen**, and **D. Berteaux**. 2000. Anticipatory parental care: acquiring resources for offspring prior to conception. Proceedings of the Royal Society London B 267:2081-2085

73. **Humphries, M.M.** and S. Boutin. 2000. The determinants of optimal litter size in free ranging squirrels. Ecology 81:2867-2877

72. Sinclair, A.R.E., C.J. Krebs, J.M. Fryxell, R. Turkington, S. Boutin, R. Boonstra, P. Seccombe-Hett, P. Lundberg and L. Oksanen. 2000. Testing hypotheses of trophic level interactions: a boreal forest ecosystem. Oikos 89:313-328

71. **Berteaux, D.** and S. Boutin. 2000. Breeding dispersal in female North American red squirrels. Ecology 81:1311-1326

---

70. Stenseth, N.C., K.S. Chan, R. Boonstra, S. Boutin, C.J. Krebs, E. Post, M. O'Donoghue, N.G. Yoccoz, M.C. Forchhammer, and J.W. Hurrell. 1999. Common dynamic structure of Canada lynx populations within three climatic regions. Science 285:1071-1073

69. **Humphries, M.M.** and S. Boutin. 1999. Mass dependent reproduction or reproduction-dependent mass? A comment on body mass and first-time reproduction in female sciurids. Canadian Journal of Zoology 77:171-173

---

68. Stenseth, N.C., W. Falck, K.S. Chan, O.N. Bjornstad, M. O'Donoghue, H. Tong, R. Boonstra, S. Boutin, C.J. Krebs, and N.G. Yoccoz. 1998. From patterns to processes: Phase- and density-dependencies in the Canadian lynx cycle. Proceedings of Natural Academy of Sciences. 95(26):15430-15435

67. Turkington, R., E. John, C.J. Krebs, M.R.T. Dale, **V.O. Nams**, R. Boonstra, S. Boutin, K. Martin, A.R.E. Sinclair, and J.M.N. Smith. 1998. The effects of NPK fertilization for nine years on boreal forest vegetation in northwestern Canada. Journal of Vegetation Science 9:333-346

66. Krebs, C.J., A.R.E Sinclair, R. Boonstra, S. Boutin, K. Martin, and J.M.N. Smith. 1998. Community dynamics of vertebrate herbivores - how can we untangle the web? Pp 447-473 *In* The 38th Symposium of the British Ecological Society. *Eds* H. Olff, V.K. Brown and R.H. Drent.

65. **Marshal, J**. and S. Boutin. 1998. Power analysis of functional responses. Journal of Wildlife Management 93(1):396-402

64. O'Donoghue, M., S. Boutin, C.J. Krebs, **D.L. Murray**, and E.J. Hofer. 1998. Behavioural responses of coyotes and lynx to the snowshoe hare cycle. Oikos 82:169-183

63. **Bradshaw, C.J.A**., S. Boutin, and D.M. Hebert. 1998. Energetic implications of disturbance caused by petroleum exploration. Canadian Journal of Zoology 76(7):1319-1324

62. **Becker, C.D.,** S. Boutin, and **K.W. Larson**. 1998. Constraints of first reproduction in North American red squirrels. Oikos 81:81-92

61. **Moses, R.A**., S. Boutin, and T. Tefari. 1998. Sex-biased mortality in woodrats occurs in the absence of parental intervention. Animal Behaviour 55:563-571

60. O'Donoghue, M., S. Boutin, C.J. Krebs, G. Zuleta, D.L. Murray, and E.J. Hofer. 1998. Functional responses of coyotes and lynx to the snowshoe hare cycle. Ecology 79:1193-1208

---

59. **Bradshaw, C.J.A.**, S. Boutin, and D.M. Hebert. 1997. Effects of petroleum exploration on woodland caribou in Northeastern Alberta. Journal of Wildlife Management 61:1127-1133

58. O'Donoghue, M., S. Boutin, C.J. Krebs, and E.J. Hofer. 1997. Numerical responses of coyotes and lynx to the snowshoe hare cycle. Oikos 80:150-162
57. **Stuart-Smith, A.K**., **C.J.A. Bradshaw**, S. Boutin, D.M. Hebert, and A.B. Rippin. 1997. Woodland caribou relative to landscape patterns in northeastern Alberta. Journal of Wildlife Management 61:622-633
56. **Ouellet, J.P**., D.C. Heard, S. Boutin, and R. Mulders. 1997. A comparison of body condition and reproduction of caribou on two predator-free arctic islands. Canadian Journal of Zoology 75:11-17
55. **Larson K.W., C. D. Becker**, S. Boutin, and **M. Blower**. 1997. Effects of hoard manipulations of life history and reproductive success of female red squirrels (*Tamiasciurus hudsonicus).* Journal of Mammalogy 78:192-203

---

54. **Humphries, M.M**. and S. Boutin. 1996. Reproductive demands and weight gains: a paradox in female red squirrels (*Tamiasciurus hudsonicus*). Journal of Animal Ecology 65:332-338
53. **Mowat, G.,** S. Boutin, and G.B. Slough. 1996. Using placental scar counts to estimate litter size and pregnancy rates in lynx. Journal of Wildlife Management 60:430-440
52. **Mowat, G**., G.B. Slough, and S. Boutin. 1996. Lynx recruitment during a snowshoe hare population decline in the southwest Yukon. Journal of Wildlife Management 60:441-452

---

51. **Larsen, K.W**. and S. Boutin. 1995. Exploring territory quality in the North American red squirrel through removal experiments. Canadian Journal of Zoology 73:1115-1122
50. Krebs, C.J., S. Boutin, R. Boonstra, A.R.E. Sinclair, J.N.M. Smith, M.R.T. Dale, K. Martin, and R. Turkington. 1995. Impact of food and predation on the snowshoe hare cycle. Science 269:1112-1115 [Outstanding Publication of the Year in Wildlife Ecology and Management (Wildlife Society)]
49. **Bradshaw, C.J.A**., D.M. Hebert, A.B. Rippin, and S. Boutin. 1995. Winter peatland habitat selection by woodland caribou in northeastern Alberta. Canadian Journal of Zoology 73:1567-1574
48. **Murray, D.L**., S. Boutin, M. O'Donoghue, and V.O. Nams. 1995. Hunting behavior of a sympatric felid and canid in relation to vegetation cover. Animal Behavior 50:1203-1210
47. Boutin, S., C.J. Krebs, A.R.E. Sinclair, J.N.M. Smith, R. Boonstra, K. Martin, S. J. Hannon, M.R.T. Dale, R. Turkington, M. O'Donoghue, F. Doyle, C. Doyle, M. Blower, L. Hofer, S. Schweiger, V. Nams. 1995. Population changes of the vertebrate community during a snowshoe hare cycle in Canada's boreal forest. Oikos 74:69-80
46. Boutin, S. 1995. Testing predator-prey theory by studying fluctuating populations of small mammals. Wildlife Research 22:89-100
45. **Schweiger, S**. and S. Boutin. 1995. The effects of winter food addition on the population dynamics of *Clethrionomys rutilus*. Canadian Journal of Zoology 73:419-426
44. O'Donoghue M. and S. Boutin. 1995. Does reproductive synchrony affect juvenile survival rates of northern mammals? Oikos 74:115-121
43. **Stuart-Smith, A.K**. and S. Boutin. 1995. Predation of red squirrel during a snowshoe hare decline. Canadian Journal of Zoology 73:713-722
42. **Stuart-Smith, A.K**. and S. Boutin. 1995. Behavioural differences between surviving and depredated juvenile red squirrels. Ecoscience 2:34-40
41. Boonstra, R., J.M. Eadie, C.J. Krebs, and S. Boutin. 1995. Limitations of far infrared thermal imaging in locating birds. Journal of Field Ornithology 66:192-198

---

40. **Stuart-Smith, A. K.** and S. Boutin. 1994. Costs of escalated territory defence in red squirrels. Canadian Journal of Zoology 76:1162-1167
39. **Ouellet, J-P**., D.C. Heard, and S. Boutin. 1994. Responses to simulated grazing and browsing of vegetation available to caribou in the Arctic. Canadian Journal of Zoology 72:1426-1435
38. **Murray, D**., S. Boutin, and M. O'Donoghue. 1994. Winter habitat selection by lynx and coyotes in relation to snowshoe hare abundance. Canadian Journal of Zoology 72:1444-1451
37. Boonstra, R., J.M. Eadie, C.J. Krebs, and S. Boutin. 1994. Finding animals using infrared thermal imaging. Journal of Mammalogy 75:1063-1068
36. **Larsen, K.W.** and S. Boutin. 1994. Movements, settlement, and survival in red squirrel (*Tamiasciurus hudsonicus*) offspring. Ecology 75:214-223

---

35. Boutin, S., Z. Tooze, and **K. Price**. 1993. Post-breeding dispersal of female red squirrels (*Tamiasciurus hudsonicus*): the effect of local vacancies. Behavioral Ecology 4:151-155
34. Boutin, S. and **K.W. Larsen**. 1993. Does food availability affect growth and survival of males and females differently in a promiscuous small mammal, *Tamiasciurus hudsonicus*. Journal of Animal Ecology 62:364-370
33. **Price, K**. and S. Boutin. 1993. Territorial bequeathal by red squirrel mothers. Behavioral Ecology 4:144-150
32. **Ouellet, J-P**., D.C. Heard, and S. Boutin. 1993. Range impacts following the introduction of caribou on Southampton Island, Northwest Territories, Canada. Arctic 25:136-141
31. Sinclair, A.R.E., J.M. Gosline, G. Holdsworth, C.J. Krebs, V.O. Nams, S. Boutin, J.N.M. Smith, R. Boonstra, and M.R.T Dale. 1993. Can the solar cycle and climate synchronize the snowshoe hare cycle in Canada? Evidence from tree rings and ice cores. American Naturalist 14:173-198
30. **Simpson M.R**. and S. Boutin 1993. Muskrat life history: a comparison of a northern and southern population. Ecography 16:5-10

---

29. Boutin, S. 1992. Predation and moose population dynamics: a critique. Journal of Wildlife Management 56:116-127

---

28. **Murray, D.** and S. Boutin. 1991. The influence of snow on lynx and coyote movements in southwestern Yukon: does morphology affect behaviour? Oecologia 88:463-469
27. **Nams, V.O.** and S. Boutin. 1991. What is wrong with error polygons? Journal of Wildlife Management 55:172-176
26. Gilbert B.S. and S. Boutin. 1991. Effect of moonlight on winter activities of snowshoe hares. Arctic and Alpine Research 23:61-65

---

25. **Price, K.**, S. Boutin, and R.C. Ydenberg. 1990. Intensity of territorial defence in red squirrels: an experimental test of the asymmetric war of attrition. Behavioural Ecology and Sociobiology 27:217-222
24. Boutin, S. 1990. Food supplementation experiments with terrestrial vertebrates: Patterns, problems, and the future. Canadian Journal of Zoology 68:203-220

23. Dublin, H.T., A.R.E. Sinclair, S. Boutin, E. Anderson, M. Jago, and P. Arcese. 1990. Does competition regulate populations? Further evidence from Serengeti, Tanzania. Oecologia 82:283-288

22. Boutin, S. and **D. Cluff**. 1989. Coyote prey choice: optimal or opportunistic foraging?: a comment. Journal of Wildlife Management 53:663-667

21. **Simpson, M.R.** and S. Boutin. 1989. Muskrat population responses to harvest on Old Crow Flats (Yukon). Canadian Field Naturalist 103:420-422

20. Boutin, S., R.A. Moses, and **M.J. Caley**. 1988. The relationship between juvenile survival and litter size in wild muskrats (*Ondatra zibethicus*). Journal of Animal Ecology 57:455-462

19. Boutin, S. and **S. Schweiger**. 1988. Manipulation of intruder pressure in red squirrels: Effects on territory size and acquisition. Canadian Journal of Zoology 66:2270-2274

18. Moses, R.A. and S. Boutin. 1988. Problems associated with the use of the molar fluting technique: a response. Wildlife Society Bulletin 16:90-93

17. Sinclair, A.R.E., C.J. Krebs, J.N.M. Smith, and S. Boutin. 1988. Population biology of snowshoe hares. III. Nutrition, plant secondary compounds and food limitation. Journal of Animal Ecology 57:787-806

16. **Caley, M.J**., S. Boutin, and R.A. Moses. 1988. Male biased reproduction and sex-ratio adjustments in muskrats. Oecologia 74:501-506

15. Moses, R.A. and S. Boutin. 1987. Aging raccoons in Ontario by logistics regression on pelt sizes. Journal of Wildlife Management 51:820-824

14. Krebs, C.J., B.S. Gilbert, S. Boutin, and R. Boonstra. 1987. Estimation of snowshoe hare population density from turd transects. Canadian Journal of Zoology 65:565-567

13. **Caley, M.J**. and S. Boutin. 1987. Sibling and neighbour recognition in wild juvenile muskrats. Animal Behavior 35:60-66

12. Boutin, S. and C.J. Krebs. 1986. Estimating survival rates of snowshoe hares. Journal of Wildlife Management 50:592-594

11. Boutin, S., C.J. Krebs, A.R.E. Sinclair, and J.N.M. Smith. 1986. Proximate causes of losses in a snowshoe hare population. Canadian Journal of Zoology 64:606-610

10. Krebs, C.J., B.S. Gilbert, S. Boutin, A.R.E. Sinclair, and J.N.M. Smith. 1986. Population biology of snowshoe hares: I Demography of populations in the southern Yukon, 1976-1984. Journal of Animal Ecology 55:963-982

9. Moses, R. and S. Boutin. 1986. Molar fluting and pelt primeness techniques for distinguishing age classes of muskrats: a reevaluation. Wildlife Society Bulletin 14:403-406

8. **Price, K., K. Broughton**, S. Boutin, and A.R.E. Sinclair. 1986. Territory size and ownership in red squirrels: response to removals. Canadian Journal of Zoology 64:1144-1147

7. Krebs, C.J., S. Boutin, and B.S. Gilbert. 1986. A natural feeding experiment on a declining snowshoe hare population. Oecologia 70:194-197

6. Boutin, S., B.S. Gilbert, C.J. Krebs, A.R.E. Sinclair, and J.N.M. Smith. 1985. The role of dispersal in the population dynamics of snowshoe hares. Canadian Journal of Zoology 63:106-115

5. **Caley, M.J**. and S. Boutin. 1985. Infanticide in wild populations of *Ondatra zibethicus* and *Microtus pennsylvanicus*. Animal Behavior 33:1036-1037

---

4. Boutin, S. 1984. The effects of conspecifics on juvenile survival and recruitment of snowshoe hares. Journal of Animal Ecology 53:923-937
3. Boutin, S. 1984. Home range size and methods of estimating density of snowshoe hares. III International Theriological Congress, August 1982, Helinski. Acta Zoologica Fennica 171:275-278
2. Boutin, S. 1984. The effects of late winter food addition on numbers and movements of snowshoe hares. Oecologia 62:393-400

---

1. Boutin, S. 1980. Effect of spring removal experiments on the spacing behaviour of female snowshoe hares. Canadian Journal of Zoology 58:2167-2174

An additional 22 papers were published by students while under my supervision. While I was not an author on them, I contributed to varying degrees via intellectual input, writing and editing, and research funds.

Books and Book Chapters

Krebs, C.J., **Boutin, S.** and R. Boonstra. (*Eds*). 2001. Ecosystem Dynamics of the Boreal Forest: The Kluane Project. Oxford University Press, New York.

Boutin, S. 2005. Top carnivores and biodiversity in the boreal forest. *In* Large carnivores and the conservation of biodiversity. *Eds.* J.C. Ray, K.H. Redford, R.S. Steneck, and J. Berger. Island Press.

Lee, P., Smyth, C., and **S**. **Boutin**. 2002. Large-scale planning of live treed residuals based in a natural disturbance succession template for landscapes. *In* Ecological basis for stand management: A synthesis of ecological responses to wildfire and harvesting. *Ed.* Song, S.J. Alberta Research Council Inc., Vegreville, AB.

Boutin, S, C.J. Krebs, R. Boonstra, and A.R.E. Sinclair. 2002. The role of the lynx-hare cycle in boreal forest community dynamics. *In* Mammal Community Dynamics in Coniferous Forests of Western North America. *Eds.* C.J. Zabel and R.G. Anthony. Cambridge University Press, New York

Boutin, S., C.J. Krebs, R. Boonstra, A.R.E. Sinclair, and K.E. Hodges. 2002. Understanding the snowshoe hare cycle through large-scale experiments. *In* Population cycles: the case for trophic interactions. *Ed.* A.A. Berryman. Oxford University Press.

Boutin, S., C.J. Krebs, V. Nams, A.R.E. Sinclair, R. Boonstra, M. O'Donoghue, and C. Doyle. 2001. Experimental design and the practical problems of implementation. Chapter 4 *In* Ecosystem Dynamics of the Boreal Forest: The Kluane Project. *Eds.* Krebs, C.J., **S. Boutin,** and R. Boonstra. Oxford University Press, New York.

Boonstra, R., **S. Boutin**, A. Byrom, T. Karels, A. Hubbs, K. Stuart-Smith, M. Blower, and S. Antpoehler. 2001. The role of red squirrels and arctic ground squirrels. Chapter 9 *In* Ecosystem Dynamics of the Boreal Forest: The Kluane Project. *Eds.* Krebs, C.J., **S. Boutin,** and R. Boonstra. Oxford University Press, New York.

O'Donoghue, M., **S. Boutin**, D.L. Murray, C.J. Krebs, E.J. Hofer, U. Breitenmoser, C. Breitenmoser-Würsten, G. Zuleta, C. Doyle, and V. Nams. Coyotes and lynx. Chapter 13 *In* Ecosystem Dynamics of the Boreal Forest: The Kluane Project. *Eds.* Krebs, C.J., **S. Boutin,** and R. Boonstra. Oxford University Press, New York.

O'Donoghue, M., **S. Boutin**, E.J. Hofer, and R. Boonstra. Other mammalian predators. Chapter 14 *In* Ecosystem Dynamics of the Boreal Forest: The Kluane Project. *Eds.* Krebs, C.J., **S. Boutin,** and R. Boonstra. Oxford University Press, New York.

Sinclair, A.R.E., C.J. Krebs, R. Boonstra, **S. Boutin**, and R. Turkington. 2001. Testing hypotheses of community organization for the Kluane ecosystem. Chapter 17 *In* Ecosystem Dynamics of the Boreal Forest: The Kluane Project. *Eds.* Krebs, C.J., **S. Boutin,** and R. Boonstra. Oxford University Press, New York.

Choquenot, D., C.J. Krebs, A.R.E. Sinclair, R. Boonstra, and **S. Boutin.** 2001. Vertebrate community structure in the boreal forest: modelling the effects of trophic interaction. Chapter 18 *In* Ecosystem Dynamics of the Boreal Forest: The Kluane Project. *Eds.* Krebs, C.J., **S. Boutin,** and R. Boonstra. Oxford University Press, New York.

Krebs, C.J., R. Boonstra, **S. Boutin**, and A.R.E. Sinclair. 2001. Conclusions and future directions. *In* Ecosystem Dynamics of the Boreal Forest: The Kluane Project. *Eds.* Krebs, C.J., **S. Boutin,** and R. Boonstra. Oxford University Press, New York.

Larsen, K. and **S. Boutin**. 1998. Sex-unbiased dispersal in red squirrels. *In* Ecology and evolutionary biology of tree squirrels. *Eds.* M.A. Steele, J.F. Merritt, and D.A. Zegers. Proceedings of the International Colloquium on the Ecology of Tree Squirrels. Carnegie Museum Special Publications.

Hebert, D. and **S. Boutin**. 1998. Integrating strategies to retain ecological variability. Pp 538-541 *In* Linking protected areas with working landscapes conserving biodiversity. *Eds.* N.W.P. Munro and J.H.M. Willison. Proceedings of the Third International Conference on Science and Management of Protected Areas. Science and Management of Protected Areas Association, Wolfville, Nova Scotia, Canada.

Krebs, C.J., A.R.E. Sinclair, and **S. Boutin**. 1995. Vertebrate community dynamics in the Boreal Forest of North-western Canada. Pp. 155-161 *In* Frontiers and Applications of Population Ecology. *Eds.* Floyd, R.B., A.W. Sheppard, and P.J. De Barro. CSIRO Publishing, Collingwood, Victoria, Australia.

Krebs, C.J., R. Boonstra, **S. Boutin**, M. Dale, S. Hannon, K. Martin, A.R.E. Sinclair, J.N.M. Smith, and R. Turkington. 1992. What drives the snowshoe hare cycle in Canada's Yukon? Pp. 886-896. *In* Wildlife 2001: Populations. *Eds.* D. McCullough and R. Barrett.

Boutin, S. 1988. Biology and management of muskrats. Chapter 23. *In* Wild fur management and conservation. *Eds.* M. Novak, and J.A. Baker. Ontario Trappers' Association and Ontario Ministry of Natural Resources.