



NATIONAL COUNCIL FOR AIR AND STREAM IMPROVEMENT

**STATE OF KNOWLEDGE AND ANALYSIS
OF CURRENT RESEARCH ON WOODLAND
CARIBOU IN CANADA**

**TECHNICAL BULLETIN NO. 939
SEPTEMBER 2007**

**by
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PRESIDENT'S NOTE

Concerns have been raised by stakeholders regarding the interrelationships of Canadian forest management and caribou. These concerns are rooted in the recognition that five populations of forest-dwelling caribou are listed under the Canadian Species at Risk Act, with some herds in these populations experiencing range retraction and population declines.

Given the reliance of listed caribou populations on forested areas in Canada, the forest industry has been increasingly engaged in research and on-the-ground management to mitigate the potential influence of forest harvesting on caribou. To enable the identification of effective future research pathways, it is necessary to synthesize current knowledge and take stock of ongoing research.

This report reviews the basics of caribou taxonomy, biology, and ecology and summarizes current scientific information about factors affecting populations of forest-dwelling caribou. It also summarizes the findings of two previous NCASI reports on caribou that identified important gaps in scientific knowledge and ongoing research. By comparing these gaps with a current inventory of caribou research projects in Canada, the report further estimates which of the gaps are being addressed at present and which should be examined by future research efforts.

The findings here suggest that while some research areas appear to be adequately addressed by researchers in the field, further work needs to be done. Several areas, such as woodland caribou basic ecology and predator ecology, are being addressed in substantial numbers of research projects. Other areas, such as caribou energetics and nutrition, appear to be poorly understood with few projects addressing them. This report suggests that while current projects are being completed, future research planning and funding should be directed towards these topics, which have significant potential to influence our ability to manage and conserve this species.

A handwritten signature in black ink, appearing to read "Ron Yeske", is written over a light blue horizontal line.

Ronald A. Yeske

September 2007

MOT DU PRÉSIDENT

Depuis quelques années, les groupes d'intérêt s'interrogent sur les relations de cause à effet entre les méthodes d'aménagement des forêts canadiennes et le caribou. Leurs préoccupations reposent sur le fait que cinq populations de caribou des bois figurent sur la liste de la *Loi canadienne sur les espèces en péril* et que certaines hardes connaissent une rétraction de leur aire de répartition et un déclin de leur population.

Compte tenu que les populations de caribous sur cette liste dépendent des forêts canadiennes pour se nourrir, l'industrie forestière a entrepris de plus en plus de projets de recherche et d'activités d'aménagement sur le terrain afin d'atténuer l'influence potentielle de la récolte forestière sur le caribou. Afin d'aider l'industrie à définir l'orientation à donner à la recherche future de façon qu'elle soit efficace, il est essentiel de faire la synthèse des connaissances actuelles et de faire le point sur la recherche en cours.

Le présent rapport passe en revue les notions de base en matière de taxonomie, de biologie et d'écologie du caribou et résume l'information scientifique existante sur les facteurs qui agissent sur les populations de caribous des bois. Il contient également un résumé des conclusions de deux rapports publiés antérieurement par NCASI qui faisaient ressortir d'importantes lacunes dans les connaissances scientifiques et dans les orientations de recherche sur le caribou. En comparant ces lacunes avec l'inventaire des projets de recherche en cours sur le caribou au Canada, le présent rapport permet de dégager les lacunes qui sont comblées par les projets de recherche existants et celles sur lesquelles devrait s'orienter la recherche future.

Les conclusions du présent rapport semblent indiquer qu'il faudra mener d'autres travaux même si certains domaines de recherche semblent bien couverts par les chercheurs sur le terrain. Plusieurs domaines, notamment l'écologie de base du caribou des bois et l'écologie des prédateurs, sont abordés dans un grand nombre de projets de recherche. Par contre, d'autres domaines, tels que le bilan énergétique et le régime alimentaire du caribou, semblent mal connus, et il existe peu de projets portant sur ces questions. Dans le présent rapport, on suggère d'orienter le programme de recherche futur et son financement vers ces deux domaines avant que se termine les projets en cours car ces deux domaines ont le potentiel d'influencer considérablement notre capacité à gérer et à conserver cette espèce.



Ronald A. Yeske

Septembre 2007

STATE OF KNOWLEDGE AND ANALYSIS OF CURRENT RESEARCH ON WOODLAND CARIBOU IN CANADA

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ABSTRACT

Caribou or *Rangifer tarandus* is a species of deer that lives in tundra, taiga, and forest habitats at high latitudes in the northern hemisphere, including in Russia and Scandinavia, Alaska, Idaho and Washington states, and Canada. The species' common name is caribou in North America and reindeer in Europe and Asia. Five populations of woodland caribou (*Rangifer tarandus caribou*), a subspecies of caribou, are listed under the Canadian Species at Risk Act, with one endangered, two threatened, one special concern, and one not at risk. Some areas are experiencing range retraction and population declines. Causes of declines and range retractions remain poorly understood, and are hypothesized to involve forest management, industrial disturbance, predator-prey dynamics, encroachment by other ungulates, climate change, or combinations of several factors. Scientific research into the biology and ecology of this species is substantial, but incomplete. While a good understanding of the species' basic ecology has been documented, many questions remain unanswered. The current status of a quarter of the herds in listed populations in Canada remains unknown. Moreover, information about summer and fall foraging and nutritional requirements (factors that are well known to have significant effects on all ungulates in which they have been examined) is virtually absent from woodland caribou literature. Literature reviews examined here suggest a range of areas in which more effort is needed to fill gaps and better equip recovery efforts. Using a survey of researchers in Canada, this report compares current knowledge gaps with current research projects. While several research areas (e.g., basic ecology, predation) appear to be well addressed by current projects, research on woodland caribou energetics and nutrition is under-represented among ongoing projects. This suggests potential avenues for future research planning, both of which have the potential to influence future management strategies and recovery efforts.

KEYWORDS

boreal, caribou, forest management, gap analysis, mountain caribou, *Rangifer tarandus caribou*, research, woodland caribou

RELATED NCASI PUBLICATIONS

Technical Bulletin No. 934. (June 2007). *A review of ungulate nutrition and the role of top-down and bottom-up forces in woodland caribou population dynamics.*

Technical Bulletin No. 893 (December 2004). *Ecological interactions among caribou, moose, and wolves: Literature review.*

ÉTAT DES CONNAISSANCES ET ANALYSE DE LA RECHERCHE ACTUELLE SUR LE CARIBOU DES BOIS DU CANADA

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SEPTEMBRE 2007

RÉSUMÉ

Le caribou ou *Rangifer tarandus* est un membre de la famille des cervidés qui vit dans la toundra, la taïga et dans les habitats forestiers des hautes latitudes de l'hémisphère nord, notamment en Russie, en Scandinavie, dans les États de l'Alaska, de l'Idaho et de Washington, et au Canada. On l'appelle communément « caribou » en Amérique du Nord et « renne » en Europe et en Asie. Cinq populations de caribou des bois (*Rangifer tarandus caribou*), une des sous-espèces du caribou, figurent sur la liste de la *Loi canadienne sur les espèces en péril*. Leur statut est le suivant : 1 de ces populations est en voie de disparition, 2 sont menacées, 1 est préoccupante et 1 n'est pas en péril. Dans certaines régions, on constate une rétraction de leur aire de répartition et un déclin des populations, mais on comprend peu les causes de ces phénomènes. Certains font l'hypothèse que l'aménagement des forêts, les perturbations industrielles, la dynamique prédateur-proie, l'empiètement du territoire par d'autres ongulés, les changements climatiques ou une combinaison de plusieurs facteurs interviennent dans le déclin et la rétraction des caribous des bois. La recherche scientifique sur la biologie et l'écologie de cette espèce est abondante, mais elle est incomplète. La communauté scientifique comprend bien l'écologie de base de cette espèce et a bien documenté ces connaissances. Cependant, de nombreuses questions demeurent sans réponses. La situation actuelle d'un quart des hardes de caribous au Canada dont les populations figurent sur la liste de la LEP reste inconnue. De plus, l'information sur leurs activités d'alimentation estivales et automnales et sur leurs besoins nutritionnels (facteurs bien connus qui ont un impact important sur les ongulés) est à peu près inexistante dans la littérature. La revue de la littérature effectuée dans la présente étude a permis de dégager diverses avenues de recherche où il faudra concentrer les efforts pour combler les lacunes et se doter d'outils qui serviront aux efforts de rétablissement des populations. Dans le présent rapport, on compare les lacunes en matière de connaissances actuelles avec les projets de recherche en cours et ce, après avoir réalisé une enquête auprès de chercheurs au Canada. Bien que plusieurs projets de recherche actuels semblent porter sur les bonnes questions (par ex. écologie de base, prédation), la recherche sur le bilan énergétique et le régime alimentaire du caribou des bois semblent être sous-représentée parmi les projets en cours. Ce constat montre qu'il existe encore deux domaines de recherche à considérer quand viendra le temps de planifier la recherche sur le caribou des bois, domaines qui ont le potentiel d'influencer les futures stratégies de gestion de l'industrie et les efforts de rétablissement des populations.

MOTS-CLES

aménagement forestier, analyse des lacunes, boréal, caribou, caribou de montagne, caribou des bois, *Rangifer tarandus caribou*, recherche

AUTRES PUBLICATIONS DE NCASI DANS CE DOMAINE

Bulletin technique n° 934. (juin 2007). *Revue des effets du régime alimentaire saisonnier sur les dynamiques de populations de caribous des bois.*

Bulletin technique n° 893 (décembre 2004). *Les interactions écologiques entre le caribou, l'orignal et le loup : une revue de la littérature.*

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STATE OF KNOWLEDGE AND ANALYSIS OF CURRENT RESEARCH ON WOODLAND CARIBOU IN CANADA

1.0 INTRODUCTION

Caribou or *Rangifer tarandus* is a species of deer that lives in tundra, taiga, and forest habitats at high latitudes in the northern hemisphere, including in Russia and Scandinavia, Alaska, Idaho and Washington states and Canada. The species' common name is caribou in North America and reindeer in Europe and Asia.

All caribou and reindeer are members of one species (*Rangifer tarandus*) which maintains healthy numbers worldwide and is not in danger of extinction. In fact, the species' World Conservation Union (IUCN) conservation status is "Lower Risk / Least Concern" (i.e., the most secure status in IUCN's "red book" system). The species' NatureServe conservation status is G5 ("Secure" – "Common; widespread and abundant").

North America is home to approximately three million caribou with roughly two-thirds living in the far north in open tundra habitats. Moving south from the tundra into woodland habitats, caribou become progressively less abundant.

Most experts recognize woodland caribou as a subspecies (*Rangifer tarandus caribou*). The IUCN has not assessed this subspecies separately from caribou overall. The subspecies' NatureServe conservation status is G5T4 ("Apparently Secure" - "Uncommon but not rare; some cause for long-term concern due to declines or other factors"). The largest populations of the woodland subspecies occur in northern Quebec and Labrador. These populations include perhaps a million animals that migrate between open and forested habitats (Thomas and Gray 2002).

Concerns about caribou conservation status and trends in Canada are focused on five forest-dwelling populations of the woodland subspecies that contain about 180,000 of the roughly two million caribou in Canada (Thomas and Gray 2002). The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has reviewed scientific information about the five populations and assessed their conservation status. One population is listed as endangered, two as threatened, one as special concern, and one as not at risk.

Caribou in Canada are generally well understood and there is an abundance of research projects sponsored by universities, governments and industries – over 2,300 articles and books have been published, more than half of which have been peer-reviewed by fellow scientists in the field. Despite this abundance of knowledge, it is generally accepted that managing woodland caribou presents challenges. Research questions surrounding declines in some forest-dwelling herds remain complex. Factors affecting forest-dwelling populations and herds include predation by wolves and other species; fire; parasites and diseases; hunting; climate warming; and human land uses including forestry (Thomas and Gray 2002). Interactions among these factors are thought to be important. For example, some caribou populations are affected by expanding populations of white-tail deer and moose, which bring with them predators such as wolves and bears, and parasites and diseases that caribou are ill-equipped to handle. There is concern that caribou are more vulnerable to predators where forests are disturbed by human activities including timber harvesting and exploration for oil and gas. There is also concern that climate warming may be responsible for northward expansion of white-tail deer populations.

In spite of the significant amount of research focused on this species, there are many important gaps in information about caribou management and conservation. The purpose of this report is to outline what we do understand about woodland caribou, determine where further research is needed, identify and

characterize the ongoing research effort in Canada, and through a gap analysis, suggest direction and research targets for future research efforts.

2.0 CARIBOU: BIOLOGY AND ECOLOGY

2.1 Caribou Taxonomy

Caribou, or reindeer, are medium-sized deer in the order Artiodactyla (even-toed ungulates), and a member of the subfamily Capreolinae, which comprises deer, moose, and their allies (Figure 2.1).

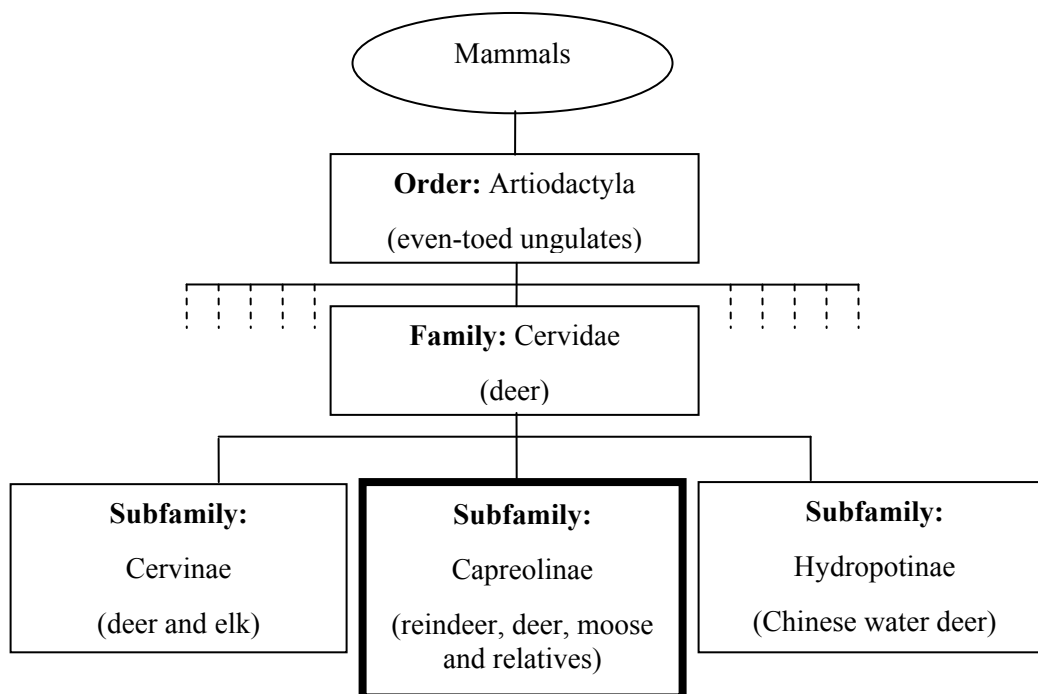


Figure 2.1 A Cladogram of the Classification of Deer to the Sub-Family Level

All caribou and reindeer are in the same subfamily, Capreolinae, the same Genus, *Rangifer*, and the same species (able to interbreed and produce viable, fertile offspring), *tarandus* (Lonnberg 1969). Scientists do recognize various finer scales of classification of subspecies, populations, ecotypes and herds. Subspecies are defined by slight differences in physical form (e.g., colour of pelage [fur] or body size); sometimes dramatically different behaviours (e.g., seasonal migration distances, herding behaviour); and by the geographic range they occupy, with small to non-existent areas of overlap. The four extant subspecies are:

- *Rangifer tarandus caribou*: **American Woodland Caribou**, Canada and southeast Alaska (Gmelin 1788).
- *Rangifer tarandus granti*: **Grant's Reindeer**, Alaska (J.A. Allen 1902).
- *Rangifer tarandus groenlandicus*: **Greenland or American Tundra (barren ground) Caribou**, Greenland, Canada (Borowski 1780).
- *Rangifer tarandus pearyi*: **Peary Reindeer**, Ellesmere, Melville and other islands of Canadian Arctic Archipelago (J.A. Allen 1902).

The definition of such classifications below subspecies has undergone much debate. In this context, “population” has been defined as “all individuals of a species within an ecologically defined area” (Thomas and Gray 2002). A general definition of ecotype has been suggested as “a geographically defined aggregate of local populations, which differ taxonomically from other subdivisions of the species” (Mayr 1969). Finally, the term “herd” is used to describe a group of caribou that occupy a specified geographic range and appear to be separate from other such groups (Banfield 1954).

Among forest-dwelling caribou, scientists recognize six primary populations. Five populations (northern and southern mountain populations, boreal population, Atlantic-Gaspésie population, and the insular Newfoundland population) occupy the alpine forest of the Rocky Mountains in British Columbia and Alberta, and the southern portion of the boreal forest across Canada. A sixth population involves two herds from northern Quebec (the George River herd and the Leaf herd) which are forest-dwelling but migrate long distances annually. These woodland caribou are classified as “forest-tundra migratory caribou” and are not included with conservation efforts of “sedentary” forest-dwelling caribou. Nationally, some populations have been documented to be in decline, and in spite of estimates of range recession of 34 km per decade (Schaefer 2003), Thomas and Gray (2002) report that the range of Caribou in Canada has not changed significantly since Kelsall’s review 18 years ago (Kelsall 1984).

2.2 Caribou Subspecies and Populations

As mentioned previously, defining the required differences to delineate between subclassifications is difficult, and the subject of debate among scientists. In the case of caribou, beyond geographic location, the primary differences between the subspecies of barren ground caribou (*Rangifer tarandus groenlandicus*) and woodland caribou (*Rangifer tarandus caribou*) are their size and behaviour, with some evidence of genetic differentiation. Barren ground caribou tend to be slightly smaller (*R.t. groenlandicus*, 150 kg [males], 90 kg [females]; *R.t. caribou*, 185 kg [males], 130 kg [females]; Bergerud 2000; Hall 1981).

Behaviourally, the groups are further differentiated. In general, barren ground caribou tend to aggregate into large herds comprising hundreds of individuals, and undertake large seasonal migrations of up to several thousand kilometers. Populations of barren ground caribou are thought to be limited by availability of suitable food, grazing on arctic forbs, sedges and lichens as they move across the landscape (Banfield 1954).

As noted above, sedentary forest-dwelling caribou in Canada are broken down into five populations: northern mountain, southern mountain, boreal, Newfoundland, and Atlantic-Gaspésie (Thomas and Gray 2002). Group sizes tend to be small, rarely exceeding fifty individuals (Edmonds 1992). Each population occupies a distinct geographic region. Seasonal movement patterns differ between them as well. During much of the winter, all five populations occupy dense forested areas. However, in the spring and summer, mountain caribou (both northern and southern) move to high elevations, often above tree-line. In contrast, the boreal caribou migrate short distances to calving areas, usually as solitary individuals. With respect to forest management and conservation planning, the forest industry is primarily concerned with the mountain, boreal, and Newfoundland populations. The Atlantic-Gaspésie population is primarily restricted to a protected area in Québec.

Determining the area of occupancy in forests for caribou is difficult, and provinces use differing methods and approaches. Individual caribou herds are recognized in British Columbia, Alberta, Saskatchewan, Manitoba, and Newfoundland, but are not recognized in Ontario and Quebec, where caribou range is defined as contiguous across the northern portions of each province. As a result, jurisdictions that recognize herds (BC, Alberta, Saskatchewan, Manitoba, Newfoundland) are thought to have clumped, herd-specific areas of occupancy interspersed with forested areas where caribou are thought to be absent, whereas Ontario and Quebec are considered to have contiguous areas of occupancy across their caribou ranges of boreal forest (Thomas and Gray 2002).

2.3 Caribou Ecology

2.3.1 *Habitat*

Depending on the specific ecotype and topography, various habitat types are used seasonally for foraging, calving, predator avoidance and over-winter survival. In northern Alberta, boreal caribou prefer less productive black-spruce fens and peatlands (Stuart-Smith et al. 1997; Bradshaw et al. 1995). In Ontario, the boreal ecotype tends to favour mature, lichen-rich conifer stands for foraging in late winter (Harris 1999). To avoid predators during spring calving, dense forested areas may be favoured by cows, or where available, small isolated islands. In Quebec, caribou calves have been found hidden in thick regenerating areas, which may put them at risk of opportunistic predation by black bears foraging on seasonal berry crops (D. Fortin, pers. comm.). Summer and fall range is often less productive black-spruce swamps (Stuart-Smith et al. 1997).

Mountain caribou often exhibit similar seasonal shifts in habitat use, but elevation and snow pack are significant factors in determining habitat use. In winter, northern mountain caribou tend to be found where snow pack is low and access to terrestrial lichen and secondarily arboreal lichen is easy (Bergerud 1978; Heard and Vagt 1998). Some caribou forage in lower elevation forests, while others prefer higher elevations where wind may keep snow depth low (Kuzyk et al. 1999). Southern mountain caribou alternate between low elevation areas in early winter and spring, and upper elevations in late winter and fall (Simpson, Terry, and Hamilton 1997; Stevenson 1991).

2.3.2 *Feeding*

Little is known about the general feeding habits of caribou on forested landscapes. Feeding habits of barren ground caribou are well studied owing to the ease of observation of large herds in open habitat. In contrast, forest-dwelling caribou present significant challenges to biologists attempting to document their habits. During late winter, arboreal lichens (particularly for southern mountain caribou) and other lichen species for most caribou are available in late-seral stage conifer forests, and are important to winter survival (Simpson, Terry, and Hamilton 1997; Thomas, Edmonds, and Brown 1996). Lichen tend to be high in carbohydrates, but low in protein, providing a rich energy source during the forage-limited late winter. Diet breadth during spring, summer and fall expands to include forbs, sedges and other vascular plants (Thomas and Gray 2002), but data documenting this are few.

2.3.3 *Ecological Interactions*

There is little evidence that caribou actively avoid sympatric ungulates (ungulates that occupy the same range), but ample evidence suggests that their habitat preferences differ substantially from moose and deer, promoting their separation (Cumming, Beange, and Lavoie 1996; Thomas and Gray 2002).

Throughout most of Canadian caribou range, the primary documented predator is the wolf. In certain circumstances, wolf densities above a certain threshold are thought to be incompatible with the persistence of caribou. However, in other regions other predators become more important, such as black bears (Quebec: Boileau et al. 1994; Courtois 2004), coyotes (Newfoundland: Mahoney et al. 1990) or both (Gaspésie: Crete and Desrosiers 1995; Crete et al. 1994). Some evidence also suggest that caribou are sensitive to disturbance in the form of noise resulting from industrial activity or transportation corridors (Cumming and Hyer 1998).

2.4 Cultural Significance of Caribou

Caribou, both barren ground and woodland, have been of significant cultural value to Canada's aboriginal peoples, having been hunted for some 13,000 years. The caribou is a central cultural focus for many aboriginal peoples and Canada's Inuit, and the barren ground subspecies is still hunted throughout Canada's north (Thomas and Gray 2002). Forest-dwelling caribou are hunted in Newfoundland and

northern BC, and represent a significant source of income for outfitters in those areas. Additionally, wildlife tourism is of significant value throughout its Canadian range, with caribou being a sought-after spectacle for many. The caribou is considered a long-time Canadian emblem, first appearing on the reverse of the 25-cent piece (opposite King George VI on the obverse) in 1937 (Royal Canadian Mint 2007).

3.0 RANGE AND STATUS OF CARIBOU POPULATIONS

Useful Definitions:

Range or extent of occurrence - the area within an imaginary boundary over which an entire species is distributed (IUCN 2001).

Area of occupancy - the geographic space within its 'extent of occurrence' in which a taxon is found.

Herd - a group of individuals that occupy a specific range or geographic area and appear to be separate from other such groups.

3.1 The Range of Forest-Dwelling Caribou

The *range* of sedentary forest-dwelling caribou in Canada encompasses a wide swath of boreal and alpine forests across every province except Nova Scotia, New Brunswick and Prince Edward Island (Figure 3.1; Thomas and Gray 2002). Historically, the southern limit of forest-dwelling caribou range extended much farther to the south, covering many parts of southern BC, Alberta, Ontario, Quebec and the Maritimes (Kelsall 1984). Within the current range, caribou herds have a clumped distribution, or *area of occupancy*, leaving much of the existing range unoccupied, owing to natural variability in resource and predator distribution. In Ontario and Quebec, individual herd ranges are poorly defined, making both their respective provincial *range* and *area of occupancy* synonymous.

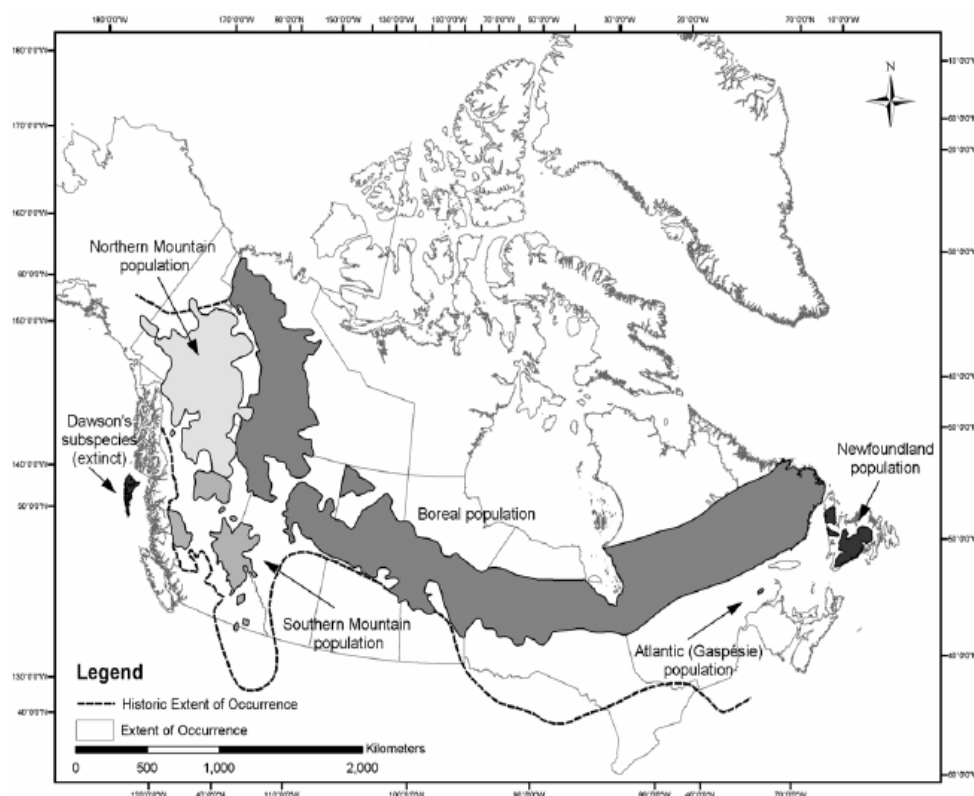


Figure 3.1 Current (grey) and Historic (dashed line) Range of Forest-Dwelling Caribou in Canada (from Thomas and Gray 2002)

3.2 Herds

A *herd* is defined as a group of individuals that occupy a specific range or geographic area and appears to be separate from other such groups (Banfield 1954). As such, within ecotypes, individual herds differ primarily in the territories they occupy. However, in some areas, the geographic ranges of individual herds may overlap with one another, and some herds have been known to exchange individuals from time to time. In contrast, some herds are completely geographically isolated from other herds by barriers such as lakes or rivers. Within Canadian provinces (excluding Ontario), ecologists have delineated 146 herds of forest-dwelling caribou.

Most herds are affected by similar proximate factors (e.g., predation, habitat loss, forage quality/quantity, sensory disturbance) but the importance of each may differ between herds. For isolated herds in the northern boreal forest, we would expect that factors such as predators and forage quality/quantity would be of primary importance, whereas herds whose ranges overlap with significant industrial development may be at greater risk from habitat loss.

3.3 Population Trends

Obtaining accurate and/or precise estimates of forest-dwelling caribou populations and population trends is notoriously difficult (Thomas 1998). Some herds are small, well documented locally and relatively easily accessed; others may be virtually unknown and difficult to reach. Further, proportion of individuals visible versus those in tree cover is difficult to estimate, and sex ratios may be biased based on non-representative samples in view (Hatler 1986). Estimates range from pure guesses based on no data to total counts, with a range of extrapolation and modeling tools in between (Thomas and Gray 2002). Further, many populations have only been assessed once or twice, and may not represent current conditions. As a result, most population estimates and associated trends must be viewed with some scepticism, and variability within estimates may be very high.

The populations listed by COSEWIC comprise 147 herds. Roughly 27% of these herds are declining in numbers or suspected of declining. Another 48% are thought to be stable or increasing. Data are not sufficient to determine population trends for 25% of the forest-dwelling herds (Figure 3.2).

When looking at the number of individual caribou as opposed to herds of caribou, another picture emerges (Figure 3.2). For forest-dwelling caribou, 5.5% of the population is in herds that are declining or suspected of being in decline, while 71.5% of forest-dwelling caribou are in herds with stable or increasing numbers of animals. The remaining 23% of forest-dwelling caribou are in herds with an unknown population trend.

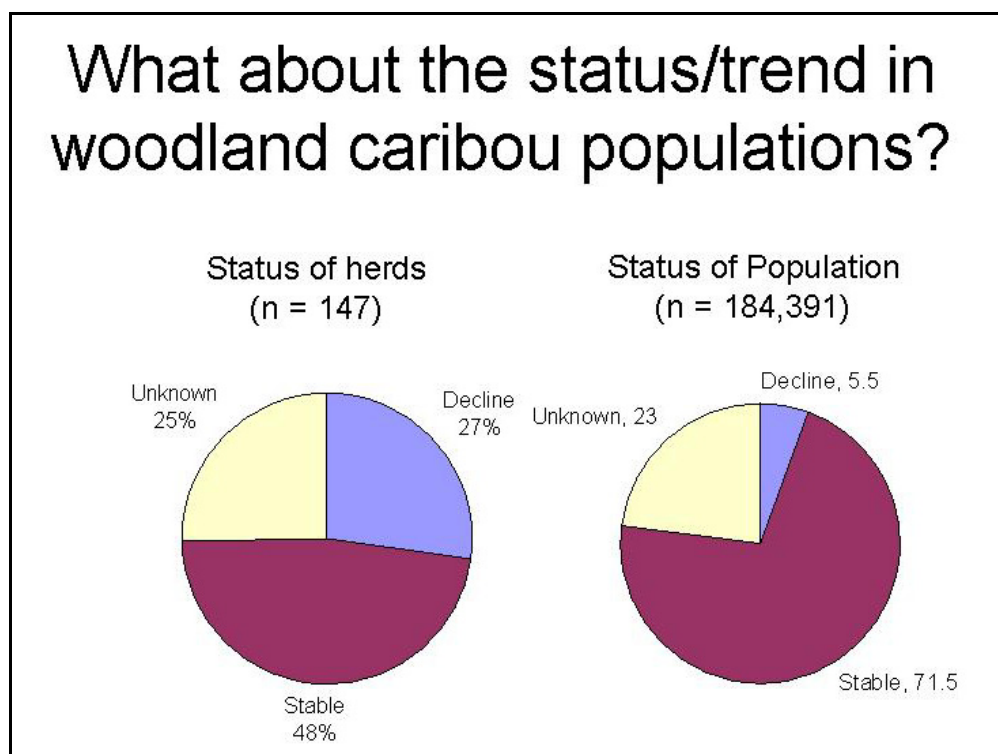


Figure 3.2 Population Status of Forest-Dwelling Sedentary Woodland Caribou in Canada by Herd and Number of Animals

Among the southern mountain caribou ecotype, there are an estimated 7,208 individuals, with population estimates for various herds dating from 1982 to 2002 (Thomas and Gray 2002). Among herds, 45% are estimated to be declining, while 35% are stable. The remaining 20% have no trend estimates available. By population, these categories represent 29% in declining herds, 56% of the population in stable herds, and 15% of the population having no trend estimate available (Table 3.1). Among northern mountain caribou, with population estimates of herds ranging from the early 1970s to 2001, there are approximately 43,950 individuals (Thomas and Gray 2002). By herd, 7.9% are estimated to be in decline, 55.2% are thought to be stable or increasing, and 36.9 have no trend data available. By population, these represent 3.3% of the population in declining herds, 50.7% of the population in stable or increasing herds, and 46% of the population with no trend data.

In the insular Newfoundland forest-dwelling caribou (NFLD), only one of 27 herds is reportedly in decline (3.7% of herds) and the remaining 96.3% of herds are stable or increasing, with a total estimated population of 100,012 (Thomas and Gray 2002). By population, the one declining herd represents 1.8% of the total Newfoundland population, with 98.2% of the population stable or increasing. The Gaspésie population comprises one herd estimated to be in decline, with a current population of 143 individuals (Environment Canada 2007a).

Table 3.1 Herd and Population Estimates for the Five Forest-Dwelling Caribou Ecotypes in Canada Classified as in Decline (including suspected of being in decline), Stable (including increasing) and Unknown, Based on Best Available Information**

Ecotype		Decline	Stable	Unknown
Northern Mountain	# herds	3	21	14
	% herds	7.9	55.3	36.8
	% pop'l	3.3	50.9	45.8
Southern Mountain	# herds	14	11	6
	% herds	45.2	35.5	19.3
	% pop'l	29.5	55	15.5
Boreal*	# herds	21	12	17
	% herds	42	24	34
	% pop'l	13.6	22.5	63.9
NFLD	# herds	1	26	0
	% herds	3.7	96.3	0
	% pop'l	1.8	98.2	0
Gaspésie	# herds	1	0	0
	% herds	100	0	0
	% pop'l	100	0	0
Forest-Dwelling Caribou (in Canada)	# herds	40	70	37
	% herds	27.2	47.6	25.2
	% pop'l	5.5	71.5	23

* Based on available information, Ontario is considered as one herd.

** Values taken from Thomas and Gray 2002 (NMP, SMP, NFLD), Environment Canada 2007b (Boreal), and Environment Canada 2007a (Gaspésie).

4.0 CONCERNS ABOUT CARIBOU POPULATIONS

4.1 Habitat and Seasonal Forage Supply

One of the primary concerns of the forest industry with respect to wildlife is the relationship of forest management to the amount and availability of habitat for species of concern. Wildlife require habitat for a variety of uses, including foraging, predator avoidance, and reproduction. The degree to which forest management can accommodate these requirements is shaped primarily by two factors: the natural abundance of habitat features on a landscape, and the level and certainty of knowledge of a given species' habitat requirements.

There are three primary ways that forest management can alter habitat. Forest harvesting reduces the extent of late-seral habitat (in the case of even-aged management) or changes the structure of that habitat (in the case of uneven-aged management). By altering habitat in one area, remaining areas of unaltered habitat can be spatially separated and may no longer fully support the needs of some species. Finally, as forest management tends to focus primarily on tree species regeneration and composition, forest management can have effects on understory and ground cover plants, which can alter forage quantity and quality for some species. Well managed forestry operations must take all of these factors into consideration.

Caribou appear to use lichen as their dominant winter forage. Depending on the caribou ecotype, the lichen species consumed may be ground lichen (e.g., *Cladonia spp.*, *Cladina spp.*, *Cetraria spp.*) or arboreal lichen (e.g., *Alectoria spp.*, *Bryoria spp.*, *Usnea spp.*; Edwards, Soos, and Ritcey 1960; Harris 1996). Being available throughout the winter, lichen make up the majority of caribou winter diet. Lichen is generally high in carbohydrate content, providing needed energy for survival during the forage limited late-winter months. Winter foraging habitat use by caribou has usually been described as mature conifer forests with significant lichen production (Antoniak and Cumming 1998; Bjorge 1984). Silvicultural methods have been able to retain or promote lichen production in harvested areas with some success (Racey, Harris, and Foster 1996).

Biologists are far less certain when it comes to summer foraging habitat. Caribou have been documented to use fens and bogs extensively in the summer (Edmonds and Smith 1991), but selected forage is virtually unknown. Examinations of stomach contents have suggested that diet expands to include sedges, grasses, forbs, fungi and leaves of shrubs, particularly willow. Thomas and Gray (2002) describe caribou as broad-spectrum, fine feeders, selecting nutritiously valuable plant parts from a range of plant species. Forage quality and quantity studies on a wide range of ungulate species have documented significant effects of summer and fall forage on ungulate physiology and reproduction, but little is known about the effects of summer and fall forage on caribou (NCASI 2007).

4.2 Inter-Specific Overlap with Other Ungulates

Forest-dwelling caribou do not avoid other species of ungulates, but are often separated from ungulates living in the same area due to habitat selection which differs significantly from other species (e.g., moose, deer). This habitat separation appears to provide some benefit to caribou, as other ungulates carry diseases and parasites which caribou may not be equipped to handle. Some caribou reintroduction programs have met with failure as a result of reintroducing them to forested habitats with abundant white-tailed deer. White-tailed deer carry a benign meningeal nematode, *P. tenuis*, which is thought to be limiting to caribou (Pitt and Jordan 1994).

In some areas, forest management has been suggested as a factor in altering the dynamics between caribou and other ungulates. Dense conifer forests are not necessarily prime habitat for either white-tailed deer or moose. However, early succession after forest harvesting of these areas without site treatment results in significant deciduous growth (“green up”) of early successional plants. These areas provide good forage for white-tailed deer and moose, which may then begin to encroach and overlap with caribou. Direct competition is not thought to be a factor between the two, but change in habitat succession is thought to bring them together, along with the parasites and diseases that caribou are thought to be unable to cope with.

Many ungulate parasites have fairly complex life cycles (Erickson and Higby 1942). The tapeworm *E. granulosus* resides in wolves and other canids and cycles through snails, moose and caribou. Mature woodland caribou are thought to have relatively high incidence of hydatid cysts (*E. granulosus* cysts), which may make them more susceptible to predation, often by wolves, completing the cycle. *P. tenuis* also has an intermediate host in snails that are found in high densities in treed swamps, which may be seasonally preferred foraging habitat for caribou.

4.3 Predator/Prey Dynamics

Some ungulates like moose and white-tailed deer are adapted to take full advantage of sudden increases in quality forage. Unlike caribou, which has a very rare frequency of multiple births, moose and white-tailed deer have relatively high frequencies of twins and occasional triplets (McEwan 1971). As a result, green-up after forest management has been suggested in some cases to result in significant numerical increases in moose and deer populations in response to increases in forage. Similarly, increasing densities of deer and moose may result in a significant numerical increases in populations of large predators, most often wolves (Seip 1991, 1992), but occasionally black bear (James, Boutin, and Hebert 2004). Caribou are secondary prey items for wolves, but increasing wolf numbers on a landscape will undoubtedly result in increased encounters between the two, leading some to suggest a maximum wolf density at which caribou populations may persist. Further, it has been suggested that caribou may be less desirable than moose owing to their smaller size, but may represent significantly less risk to the predator, as wolves have been known to be killed while attacking moose. Taken together, alterations to predator-prey dynamics have been implicated in caribou decline, and have been the subject of significant research (reviewed by NCASI 2004).

Other elements of natural resource management may play a part in predator/prey dynamics. Linear features (e.g., seismic lines, roads, and straight forest edges) are thought to increase both the sight lines and rate of travel for predators. If traffic levels are below a certain threshold, wolves have been known to use linear features as travel corridors. Depending on the habitat the feature crosses, this may further increase the rate of encounter between predator and prey (James Boutin, and Hebert 2004; James and Stuart-Smith 2000). Caribou have been documented to avoid linear features, but primarily in response to high traffic levels (Cumming and Hyer 1998). Linear features such as seismic lines and roads may also increase access to previously inaccessible forested areas for hunters, which may increase both the incidental and/or illegal killing of caribou as well as habitat disturbance in the form of vehicular traffic or off-road vehicles (Bloomfield 1980).

Taken together, the effects of linear features, forest harvesting, natural disturbance and human activity have been hypothesized to be detrimental to woodland caribou populations (Schaefer 2003; Vors et al 2007; Schaefer and Mahoney 2007), resulting in significant research efforts (Brown et al 2007; Dyer et al 2001; Smith et al 2000).

5.0 GOVERNMENT INVOLVEMENT

5.1 COSEWIC and the Canadian Species at Risk Act

Forest-dwelling caribou are currently considered by COSEWIC as five distinct subpopulations, each with its own conservation status (Table 5.1).

Table 5.1 Conservation Status of Forest-Dwelling Sedentary Populations of Woodland Caribou in Canada. [Estimates for Northern Mountain, Southern Mountain and Newfoundland populations are from Thomas and Gray (2002). Estimates for Gaspésie and Boreal populations are from Environment Canada (2007a) and Environment Canada (2007b), respectively. Definitions are from COSEWIC 2006.]

Population	Population Estimate	Conservation Status
Northern Mountain	43,950	Special Concern - species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats
Southern Mountain	7,208	Threatened - species likely to become endangered if limiting factors are not reversed
Boreal	33,113	Threatened - species likely to become endangered if limiting factors are not reversed
Newfoundland	100,012	Not at Risk - species that has been evaluated and found to be not at risk of extinction given the current circumstances
Gaspésie	143	Endangered - species facing imminent extirpation or extinction

Each of these populations has been included on Schedule 1 of the Canadian Species at Risk Act (SARA) and are therefore officially listed under their respective status. Under SARA, this affords legal protection specific to each conservation status to those animals living on all federal lands. Under SARA, recovery strategies must be prepared within one year of a species or population being officially listed as endangered, and two years after a species or population is officially listed as threatened (Environment Canada 2007b). Provincial and territorial jurisdictions with members of those populations present on non-federal lands that are listed as threatened or endangered must also develop recovery strategies for that segment of the population.

5.2 Provincial Programs and Strategies

Recovery strategies are designed to outline short-term objectives and long-term goals for providing for the protection and recovery of at risk populations (CDFO 2007). In general, recovery strategies describe what is known about the species of concern and its population, identify threats to its population, describe information gaps and research needs, describe approaches to be used in protection and recovery of the species, define critical habitat and suggest a timeline for action. However, there is significant variation in the amount of detail each jurisdiction has applied to its respective recovery strategy (Table 5.2, see literature cited). Thus far, only Alberta and Newfoundland have defined and delineated critical habitat.

Most provinces have defined herds similarly to Banfield (1954), where a *herd* is defined as a group of individuals that occupy a specific range or geographic area and appears to be separate from other such groups. British Columbia, Alberta, Saskatchewan, Manitoba, and Newfoundland have all defined herds in accordance with this concept. In practice, herds are often defined through behavioural research using radio-collars and telemetry to estimate herd range size, movement patterns and habitat selection. Traditional knowledge from local residents has sometimes proved useful in helping to separate and define herds and herd boundaries.

In some provinces, large tracts of forest are uninhabited by humans, and the movement and interbreeding status of many caribou is virtually unknown. This makes it very difficult to say with any degree of certainty that groups of animals are or are not mixing and breeding from one region to another. Therefore, rather than defining and delineating herds and their ranges, Ontario has opted instead to define broad management areas where specific recovery action plans will be implemented. In this case, the term herd has not been applied. Ontario (Figure 5.1) has designated the Northwest, Northeast, Lake Superior Coast, Lake Nipigon and Central Highlands recovery zones (OMNR 2005). Recovery zones are designated based on variation in landscape ecology, caribou distribution and human use of caribou.



Figure 5.1 Map Outlining Five Proposed Sedentary Forest-Dwelling Caribou Recovery Zones in Ontario (from OMNR 2005)

Table 5.2 Comparison of Provincial Recovery Strategies (AWCRT 2005; BCTAC in prep.; Manitoba Conservation 2005; MCTAC 2002; Schmeltzer et al. 2004)

	Identified Threats									Estimate		Trends		Recovery Efforts									Monitoring	Timeline for Recovery	Quantified targets
	Anthropogenic habitat change	Natural habitat change	Predation	Hunting/poaching	Parasites disease	Climate/weather	Forage supply	Nutrition	Sensory disturbance	Herds	Province/Nation	Herds	Province/Nation	Industrial Restrictions	Access management	Predator control	Alternate prey control	Caribou harvesting	Poaching	Vehicle collisions	Translocation	Calving enhancement			
BC																									
Mountain	•	•	•	•	+	+	•		•	•	•	•	•		•	•	•	•			•				
Boreal																									
AB	•	•	•	•	+	+				•	•	•	•	•	•	•	•	•	•	•		•			
SK																									
MB	•	+	•	•	•	+			•	•	•	•	•	•				•		•			•		
ON	•	•	•	•	•	•	-	-	•					•	+	+		+					•		
QC																									
Gaspésie	•			-	+	+	•		•	•		•		•	•	•							•		•
NFLD/LB	•	•	•	•		•			•	•		•		•	•			•	•				•		•
Canada																									

■ Report not available, Recovery Strategy in draft form. • Major consideration in recovery strategy. + Minor consideration in recovery strategy.

- Consideration given to factor, but rejected as having influence on caribou populations.

6.0 OTHER STAKEHOLDERS

Concerns about declining population trends of forest-dwelling caribou extend to the effects of all stakeholder activity across forested landscapes. Several studies have examined adverse effects of linear features (e.g., roads, seismic lines, hydro corridors) as both habitat avoided by caribou, sources of vascular forage for alternate prey, and travel corridors for predators (British Columbia Forest Practices Board. 2001; Curatolo and Murphy 1986; Dyer et al. 2002; Hyer 1997; Murphy and Curatolo 1987; O'Neill and Boutin 2002; Smith, Cameron, and Reed 1994; Vistnes and Nellemann 2001). Roads are necessary for forest management, oil and gas production, mineral extraction, tourism outfitters, hunting, fishing and trapping. Seismic lines, long corridors across the landscape used for oil and gas exploration, have doubled the area harvested by forest management in some areas (Alberta Environmental Protection 1998), and many of these features have been found to re-generate poorly on their own (Revel, Dougherty, and Downing 1984). Hydro corridors are necessary for delivery of power from remote hydro-electric facilities, and to remote communities or distant population centers.

In some parts of Canada, such as Quebec, legal hunting of forest-dwelling caribou has been thought to be the primary cause of the early decline of populations (Cinq-Mars 1977). Further, legal hunting of migratory forest-tundra caribou in Quebec may have a notable impact on sedentary forest-dwelling caribou. In some regions, migratory and sedentary populations are known to occasionally overlap, and being the same species, it is very difficult to distinguish between the two in the field, which may result in accidental shooting of sedentary caribou. This has been suggested as a contributor to the decline of the sedentary forest-dwelling subspecies in Quebec (Comité de rétablissement du caribou forestier 2007). The magnitude of the effect is unknown in all jurisdictions, and illegal hunting has also been implicated in suspected declines. In several jurisdictions, aboriginal and peoples have a significant relationship with caribou, and some hunting is still permitted.

Other recreation activities have also been suggested to influence declines some forest-dwelling caribou populations. Sensory disturbance, either through industrial activity or recreation, is thought to alter caribou behaviour, either reducing the amount of habitat used by the animals, or disrupting feeding and/or calving activities (Fancy 1983; Lewis 2005; Mahoney et al. 2001; Otto et al. 2003; Price 2004; Reimers, Eftesol, and Colman 2003; Simpson 1987, 2000). This has been noted among mountain populations, where snowmobiling and heli-skiing have been suggested as important causal factors (British Columbia Ministry of Environment and Parks 1987). Low-level training flights by military aircraft in Labrador have also been cited as a threat (Klein 1974). Disturbances as small as hiking in caribou areas have been suggested to alter behaviour (Simpson 2000).

7.0 RESEARCH NEEDS

7.1 Overview

Research on forest-dwelling caribou has provided a substantial body of information, but much remains poorly understood. It is a fundamental presumption that substantially increasing the depth and breadth of scientific information about caribou will improve conservation programs and our ability to forecast future threats from changes in climate, ecosystems, and disturbance regimes. Indeed, such information may prove crucial for conservation of forest-dwelling caribou over the long term. Examples of general research needs include:

- Information on the effects of the current mountain pine beetle epidemic is lacking in western Canada. It could be argued that salvage logging of lodgepole pine may exacerbate the problem of late-seral habitat loss, but the fundamental value of beetle-killed stands as habitat for caribou is still unknown. Additionally, the subsequent effects on other species, notably

alternate wolf prey such as deer, may also play a substantial role. Overall, these issues point to a need for better understanding of caribou habitat selection/use as it relates to forest structure.

- Various reports, recovery documents, and primary sources have documented a variety of factors that may contribute to declines of caribou, but few have examined the interplay and relative effect size of these factors. Research is needed not only to assess their relative contributions, but in many cases to test and quantify the direct causative link between specific factors and caribou demography.
- Substantial research from around the world has documented that spring, summer and fall forage quantity and quality have significant effects on reproduction, survival, and population growth for a wide range of ungulates. However, detailed studies on woodland caribou forage and nutritional dynamics are almost non-existent. Much of our understanding on this topic comes from work on barren ground caribou, which may or may not be relevant to the forested environment. Understanding the relationships between preferred forage items and forest structure can only be examined once foraging ecology is better understood.
- Detailed, realistic, and tested models for caribou demographics as they relate to both natural and anthropogenic factors are lacking. Recent attempts at modeling caribou persistence and forestry have met with some success, but remain untested in the long-term. Understanding and adapting such models to field conditions are vital to managing caribou over the medium- and long-term.
- Following an increased understanding of foraging needs through all seasons, research into silvicultural practices that promote winter and summer forage and discourage the proliferation of less desirable forage species would be helpful in increasing the fitness of individuals and populations of caribou.
- There has been much speculation that population dynamics of other ungulates (e.g., moose and deer) in the immediate geographical region of caribou populations have indirect consequences for caribou population dynamics. These hypotheses, which link to forest management and to other factors such as climate change and parasitic loading, could be tested through predictions about increases or decreases in specific species. Given that most of these species are legally harvested, research to test such causative links would be useful.

Currency and reliability of population estimates vary by herd, subpopulation, and population. Estimates of both population numbers and demographics are available for only 29 of the 147 defined herds of sedentary forest dwelling caribou. The population status of 25% of herds is essentially unknown, representing 23% of the total population of non-migratory caribou in forested landscapes in Canada. Ontario is home to roughly 15% of the boreal population of sedentary forest-dwelling caribou in Canada but has neither an estimate of population trend, nor a measure of the reliability of their provincial population estimate. Lack of data makes it difficult to assess the current status of caribou populations in forested landscapes.

Mortality through wolf predation, other predator action, vehicle collisions or disease and parasite action has resulted in the decline of caribou in forested environments. However, most research has focused on the secondary drivers of those factors rather than actual mortality rates associated with these factors. In only a few research situations are reliable estimates of mortality rates available, and for many of those there are significant methodological issues. Estimates of mortality rates for radio-collared animals in managed forest landscapes are informative, but mortality rates are needed for caribou in unmanaged forests to facilitate comparisons with those on manipulated landscapes.

NCASI has published two in-depth literature reviews on important aspects of woodland caribou ecology and management (NCASI 2004, 2007). These reviews have identified a variety of gaps in current research that will be summarized and analyzed later in this section.

7.2 Current Research Survey

In order to improve the chances of successful management of woodland caribou, it is vital that we understand not only what has been examined and tested, but what research efforts are currently underway. Thus we surveyed ongoing research efforts concerning woodland caribou in Canada.

We identified projects across Canada through a combination of Internet searches, discussions with other researchers in the field, attendance at caribou-related conferences and meetings (e.g., the 11th North American Caribou Conference in Jasper, AB), and an informal survey of researchers. Projects and researchers were identified in every province, and where available, in each of five primary sectors: academia, industry, government (provincial or federal), and ENGO. Once projects were identified, Primary Contacts and graduate students were contacted regarding the details of each project. If possible, researchers were asked to provide an abstract for their project and timelines for completion. Finally, researchers were asked to provide contacts with other projects not yet identified by the survey and search methods.

Our objective was to document all research underway concerning woodland caribou in Canada but it is very likely that some projects have been missed. Further, several kinds of woodland caribou related projects that do not constitute research *per se* were not included: i.e., long-term monitoring programs; recovery planning efforts; educational material development projects; and outreach programs.

Despite important limitations mentioned above, the projects identified in this report constitute a significant majority of ongoing research in Canada, and therefore are a good representation of the scope of current research.

7.3 Analysis of Current Research

Abstracts provided for ongoing research projects are listed in Appendix A. Based on information provided, projects were broadly classified as to the fundamental nature of the research questions or areas being examined. For simplicity, six categories were defined.

- 1) **Basic Ecology** – Any project in which the primary research question examines the basic relationships between woodland caribou and the abiotic or biotic environment. Factors of interest may include population demographics, habitat selection or behaviour.
- 2) **Disturbance Driven** – Any project in which the primary research question examined any woodland caribou-related parameter as it directly relates to various disturbance factors (roads and other linear features, harvesting, wildfire, insect infestation, sensory disturbance, etc.).
- 3) **Predator/Prey** – Any project in which the primary research question examined altered or increased predation rates on caribou, the cause of such changes, and the underlying causes of changes to predator/prey dynamics.
- 4) **Energetics/Nutrition** – Any project in which the primary research question examined the use and availability of forage resources and the physiological relationship between individual and population-level demographics.
- 5) **Genetic** – Any project in which the fundamental research question examined genetic information (e.g., genetic diversity, allelic frequency) or methods (e.g., sample capture techniques).
- 6) **Administrative** – Any project in which the primary research question examined the use of mitigative or best management practices to minimize effects of human activity on woodland caribou, and the related effects on those activities of such actions.

The following *key words* were defined as a means to identify projects that address some important recurring themes in the research portfolio.

- **Traditional Ecological Knowledge (TEK)** – knowledge available through aboriginal peoples or local knowledge
- **Alternative Prey (AP)** – dynamics or abundances of other sympatric ungulates (e.g., moose, white-tailed deer, etc.)
- **Predators (PRED)** – dynamics and effects on caribou populations of predators
- **Population Dynamics (PD)** – measurement or modeling of population metrics such as population growth rates, herd demographics, birth rates, recruitment, survival and mortality.
- **Range Dynamics (RD)** – dynamics or state of area of occurrence or area of occupancy
- **Habitat Selection and Use (HSU)** – descriptions or models describing current or probable habitat selection or use by caribou individuals or herds
- **Genetics (GEN)** – measurement or descriptions of genetic makeup of caribou populations
- **Disturbance (DIS)** – large-scale natural (e.g., insect infestation, blowdown, wildfire) or anthropogenic (e.g., harvesting, oil and gas development) changes to landscapes
- **Forage (FOR)** – supply and dynamics of caribou forage.

Classification of projects by *research areas and key words* does a reasonable job of characterizing all the project abstracts received. However, this classification is based solely on information in the abstract provided, and may not perfectly capture the fundamental nature of the work.

Table 7.1 Current Research Projects Identified in a Cross-Canada Survey Classified into One of Six Broad Research Areas

Project Title	Province	Basic Ecology	Disturbance Driven	Predation Driven	Energetics and Nutrition	Genetics	Administrative	Keyword
Temporal patterns in the change in distribution of caribou and moose in north-central BC	BC	•						TEK, AP, RD
Ecological relationships between Threatened caribou and their habitat in the central Rocky Mountains Ecoregion	BC	•						HSU
Impact of mountain pine beetle on caribou winter range.	BC		•					DIS
Effects of a mountain pine beetle epidemic on forest floor vegetation dynamics and regeneration in the Itchallgachuz caribou winter range in the Quesnel TSA	BC		•					DIS
The response of caribou terrestrial forage lichens to mountain pine beetles and forest harvesting in the East Ootsa and Entiako areas.	BC		•					DIS
Effects of a MPB epidemic on Northern Caribou habitat use, migration and population status	BC		•					HSU
Use of adaptive management to mitigate risk of predation for woodland caribou in north central British Columbia	BC			•				PRED
Extension of habitat supply tools: The caribou habitat assessment and supply estimator (CHASE).	BC	•						HSU
Establishing a Science Basis for Recovery of Woodland Caribou in North central British Columbia	BC						•	
Ecological relationships between threatened caribou and their habitat in the central Rocky Mountains Ecoregion	BC	•						HSU
Regional coordination of caribou recovery initiatives	BC						•	

(Continued on next page.)

Table 7.1 Continued

Project Title	Province	Basic Ecology	Disturbance Driven	Predation Driven	Energetics and Nutrition	Genetics	Administrative	Keyword
Caribou response to encounters with people in Jasper National Park	BC		•					
Effects of disturbance on the abundance of mountain caribou.	BC		•					DIS
Wolf movements in relation to natural and industrial landscape features on caribou range in on east slopes of Rocky Mountains, BC.	BC			•				PRED
Mitigating Risks of Predation for Caribou	BC			•				PRED
Promotion of Mountain Caribou Recovery through Alternate Species Management	BC			•				AP
The use of alternative prey management in caribou conservation.	BC			•				AP
The predator-prey dynamics of wolves and moose in the North Columbia Mountains: ecology and habitat use in relation to mountain caribou decline	AB			•				HSU
Predator efficiency and linear feature study	AB			•				PRED
Diet and Nutrition of Woodland Caribou in West-Central Alberta	AB				•			FOR
Wolf-caribou dynamics in West Central Alberta	AB			•				PRED
Woodland caribou response to wolf-ungulate management in Alberta	AB			•				PRED, AP
Linear features impact predator-prey encounters: analysis with first passage time.	AB			•				DIS, PRED

(Continued on next page.)

Table 7.1 Continued

Project Title	Province	Basic Ecology	Disturbance Driven	Predation Driven	Energetics and Nutrition	Genetics	Administrative	Keyword
Ecological and economic trade-offs between woodland caribou conservation strategies.	AB						•	
Little Smoky Caribou Calf Protection Project	AB			•				PRED
Use of location data to inform conservation of woodland caribou in Alberta	AB	•						HSU
Qualitative assessment of woodland caribou (<i>Rangifer tarandus caribou</i>) distribution in central Saskatchewan through local knowledge.	SK	•						TEK, PD
Prince Albert National Park Greater Ecosystem Project (PAGE).	SK	•						
Historical distribution of woodland caribou (<i>Rangifer tarandus caribou</i>) in the Prince Albert Greater Ecosystem, Saskatchewan, Canada in relation to landscape changes.	SK		•					PD
Testing the importance of spatial configuration of winter habitat for woodland caribou: An application of graph theory.	MB	•						HSU
Habitat Connectivity using Spatial Graph Theory.	MB	•						HSU
Analysis of woodland caribou habitat selection using generalized estimating equations.	MB	•						HSU
Distribution and Movement of Woodland Caribou on Disturbed Landscapes in west-central Manitoba.	MB		•					HSU
Spatial and temporal characteristics of calving areas for boreal caribou (<i>Rangifer tarandus caribou</i>) in different boreal ecozones.	MB	•						HSU

(Continued on next page.)

Table 7.1 Continued

Project Title	Province	Basic Ecology	Disturbance Driven	Predation Driven	Energetics and Nutrition	Genetics	Administrative	Keyword
Characterization of target nuclear DNA from feces reduces technical issues associated with the assumptions of low-quality and quantity template.	MB					•		GEN
Relating the population genetic structure of woodland caribou to landscape connectivity.	MB					•		GEN
Site fidelity in caribou calving areas in Wabakimi Provincial Park and Woodland Caribou Signature Site.	ON	•						HSU
Impact of timber harvesting on landscape connectivity for forest dwelling woodland caribou populations	ON		•					DIS
Impacts of human activities on woodland caribou in managed boreal forests	QC		•					DIS
Effect of forest management strategies on predation of woodland caribou	QC			•				DIS, PRED
Impact on woodland caribou of logging practices under the Quebec-Cree agreement.	QC		•					DIS
Monitoring the impact on woodland caribou of reconstruction of highway 175	QC		•					DIS
Interaction between wolves, caribou and moose in managed boreal forests.	QC			•				PRED, AP, DIS
Habitat selection by woodland caribou: Identification of variations in movement patterns and habitat selection	QC	•						HSU
Use of space, physical condition and demographics of caribou in Quebec and Labrador: from the individual to the metapopulation	QC	•						PD

(Continued on next page.)

Table 7.1 Continued

Project Title	Province	Basic Ecology	Disturbance Driven	Predation Driven	Energetics and Nutrition	Genetics	Administrative	Keyword
Impact of the Trans-Labrador Highway on satellite-collared woodland caribou of the Mealy Mountain caribou in eastern Labrador.	NFLD/LB		•					DIS
The behavioural ecology of the Gaff-Topsail Caribou Herd on their summer range	NFLD/LB	•						
Developing a statistical model using caribou populations data from insular Newfoundland	NFLD/LB	•						
Population genetics of woodland caribou (<i>Rangifer tarandus caribou</i>) on the island of Newfoundland	NFLD/LB					•		GEN
Conservation Assessment and Strategy for Caribou of the Y2Y Region	YK						•	
Total Occurrences (50 Projects)		16	13	13	1	3	4	

The provinces with the greatest numbers of research projects were British Columbia (17), Alberta (9), Manitoba (7) and Quebec (7). Distribution of projects among research areas is uneven (Figure 7.1) with the greatest numbers of projects in Basic Ecology, Disturbance Driven, and Predator / Prey. There is only one project in the research area Energetics and Nutrition. Numbers of projects characterized by key words are as follows: Traditional Ecological Knowledge (2); Alternative Prey (6); Population Dynamics (5); Range Dynamics (1); Habitat Selection and Use (13); Genetics (3); Disturbance (11); Forage (1). Funding for these research projects comes from a variety of sources, with the majority being sponsored directly or indirectly (e.g., government/industry partnerships) from the forest industry.

In Table 7.2, research needs identified by literature reviews (NCASI 2004, 2007) are classified using the same six research areas used to classify research projects. Results summarized in Figure 7.2 simply reflect the fact that the NCASI literature reviews were focused on research needs in three research areas: Energetics and Nutrition; Disturbance Driven; and Predation Driven. However, the exercise of classifying research needs allowed us to make a preliminary assessment of the degree to which current research projects may be addressing the research needs identified in the literature reviews (Table 7.3). Results suggest a major gap in current research in the Energetics and Nutrition area. No doubt there are important gaps in other areas as well. The compilation of project information in this report provides a good starting point for more detailed analyses of research gaps.

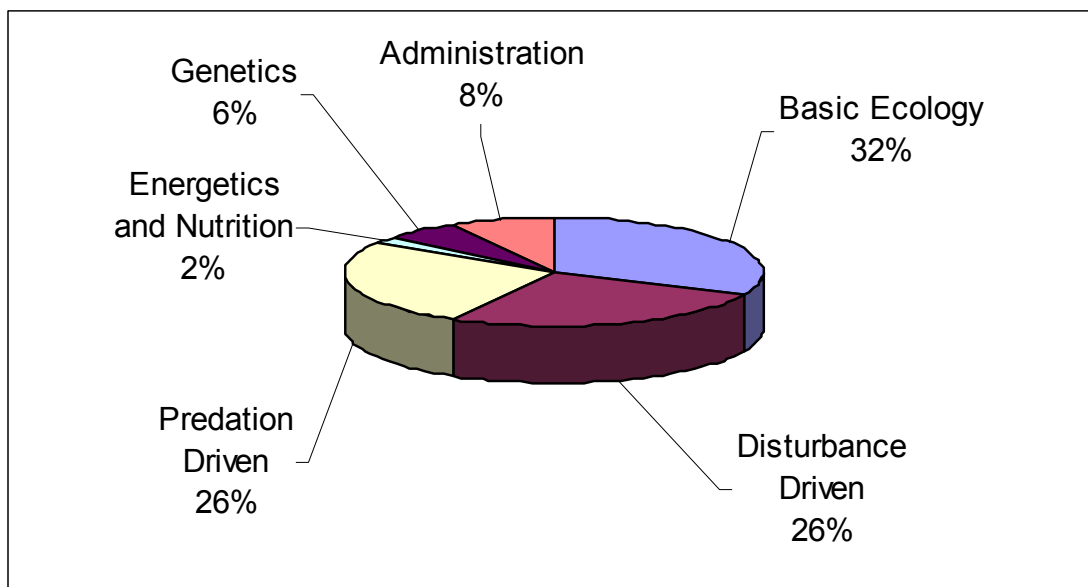


Figure 7.1 Percentages of Current Canadian Woodland Caribou Research Projects in Each Research Area, as of September 2007

Table 7.2 Research Needs as Identified by Literature Reviews, Classified According to Broad Research Area

Identified Research Need	Basic Ecology	Disturbance Driven	Predation Driven	Energetics and Nutrition	Genetics	Administrative
More long-term caribou, moose, and wolf demographic studies to account for changes in forest succession, weather, disease prevalence, and human exploitation			•			
Silvicultural techniques for minimising production of moose browse and enhancing production of lichen and other forage species generally used only by caribou				•		
Nutritional requirements of caribou at the population and individual animal level				•		
Importance and most critical period for predation on caribou calves for each region			•			
Impacts of other predators such as black bears and lynx			•			
Caribou and wolf responses to roads in varied ecological settings		•				
Habitat alteration thresholds for caribou populations		•				
Experimental intervention to manipulate moose densities (hunting pressure) to test wolf and caribou population responses			•			
Consequences of declining moose populations on caribou predation			•			
Conditions affecting wolf encounter rates with caribou		•				
Coarse- and fine-scale levels of prey selectivity in caribou-moose-wolf systems		•				
Optimal juxtaposition and geometry of cutblocks in relation to caribou habitat and travel routes of wolves		•				

(Continued on next page.)

Table 7.2 Continued

Identified Research Need	Basic Ecology	Disturbance Driven	Predation Driven	Energetics and Nutrition	Genetics	Administrative
Effect of habitat quality and enhancement on resilience of caribou populations to withstand wolf predation				•		
Standardization and further classification of ecotypes					•	
Intraspecific morphological variation in caribou, wolves, and moose and its effect on predator-prey relationships			•			
Adaptive environmental assessment and management processes to organize agencies and stakeholders to use knowledge and models for resource management decision making						•
A better understanding of woodland caribou foraging ecology and nutrition is required to properly evaluate its effect on population parameters				•		
Multifactorial hypothesis testing is needed to better understand interactions among limiting factors that may affect caribou populations	•					
The effects of herbicides on summer and winter forage availability require further study				•		
Fine-scale studies of foraging behaviour by caribou in summer are needed to gain a more complete picture of the temporal patterns in caribou response to variation in forage availability				•		
The hypothesized link between habitat alteration and caribou mortality should be addressed using appropriate experimental design and hypothesis testing, integrated with forest management planning that carefully monitors short- and long-term treatment effects		•				
Total Occurrences	1	6	6	6	1	1

Based on percentage research needs identified that fall into these broad categories (Figure 7.2), research projects are needed in the following categories:

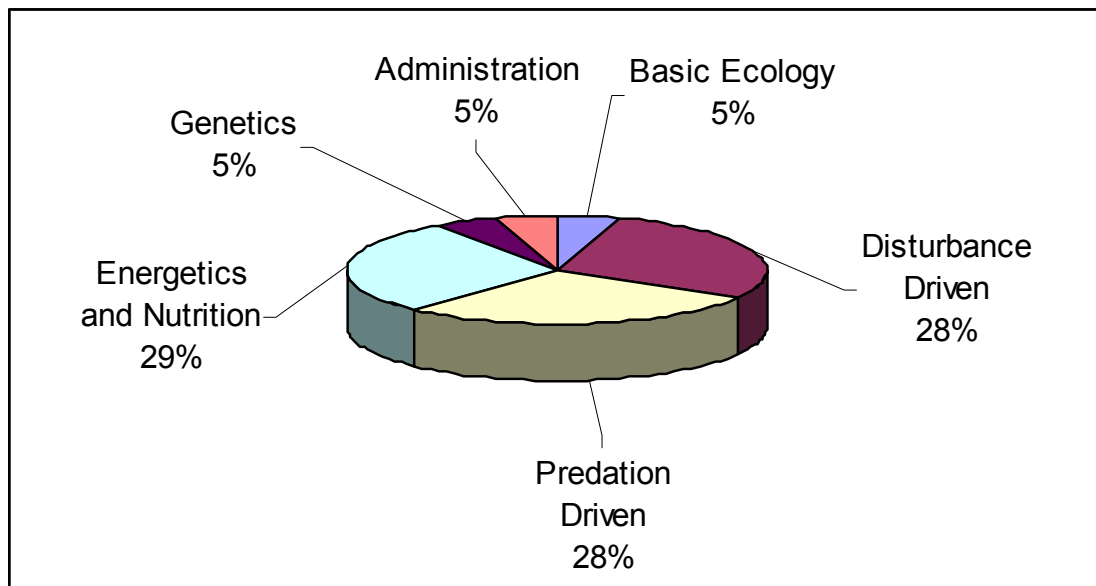


Figure 7.2 Percentage Breakdown of Research Topics Currently in Need of Projects in Canada, as Identified in Literature Reviews

Table 7.3 A Comparison of Current versus Needed Research on Woodland Caribou in Canada, Based on Percentage of Total Research Projects and Research Needs Identified [Ratio of current to needed research is a crude indicator of potential research gaps (with lower values indicating a potential gap)].

	Current Research (% of total projects)	Needed Research (% of needs identified)	Ratio of Current to needed research (current/needed)
Basic Ecology	30	5	6.0
Disturbance Driven	26	28	0.93
Predation Driven	28	28	1.0
Energetics and Nutrition	2	29	0.07
Genetics	6	5	1.2
Administrative	8	5	1.6

8.0 CONCLUSIONS

Past research has produced a substantial body of information about forest-dwelling populations of woodland caribou in Canada. Nevertheless, there are significant gaps in current knowledge about topics of great importance to the management and conservation of these populations. For example, basic information about the status and trends of woodland caribou populations is lacking for many herds.

Disturbances to woodland caribou habitat caused by natural and human factors have been hypothesized as major threats to woodland caribou in some areas. A leading hypothesis is that habitat disturbance increases the vulnerability of caribou to predation.

More than 25 current research projects on woodland caribou are investigating various aspects of disturbance and predation. This suggests that significant advances in scientific understanding of disturbance and predation will be forthcoming. Information about ongoing projects compiled in this report will be useful in tracking ongoing research and identifying gaps in current efforts that should be filled.

Understanding the energetic and nutritional requirements of a species, both at the individual and population levels, is vital to understanding a range of population parameters, including survival, recruitment, longevity and persistence. Given the demonstrated importance of these topics in several species related to caribou and the small number of current caribou research projects that address them, it is reasonable to suggest a need for more research.

It should be noted that this analysis did not consider the size or scope of research projects (e.g., research budget, number of personnel involved). Nor did we attempt to evaluate the sufficiency of research project designs to achieve stated objectives. These are important limitations that should be addressed in future assessments of Canada's research portfolio on forest-dwelling populations of woodland caribou.

Finally, there are likely a limited number of ways in which management efforts can significantly affect caribou populations over the long-term. Managing disturbance regimes through modifying and ameliorating harvesting practices within the range of social, silvicultural and economic limitations shows promise for mitigating adverse effects and aiding caribou conservation efforts. Altering seasonal forage quality and quantity to improve woodland caribou range condition while minimizing forage for alternate prey species may become possible with better understanding of non-lichen forage requirements.

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APPENDIX A

PROJECTS IDENTIFIED

The following projects were identified using the methodology detailed above. Projects are listed under the province/territory in which the research is primarily taking place, irrespective of the location of the primary contact or organization. Abstracts were either available from various online sources, or were communicated directly from primary contacts or graduate students, and appear here as received, unedited or reviewed, except for spelling or grammatical errors.

British Columbia (16)

Title: Temporal patterns in the change in distribution of caribou and moose in north-central BC

Primary Contact: Chris Johnson

Graduate Student: Dan Santomauro

Organization: University of Northern British Columbia, BC

Abstract: Woodland caribou (*Rangifer tarandus caribou*) of the boreal forests of British Columbia have demonstrated a long-history of decline in distribution and abundance. In contrast to this pattern of decline, moose (*Alces alces*) have expanded their distribution across the province. Research on the ecology of these two species suggests that these shifts in distribution are related. I documented temporal patterns in the shifting distribution of caribou and moose in the Fort St. James region, northern British Columbia, between the years 1820-1950. I inferred changes in distribution and possible causative mechanisms from historical information gathered from four sources: 1) scientific literature; 2) semi-structured interviews with local aboriginal and non-aboriginal elders; 3) archives of the Hudson Bay Company; and 4) community histories. This research will provide valuable insights on the use of historical information to infer long-term ecological processes and patterns and increase our understanding of the historical changes in distribution of woodland caribou and moose in the Fort St. James area and across northern British Columbia (*D. Santomauro, pers. comm.*).

Title: Ecological relationships between Threatened caribou and their habitat in the central Rocky Mountains Ecoregion

Primary Contact: Dale Seip

Organization: BC Ministry of Environment

Abstract: Radio-collared caribou are being monitored to determine seasonal habitat use within an area where different herds exhibit a complex pattern of winter habitat use patterns. Some caribou use windswept alpine ridges in winter, others feed on arboreal lichens in old-growth subalpine forests, and others use low elevation pine-lichen ranges. Habitat selection information will be used to map critical habitat required for the recovery of the Threatened herds within the area.

Title: Impact of mountain pine beetle on caribou winter range

Primary Contact: Dale Seip

Organization: BC Ministry of Environment

Abstract: A low elevation pine-lichen caribou winter range is being monitored as it is attacked and killed by mountain pine beetle. Caribou use of the range as well as habitat attributes including snow depth and lichen responses are being monitored.

Title: Effects of a mountain pine beetle epidemic on forest floor vegetation dynamics and regeneration in the Itchallgachuz caribou winter range in the Quesnel TSA

Primary Contact: John Youds

Organization: BC Ministry of Environment

Abstract: none available

Title: The response of caribou terrestrial forage lichens to mountain pine beetles and forest harvesting in the East Ootsa and Entiako areas

Primary Contact: Debbie Cichowski

Organization: BC Ministry of Environment

Abstract: The recent mountain pine beetle (*Dendroctonus ponderosae*) outbreak in central British Columbia has affected significant areas of mature lodgepole pine winter range of the Tweedsmuir-Entiako woodland caribou (*Rangifer tarandus caribou*) population, and is now in the “grey attack” phase of the epidemic. Currently there is no information available on the effects of mountain pine beetles on woodland caribou or their preferred forage, terrestrial forage lichens. The objective of this project is to gain an understanding of how terrestrial caribou forage lichen species respond to mountain pine beetle and forest harvesting disturbances in the East Ootsa and Entiako areas.

Title: Effects of a MPB epidemic on Northern Caribou habitat use, migration and population status.

Primary Contact: Debbie Cichowski

Organization: Bulkley Valley Center, B.C.

Abstract: This project is part of a larger study. The overall objectives are to assess the effects of the current mountain pine beetle epidemic during the “grey-attack” phase on Tweedsmuir-Entiako caribou migration, landscape level habitat use, stand level habitat use and forage site selection using radio-collared caribou and snow tracking; to use information collected during this study to develop a management strategy specific to the Tweedsmuir-Entiako caribou population in a post-beetle landscape, and to develop a general management strategy for other caribou populations experiencing mountain pine beetle outbreaks; and to communicate information collected during this study to wildlife managers and others in a readily accessible format.

Title: Use of adaptive management to mitigate risk of predation for woodland caribou in north central British Columbia

Primary Contact: Dan Adamson

Organization: McGregor Model Forest, Prince George, BC

Abstract: The purpose of the proposed three-year research project is to assist recovery of threatened herds of woodland caribou (northern ecotype) across their range in British Columbia. A science-based comparison of predation mitigation will be made using a combination of Habitat Supply Modeling (HSM) and adaptive management. On the basis of previous studies from radio-collared caribou, moose, and wolves in three caribou herd areas, we are able to opportunistically compare efficacy of recent predation mitigation activities in an adaptive management framework. Regulated wolf trapping has occurred and is continuing in one caribou herd area while an enhanced moose harvest has been planned and will be initiated this year in another caribou herd area. The third caribou herd area will be used as a spatial control. We can also use an HSM (Caribou Habitat Assessment and Supply Estimator – CHASE) developed under previous Forest Science Program funding to guide adaptation of predation mitigation activities (*D. Adamson, pers. comm.*).

Title: Extension of habitat supply tools: The caribou habitat assessment and supply estimator (CHASE)

Primary Contact: Dan Adamson

Organization: McGregor Model Forest, Prince George, BC

Abstract: The proposed one-year research project will be used to merge together, refine, and extend to clients, two tools that currently are used to provide information for planning the recovery of woodland caribou in BC. The combined, non-proprietary tool will be designed for application to all recovery planning areas for threatened herds of caribou (mountain and northern ecotypes) (*D. Adamson, pers. comm.*).

Title: Establishing a science basis for recovery of woodland caribou in Northcentral British Columbia

Primary Contact: Dan Adamson

Organization: McGregor Model Forest, Prince George, BC

Abstract: This project focuses on synthesis and technical extension of existing information to support planning the recovery of threatened woodland caribou in north-central BC. A series of eight publications are planned over a two-year period in a strategic sequential pattern, which will ultimately provide a science basis for recovery actions (*D. Adamson, pers. comm.*).

Title: Ecological relationships between threatened caribou and their habitat in the central Rocky Mountains Ecoregion

Primary Contact: Dan Adamson

Organization: McGregor Model Forest, Prince George, BC

Abstract: This project examines the critical habitat requirement of threatened caribou herds in the central Rocky Mountains. Movements and habitat use of radio-collared caribou were monitored throughout the year, and impacts of mountain pine beetles will be examined. Results will be used to guide recovery plans for these herds (*D. Adamson, pers. comm.*).

Title: Regional coordination of caribou recovery initiatives

Primary Contact: Dan Adamson

Organization: McGregor Model Forest, Prince George, BC

Abstract: This project supports a coordinated approach to the recovery-based projects being conducted in the Omineca region. Activities have included the development of an FTP site and website (www.centralbccaribou.ca) for posting information and resources for the three Recovery Implementation Groups in the region. In addition, a newsletter was recently developed for Wildlife Infometrics to present the status of wildlife projects currently underway (*D. Adamson, pers. comm.*).

Title: Caribou response to encounters with people in Jasper National Park

Primary Contact: William Dushenko

Graduate Student: Tracy McKay

Organization: Royal Roads University, Victoria, BC

Abstract: The number of woodland caribou (*Rangifer tarandus caribou*) in south Jasper has decreased by approximately 30-50% since 1988. Possible reasons for the decreasing numbers in Jasper include a lack of high quality habitat and displacement from critical habitat by people. The South Jasper Caribou Project was initiated in 2002 to address potential causes of decline. Preliminary results suggest that caribou avoid areas near trails, and that avoidance distance increases with level of human activity. As an extension of the South Jasper Caribou Project, this study will investigate caribou response to humans along three major trail systems in Jasper National Park. The Tonquin Valley Trail, the Brazeau Loop, and the Skyline Trail pass through areas of known caribou use. Researchers will directly observe caribou behaviour in response to people along these trails. In addition, GPS radio collar data will be analyzed to determine if caribou avoid areas after encounters with people have taken place. A third component of this study includes surveying Jasper residents and backcountry users to determine their response to proposed caribou recovery measures in Jasper National Park.

Title: Wolf movements in relation to natural and industrial landscape features on caribou range in on east slopes of Rocky Mountains, BC

Primary Contact: Dale Seip

Organization: British Columbia Ministry of Forests, Prince George, BC

Abstract: Radio-collared wolves are being monitored on caribou ranges to determine the seasonal pattern of wolf use of caribou habitat, and to evaluate if industrial developments such as roads, cutblocks and seismic lines result in increased wolf use of caribou habitat.

Title: Mitigating Risks of Predation for Caribou

Primary Contact: Scott McNay

Organization: Wildlife Infometrics Inc.

Abstract: Wildlife Infometrics is part of a province-wide research team focused on mitigating predation on woodland caribou populations. The decline of caribou in BC is the result of many factors including, but not limited to: global climate change, habitat modification from resource development, displacement by human activity, and increased mortality. Regardless of the most significant cause of the population decline or the best long-term solution to reverse it, in the short-term predation has the most serious and direct effect especially on the herds in southern BC, many of which number fewer than 50 caribou.

Our objective is to evaluate the effectiveness of regulated trapping as a method to temporarily reduce predation on adult caribou as they migrate between winter and summer ranges. This objective comes after having monitored the movements and interactions among caribou, moose, and wolves in north-central BC for the past 7 – 15 years. The temporary nature of the management is intentional since we want only to maintain opportunities for the development and implementation of longer-term solutions to the population decline. The longer-term solution will include maintaining wolves as part of the natural system. In the short-term we will monitor the reduction of wolves and any subsequent effect on survival of caribou.

Results will be compared to predation rates in the control, wolverine caribou herd where no management of wolves will occur. Results will also be compared to study in the Parsnip herd area, where moose are being reduced through an aggressive Limited Entry Hunt program implemented this fall. A replicate project similar to ours has been underway in southern BC for a couple of years. Outcomes of this research will help Government to make sound, science-based decisions about the recovery of caribou in BC.

Title: Promotion of mountain caribou recovery through alternate species management

Primary Contact: Mike Gillingham

Graduate Student: Robin Steenweg

Organization: University of Northern British Columbia

Abstract: Mountain caribou are threatened throughout much of their range in British Columbia and corrective measures to reverse this decline must involve predation mitigation by managing early seral forest conditions, non-caribou ungulates, predators, or a combination of these. The project will evaluate the feasibility of increasing the numbers of a herd of caribou by reducing predation through a reduction in moose numbers. Moose hunting regulation changes, initiated in the fall of 2006, are designed to reduce moose densities throughout the study area. An adjacent caribou herd will serve as a contemporary control. Because prior demographic data exist for all species in all areas we will be able to make before-after comparisons as well as contemporary comparisons among areas/treatments. This project is funded by the British Columbia Ministry of Environment, the Peace Williston Fish and Wildlife Project and the Species at Risk Coordinating Office for British Columbia.

Title: Parsnip caribou recovery trail

Primary contact: Doug Heard

Organization: Peace-Williston Fish and Wildlife Compensation Program and BC Ministry of Environment, Prince George, BC

Abstract: This project will examine the potential for increasing caribou numbers through changes in the hunting regulations that will allow hunters to kill more moose, reduce moose numbers, resulting in a subsequent decline in wolf numbers and wolf predation rates on caribou (*Doug Heard, pers. comm.*).

Alberta (10)

Title: The predator-prey dynamics of wolves and moose in the North Columbia Mountains: Ecology and habitat use in relation to mountain caribou decline

Primary Contact: Fiona Schmiegelow

Graduate Student: Shannon Stotyn

Organization: University of Alberta, Edmonton, Alberta

Abstract: The recent "Strategy for the Recovery of Mountain Caribou in British Columbia" (Mountain Caribou Technical Advisory Committee 2002) identifies the need for research on altered predator-prey relationships (e.g., caribou, moose, and wolves) as a critical step in the recovery of threatened mountain caribou populations. In collaboration with other research projects working on the Revelstoke caribou herd in the Northern Columbia Mountain ecoregion, my research focuses on wolves and proposes to (1) collect baseline information that describe the distribution of wolves within the study area, (2) assess and compare seasonal variation of wolf territory overlap with caribou home ranges, (3) develop resource selection functions for wolves to describe their use of the landscape, and (4) explore the feasibility of GPS cluster analysis to determine kill rate, kill site location and prey selection for wolves within the study area.

Title: Predator efficiency and linear feature study

Primary Contact: Paula Bentham

Organization: Golder Associates, Edmonton, AB

Abstract: The objective of this project is to determine relative use of linear features by wolves and other predators in the Richardson Caribou Area. Research questions related to predator efficiency and line widths and types were highlighted in PTAC's RFP. During the winter of 2007, Golder is proposing to conduct a rigorous tracking survey within the Richardson Caribou Areas to identify predator use of linear features of various types and width (e.g., LIS, conventional seismic, roads, pipelines, creeks). These data would provide an initial scoping but are limited to the winter season. In general, questions about how wolves travel in a landscape with a mixture of natural and anthropogenic linear features will be explored. Research questions which could be addressed include:

- Do wolves select for anthropogenic versus natural linear features?
- Do wolves select for wide versus narrow linear features?
- Do wolves select for packed versus unpacked linear features?

The density of linear disturbance corridors (e.g., roads, cutlines, pipelines, powerlines) across the Richardson Caribou Area will be determined using Altalis data in a GIS environment. The Caribou Area will be divided in three categories of density (i.e., high, moderate, low) based on this GIS exercise and sample quadrats (25 km²) will be delineated within each density category.

Three 25 km² quadrats will be searched in each of the three density categories in early, mid and late winter. During each session, the Richardson Caribou Area will be searched for wolf tracks. The first quadrat will be placed based on the location of the first set of wolf tracks located while flying in each linear density category. Once the first quadrat has been delineated using GPS, all linear disturbances within the quadrat will be searched to determine if linear disturbances are packed or not, as well as to check for use by wolves, coyotes, moose, caribou, and deer. The subsequent two quadrats will be located by forward or backtracking the same wolves to a location at least 10 km from the edge of the initial quadrat. This process will be repeated in each linear density category until 9 - 25 km² quadrats have been completed during each of the early, mid and late winter surveys.

Winter field visits would be at least five days after a fresh snowfall to increase the likelihood that wolf tracks are encountered more frequently. Linear disturbances in each quadrat will be flown just above tree height at about 50 km/hour. Tracks will be identified from the air where possible.

When necessary, track identification will be verified by landing. Depending on time constraints, all ungulate and canid use of lines, as well as compact segments, will be recorded as start and finish points using a GPS.

Quadrats surveyed during the winter tracking season will be revisited via helicopter in the snow-free season to ground truth the Altalis data and assign width categories to mapped linear disturbances, as well as to locate and map any small linear disturbances that were not captured by Altalis and not mapped during the winter field season. This will provide a ground-truthed linear distance for all categories of cutlines, roads and other linear disturbance corridors for each sample quadrat. A preliminary assessment of the current state of revegetation on each line will also be conducted.

Segments of lines used by ungulates and canids will be mapped in each quadrat using the GPS start and end points. All disturbance corridors in each quadrat will be characterized using independent variables such as habitat type, terrain, vegetation recovery and distance to human disturbance. Characteristics of linear disturbances used by wolves will be compared to those that were not within each quadrat across linear density categories.

Title: Diet and nutrition of woodland caribou in west-central Alberta

Primary Contact: Robert Hudson, Luigi Morgantini

Graduate Student : Christie Strocel

Organization: University of Alberta, Edmonton, Alberta

Abstract: The Narraway caribou herd of west-central Alberta is a unique ecotype of woodland caribou. Each year, they migrate from their summer range in the eastern slopes of the Rocky Mountains to their winter range in the forests of British Columbia and Alberta. Terrestrial lichens have been identified as the primary winter forage for woodland caribou across Canada. However, the Narraway caribou herd occupies a landscape in which lichen abundance is low and distribution is patchy in most forest stands. Knowledge of caribou diet in this region is limited, yet in an area of low lichen availability it is important to know what the caribou are eating in order to effectively manage for their foraging needs. The purpose of my study is to investigate the winter foraging habits of the Narraway caribou herd. Fecal samples will be collected throughout the winter to determine diet composition in relation to environmental variables, such as snow pack, and time of year. Foraging paths and cratering sites, where caribou dig through the snow to feed on vegetation, will be studied for plant and topographical characteristics. By comparing these sites to those where caribou choose not to forage, we may determine the factors which contribute to forage site selection. Woodland

caribou across Canada occupy a variety of habitats with different vegetation and foraging opportunities. Understanding the foraging habits of caribou in west-central Alberta will help forest managers identify important feeding sites within this caribou winter range and give insight into how caribou may adapt to areas of low lichen availability (*C. Strocel – pers. comm.*).

Title: Wolf-caribou dynamics in west central Alberta

Primary Contact: Mark Hebblewhite, Marco Musiani

Organization: University of Montana, Missoula, MT; University of Calgary, Calgary, Alberta

Abstract: Woodland caribou are declining throughout their range in Alberta and British Columbia, and the main reasons for declines are human activities which are altering predator-prey relationships that favour caribou. There are thought to be two primary causes for declines: 1) Forestry and fire creates young forests that have high numbers of other prey for wolves, like moose and elk. Because the number of wolves depends on moose, forestry increases the number of wolves, which then prey on caribou; 2) Oil and gas exploration builds seismic lines and access roads, which are thought to increase predator efficiency by making it easier for wolves to search for and kill moose and caribou. Because of the huge spatial scale of wolf-caribou systems, few field studies have tested whether linear features increase wolf predation rates, or looked at implications of forestry for moose and thus for caribou. These have also been difficult to study because forestry and oil and gas development often occur at the same time. Thus, managers face a problem of trying to understand the relative roles of increases in predator efficiency (primarily associated with oil and gas) vs. the production of primary prey habitat (primarily associated with forestry).

The research objectives are to address: 1) What are the historic patterns of gene flow between caribou herds today, and how do existing levels of human development influence gene flow? 2) How does predator (wolf) efficiency change over a regional gradient of human development? To what degree does oil and gas vs. forestry contribute to any change? 3) How does forestry and fires contribute to increased primary prey productivity in wolf-caribou systems of west-central Alberta? And 4) How does migratory behaviour of mountain caribou alter predator-prey relationships and the effects of human development on caribou viability? (*L. Morgantini, pers. comm.*)

Title: Evaluating management for the Little Smoky caribou herd in west central Alberta

Primary Contact: Mark Boyce

Graduate Student: Christine Robichaud

Organization: University of Alberta, Edmonton, Alberta

Abstract: The Little Smoky caribou herd has been identified as a population in imminent danger of extirpation due to large declines in herd size. The herd's range is in an area with high levels of human disturbance resulting from forestry and oil and gas activity. To help the population recover, Alberta Fish and Wildlife Division implemented an aerial wolf control program during the 2005-2006 and 2006-2007 winters and populations of wolf prey (moose, elk and deer) are tentatively being reduced by increasing harvest limits.

Although wolves are believed to be the caribou's main predator, predation by other predators, notably bears, has been reported in many areas. In the Little Smoky caribou range specifically, wolf removal raises concerns that bears may be increasing in the area and that as a result they may be preying on

caribou calves at higher rates. The role of bears in caribou ecology is not well understood in the Little Smoky; therefore one of our goals is to determine the importance of caribou in black and grizzly bears diets.

We collected hair samples from bears over the 2007 summer throughout the Little Smoky range using hair snag techniques. Bait stations consisted of barbed wire enclosures (50cm above ground) around 3-6 trees with a suspended beaver carcass in the centre to attract the bears. A diet analysis will be performed using a stable isotope analysis of ^{13}C and ^{15}N of the hair.

Ungulate harvest data (moose, elk and deer) obtained from hunter surveys will be analysed to determine the effectiveness of ungulate reductions. In addition, province-wide wolf trapping data will be used to detect spatial and temporal patterns in wolf harvest which may allow us to determine if trapping is a plausible alternative to aerial gunning in the Little Smoky area (*C. Robichaud, pers. comm.*).

Title: Linear features impact predator-prey encounters: Analysis with first passage time

Primary Contact: Evelyn Merrill

Graduate Student: Hannah McKenzie

Organization: University of Alberta, Edmonton, AB

Abstract: Landscapes are heterogeneous and animals respond to this heterogeneity by altering their movement patterns. This thesis was motivated by the need to understand the impact of a particular type of heterogeneity, anthropogenic linear features, on wolf (*Canis lupus*) movement in the central east slopes of the Rocky Mountains (Alberta, Canada). First passage time refers to the length of time taken to first encounter an object, such as a prey item. Novel first passage time analysis methods for animal movement were developed and applied to wolves in the presence of linear features. The underlying movement model was parameterized using paths obtained from GPS collars. These animal movement paths were confounded by measurement error. I developed a mechanistic, empirically-based method for buffering linear features that minimized the underestimation of animal use of linear features introduced by GPS measurement error. Mean first passage time analysis showed that wolves found prey faster in landscapes with higher densities of linear features, resulting in an increased functional response, which was most prominent at low prey densities. These findings have implications for management of species at risk in highly developed landscapes.

Title: Caribou, primary prey and wolf spatial relationships in northeastern Alberta

Primary Contact: Stan Boutin

Graduate Student: Dave Latham

Organization: University of Alberta, Edmonton, AB

Abstract: It is widely accepted that increases in industrial development have contributed to caribou declines in Alberta. The current working hypothesis is that industry-induced changes in caribou range have reduced the ability of this species to spatially separate from primary prey, and that this has resulted in increased predation by shared predators such as wolves. Two factors appear to be important: (1) seismic exploration lines and other linear features may increase wolf hunting

efficiency; and (2) industrial disturbances, such as forestry, increase the quantity and quality of food needed to support higher primary prey densities, which can cause wolf numbers to increase. Although evidence continues to build in support of this hypothesis, we still lack key information that is highly relevant to effective management. Of particular concern: (1) Does spatial overlap increase because of changes on caribou range alone or is the adjacent upland habitat crucial, i.e., at what scale do we need to conduct our management activities; and (2) Are the changes taking place exacerbated by a warming climate? This research project has been investigating these issues over the past four years using the West Side of the Athabasca River (WSAR) caribou range as a model. The specific research questions of this project include: (1) Has predation risk for caribou in WSAR increased in the last 10 years (i.e., since major increases in forestry and oil and gas activity)? (2) If so, is this due to an increased number of predators, increased predator efficiency, or both? and (3) Are the changes driven by changes on caribou range, surrounding areas, or both? (*D. Latham, pers. comm.*)

Title: Ecological and economic trade-offs between woodland caribou conservation strategies

Primary Contact: Vic Adamowicz

Organization: University of Alberta, Edmonton, AB

Abstract: At least four landscape-level management actions have been proposed in response to declining caribou numbers: (1) limiting industrial footprint in areas occupied by caribou, (2) altering the industrial footprint to discourage predator and alternate prey use, (3) culling of predators, and (4) increasing hunter harvest of alternate prey. The efficacy of these actions depends on caribou population growth rate, current and projected industrial footprint, and prey and predator densities on and surrounding caribou range (*V. Adamowicz, pers. comm.*).

Title: Little Smoky caribou calf protection project

Primary Contact: Wayne Thorp

Organization: Foothills Model Forest

Abstract: An innovative project to increase recruitment numbers of the Little Smoky caribou herd has secured 10 pregnant cows within a fenced area in northwestern Alberta. Recruitment is the survival of new calves. This project is modelled after the Chisana Caribou Project. Similar to the Little Smoky herd, the Yukon-based Chisana caribou herd, experienced high calf-mortality. The Chisana Caribou Project placed cows and their calves in an enclosure to protect them from predation in an effort to restore population. Results from the Chisana Caribou Project are extremely promising; there is a 75% calf survival rate among protected calves compared to a 12.5% survival rate for calves in the unfenced population.

The government-led (Alberta Sustainable Resource Development) Little Smoky Caribou Calf Protection Project will keep the cows and their offspring in the enclosure until early summer. Providing protection from predators early in a calf's life enables the calf to reach a size where it can fend for itself in the wild, thus improving its chance of survival. The most vulnerable period in a caribou's life is during its first few months where the calves are often preyed upon by animals such as wolves.

The pregnant caribou inside the fenced area are monitored regularly and receive supplemental food and water. No public or industrial access is allowed near the project site.

Title: Use of location data to inform conservation of woodland caribou in Alberta

Primary Contact: Fiona Schmiegelow

Organization: University of Alberta

Graduate Student: Simon Slater

Abstract: Woodland caribou (*Rangifer tarandus caribou*) in Alberta are designated as a threatened species under the Provincial Wildlife Act and federally by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). In a time of increasing land use activities on many landscapes, there is a need for effective management of ecosystems to maintain biodiversity, including species at risk. Effective management includes the application of reliable knowledge in an appropriate decision-support system. This study will focus on the use of animal location data to inform conservation and management of woodland caribou in Alberta. The strengths and limitations of data will be evaluated relative to issues of spatial and temporal resolution, and the ability to inform or misinform general questions of distribution and abundance, and more specific questions regarding habitat use and determination of critical habitat. Results from this study will support managers in making sound decisions for the conservation of woodland caribou in Alberta, and inform approaches in other jurisdictions (*S. Slater, pers. comm.*)

Saskatchewan (3)

Title: Qualitative assessment of woodland caribou (*Rangifer tarandus caribou*) distribution in central Saskatchewan through local knowledge

Primary Contact: Francois Messier

Graduate Student: Naomi Carriere

Organization: University of Saskatchewan

Abstract: A declining woodland caribou (*Rangifer tarandus caribou*) population across Canada has led to the classification of woodland caribou as a threatened species. Recovery efforts are underway, however current and historical distribution of woodland caribou is still poorly understood. Traditional Ecological Knowledge (TEK) is an attribute of societies with historical continuity in resource use practice. Local Knowledge (LK), a fundamental element of TEK, includes species identification and taxonomy, life histories, distribution and behaviour. Incorporating LK and TEK will increase Aboriginal participation in the recovery effort and identify current woodland caribou distribution. The method I am developing for the collection of TEK and LK incorporates consultation, cooperation and respect of Aboriginal values. Participants for the collection of LK and TEK include active, local trappers from Lac La Ronge and surrounding areas. This project will demonstrate how TEK and LK can contribute to our understanding of woodland caribou, current distribution, identification of critical habitat, quality of habitat, changes in predator/prey balance and changes in human land-use practices. This project will also foster communication between local resource users, industry and government at local, provincial and federal levels and increase the participation of resource users in woodland caribou recovery by identifying caribou friendly practices (*N. Carriere, pers. comm.*).

Title: Prince Albert National Park Greater Ecosystem Project (PAGE)

Primary Contact: Micheline Manseau

Organization: University of Manitoba

Abstract: The purpose of this project is to acquire additional ecological and population data on woodland caribou in and around Prince Albert National Park. The results of this work will assist with land-use decisions that may affect the species including the Park's fire management plan, logging and road development beyond the Park boundary. Information obtained through this research project will also assist the provincial Woodland Caribou Management Team in developing a recovery strategy. The project's objectives are 1) to develop and apply a landscape analysis model capable of identifying critical habitat and movement corridors; 2) to clarify what constitutes high quality habitat; 3) to estimate population sizes of woodland caribou using DNA-based mark-recapture techniques; and 4) to obtain baseline data on the population genetic structure of woodland caribou in PAGE (*M. Manseau, pers. comm.*).

Title: Historical distribution of woodland caribou (*Rangifer tarandus caribou*) in the Prince Albert Greater Ecosystem, Saskatchewan, Canada in relation to landscape changes

Primary Contact: Micheline Manseau

Organization: University of Manitoba

Abstract: The Prince Albert Greater Ecosystem (PAGE) has historically been used by the boreal ecotype of woodland caribou. In order to determine if changes in use of this area have occurred, we collated caribou observations (from surveys and sightings) and telemetry data from 1946 to 2006 and reconstructed land cover maps for that same time period using current and old forest resources inventories, fire, logging, trails and roads data. Preliminary results indicate that woodland caribou are still found throughout the PAGE area but their distribution is more fragmented and their use of Prince Albert National Park, centrally located within the PAGE, appears greatly limited. A descriptive analysis of the land cover maps indicates that area logged and the amount of linear features and areas burned have increased over the last decades. Analyses are ongoing to determine if the changes in animal distribution are correlated with structural and functional attributes of landscape changes (*M. Manseau, pers. comm.*).

Manitoba (7)

Title: Testing the importance of spatial configuration of winter habitat for woodland caribou: An application of graph theory

Primary Contact: Micheline Manseau

Organization: University of Manitoba, Parks Canada

Abstract: Conservation of remaining woodland caribou (*Rangifer tarandus caribou*) populations requires land management strategies that not only maintain caribou habitat, but also favour habitat connectivity. This study presents and field tests graph theory-based measures of landscape connectivity, and demonstrate an association between the distribution of woodland caribou and well-connected winter habitat. Cost values for the intervening land cover types were determined based on the probability of selection relative to high quality winter habitat. Habitat connectivity was then represented by linking high-quality habitat patches along least-cost paths through this parameterized cost surface. A randomization procedure was used to assess the animal's association with habitat

connected at increasing distance thresholds to identify appropriate scales of response. A strong relationship was obtained between large clusters of high-quality winter habitat patches and winter GPS telemetry location points (November 1–March 15) from two woodland caribou herds in Manitoba, Canada. This relationship was stronger when only late winter location points (January 1–March 15) were used. Our results highlight the importance of accounting for the spatial configuration of habitat on the landscape and the intervening land cover types when assessing range quality for woodland caribou. They also provide support for the use of graph theory to assist in identifying core activity areas for woodland caribou and key linkages between these areas and other parts of the landscape (*M. Manseau, pers. comm.*).

Title: Habitat connectivity using spatial graph theory

Primary Contact: Micheline Manseau

Organization: University of Manitoba

Abstract: Well-founded methods to assess habitat connectivity are essential to inform land management decisions that include conservation and restoration goals. Indeed, to be able to develop a conservation plan that maintains animal movement through a fragmented landscape, spatial locations of habitat and paths among them need to be represented. Graph-based approaches have been proposed to determine paths among habitats at various scales and dispersal movement distances, and balance data requirements with information content. Conventional graphs, however, do not explicitly maintain geographic reference, reducing communication capacity and utility of other geo-spatial information. We present spatial graphs as a unifying theory for applying graph-based methods in a geographic context. Spatial graphs integrate a geometric reference system that ties patches and paths to specific spatial locations and spatial dimensions. Arguably, the complete graph, with paths between every pair of patches, may be one of the most relevant graphs from an ecosystem perspective, but it poses challenges to compute, process and visualize. We developed Minimum Planar Graphs as a spatial generalization of Delaunay triangulations to provide a reasonable approximation of complete graphs that facilitates visualization and comprehension of the network of connections across landscapes. We applied spatial graphs, and in particular the Minimum Planar Graph, to analyze woodland caribou habitat in Manitoba, Canada to support the establishment of a national park (*M. Manseau, pers. comm.*).

Title: Analysis of woodland caribou habitat selection using generalized estimating equations

Primary Contact: Micheline Manseau

Organization: University of Manitoba

Abstract: Analyzing telemetry data using traditional statistics can be problematic, because of the serially correlated nature of telemetry data. Statistics that have been developed for the analysis of correlated data avoid these problems. We demonstrate the use of generalized estimating equations for analyzing habitat selection, using data collected from woodland caribou (*Rangifer tarandus caribou*) from the Kississing herd in Manitoba, Canada. We demonstrate that the appropriate correlation structure (independent, compound symmetric, M-dependent or autoregressive) depends on the definition of available habitat, and that this definition also alters the apparent degree of habitat selection by caribou. When random points were selected from the home range (minimum convex polygon) of the caribou herd, caribou were observed to select habitats in proximity of jack pine stands and farther from mixed-wood stands. However, this pattern became less evident when random points

were selected at smaller spatial scales. We recommend the use of generalized estimating equations as an alternative to traditional statistics for analyzing habitat selection without sacrificing data (*M. Manseau, pers. comm.*).

Title: Distribution and movement of woodland caribou on disturbed landscapes in west-central Manitoba

Primary Contact: Micheline Manseau

Organization: University of Manitoba

Abstract: Forest operations have been implicated in adversely impacting woodland caribou populations. In order to improve on existing forestry mitigation plans on caribou ranges, the distribution and movements of the Kississing-Naosap herd on disturbed landscapes in west-central Manitoba was examined across a variety of scales. The results indicate a hierarchical pattern of selection by woodland caribou, with seasonal differences. Caribou avoided disturbance across all scales, and selected for mature coniferous habitat types. At a finer scale they selected for summer paths with greater arboreal lichen cover and winter paths with greater visibility. Caribou also selected areas further into cover, away from forest edges. Based on these results, I recommend that leave areas within operating areas be composed of a mosaic of mature jack pine, treed muskeg, and spruce cover types, and at least 1 km in width. I also recommend harvesting larger blocks, obliterating roads post-harvest, and encouraging the regeneration of coniferous stands (*M. Manseau, pers. comm.*).

Title: Spatial and temporal characteristics of calving areas for boreal caribou (*Rangifer tarandus caribou*) in different boreal ecozones

Primary Contact: Micheline Manseau

Organization: University of Manitoba

Abstract: Boreal caribou are found throughout the boreal region of Canada and provincial recovery efforts for this ecotype have taken different positions on the question of characteristics and fidelity to calving sites. In order to better understand the spatial and temporal characteristics of calving sites and calving seasons for boreal caribou, we analysed the movement pattern of 62 animals in the boreal plains and boreal shield ecozones. GPS collars were placed on twenty-five females from the Smoothstone-Wapaweka herd (S-W) in Saskatchewan, in 2005 and 2006, and thirty-seven woodland caribou from the Kississing-Naosap (K-N) herd in Manitoba, from 2002 to 2005. Mean daily travel rates were calculated, based on a three-hour time interval. Based on polynomial regressions, eight distinct seasons were identified for both herds. Based on reduced movement rates, 18 calving sites in the S-W herd and 13 calving sites in the K-N herd were identified. The calving period for the S-W herd extended from May 3rd to June 8th and from May 3rd to June 15th for the K-N herd. At that time, the spatial extent of their movements was also reduced, corresponding to a mean area of 0.072 km² for the S-W herd and 0.064 km² for the K-N herd. Pre-calving season for both herds started in late March and the spatial extent of the area used was 49.36 km² for the W-S herd and 264.60 km² for the K-N herd. Again, based on movement rates, post-calving season was identified and ended in late July; the spatial extent of the area used being 20.15 km² for the W-S herd and 57.56 km² for the K-N herd. We observed no significant difference between the two ecozones when comparing the calving and post-calving seasons for area, travel rate, or mean distance travelled. Significant differences were observed when looking at the pre-calving period for area and mean distance

traveled; however, no significant difference existed when comparing the travel rates of the pre-calving season of the two ecozones (*M. Manseau, pers. comm.*).

Title: Characterization of target nuclear DNA from feces reduces technical issues associated with the assumptions of low-quality and quantity template

Primary Contact: Micheline Manseau

Organization: University of Manitoba

Abstract: Faecal material has increasingly become an important non-invasive source of DNA for wildlife population genetics. However, DNA from faecal sources can have issues associated with quantity (low template and/or low target-to-total DNA ratio) and quality (degradation and/or low DNA-to-inhibitor ratio). A number of studies utilizing faecal material assume and compensate for the above properties with minimal characterization of quantity or quality of target DNA, which can unnecessarily increase the risk of downstream technical problems. Here, we present a protocol which quantifies faecal DNA using a two step approach: (1) estimating total DNA concentration using a Picogreen™ fluorescence assay and (2) estimating target nuclear DNA concentration by comparing amplification products of field samples at suspected concentrations to those of control DNA at known concentrations. We applied this protocol to faecal material collected in the field from two species: woodland caribou (*Rangifer tarandus*) and swift fox (*Vulpes velox*). Total DNA estimates ranged from 6.5 ng/l to 28.6 ng/l ($X = 16.2$ ng/l) for the caribou extracts and 1.0–26.1 ng/l ($X = 7.5$ ng/l) for the swift fox extracts. Our results showed high concordance between total and target DNA estimates from woodland caribou faecal extracts, with only 10% of the samples showing relatively lower target-to-total DNA ratios. In contrast, DNA extracts from swift fox scat exhibited low target DNA yields, with only 38% (19 of 50) of the samples showing comparative target DNA amplification of at least 0.1 ng. With this information, we were able to estimate the amount of target DNA entered into PCR amplifications, and identify samples having target DNA below a lower threshold of 0.2 ng and requiring modification to genotyping protocols such as multiple tube amplification. Our results here also show that this approach can easily be adapted to other species where faeces are the primary source of DNA template (*M. Manseau, pers. comm.*).

Title: Relating the population genetic structure of woodland caribou to landscape connectivity

Primary Contact: Micheline Manseau

Organization: University of Manitoba

Abstract: We examined the relationship between landscape connectivity and genetic similarity among populations and individuals of woodland caribou (*Rangifer tarandus caribou*) in central Manitoba, Canada. DNA was extracted from fecal pellets collected during systematic aerial surveys conducted over two winters. Genotypes were generated using six microsatellite markers and the sex of individuals was determined using a sex-linked marker. The presence of population genetic structure was first assessed using a model-based clustering program (STRUCTURE). Measures of genetic similarity were then calculated at both the population and individual. GPS telemetry data were used to generate a cost-surface map and a landscape connectivity model based on spatial graph theory was used to calculate connectivity-based landscape distances. Landscape connectivity was represented by linking habitat patches along least-cost paths at different distance thresholds through this parameterized cost surface. A matrix regression technique was then used to analyse the relationship between connectivity and genetic similarity among pairs of caribou points. Analysis revealed

significant genetic structuring at the regional scale that corresponded well with three putative populations based on landscape structure. Genetic differentiation among the populations was higher than typically found for woodland caribou elsewhere. Genetic similarity among pairs of caribou was significantly correlated with landscape connectivity. Furthermore, the relationship was stronger when only females were analysed. Our findings reveal potential genetic consequences of reduced landscape connectivity arising from the expansion of industrial activities and highlights the challenge of protecting this threatened species, especially at the southern edge of its range (*M. Manseau, pers. comm.*).

Ontario (2)

Title: Site fidelity in caribou calving areas in Wabakimi Provincial Park and Woodland Caribou Signature Site

Primary Contact: Art Rodgers

Graduate Student: Natasha Carr

Organization: Lakehead University

Abstract: To prevent further range recession, habitat features essential to the life history requisites of woodland caribou (*Rangifer tarandus caribou*) such as calving and nursery areas need to be protected for the persistence of the species. Woodland caribou may minimize predation risk during calving by either spacing out or spacing away from predators in the forest to calve on islands, wetlands, or shorelines.

The first objective of this thesis was to determine if in fact the same female caribou was using the same area for calving and nursery activity year after year. Caribou faecal samples for DNA extraction were collected from nursery areas in two provincial parks in northern Ontario: Wabakimi and Woodland Caribou Provincial Parks. Extraction yield was poor in summer-collected faecal samples and site fidelity on a specific lake could not be demonstrated. However, differentiation of caribou DNA samples between parks suggests that caribou may be exhibiting female philopatry during the nursery period: female caribou typically return to a particular area year after year for calving and nursery activities.

Another objective was to determine the fine-scale characteristics of shoreline habitats used as calving and nursery areas by female woodland caribou in the two parks. Detailed vegetation and other site characteristics were measured at shoreline nursery sites used by cow-calf pairs and compared to shoreline sites that were not used by caribou within each park. Important characteristics were used to develop and evaluate Resource Selection Functions (RSFs) for calving woodland caribou in northern Ontario. Habitat characteristics determined at nursery sites were postulated to reflect predator avoidance strategies. Observed differences in habitat variables selected by female caribou in the two study areas primarily reflected broad ecoregional differences in vegetation and topography rather than differences in female choice. In Wabakimi Provincial Park, higher understorey tree density and lower ground detection distance played key roles in distinguishing nursery sites from sites that were not used. In Woodland Caribou Provincial Park, groundcover vegetation and shrub density were important in the selection of nursery sites by female caribou. Generally, female caribou in both parks selected nursery sites with greater slope, lower shrub density, but thicker groundcover vegetation, and higher overstorey cover than shoreline sites that were not used.

The last objective was to determine what physical characteristics caribou might be using at a larger scale (i.e., distance to nearest land feature from nursery sites, distance to closest fly-in outpost from

nursery sites). In Woodland Caribou Provincial Park more nursery sites occurred in the coniferous forest landcover type when compared to unused or random sites. In Wabakimi Provincial Park, there was no difference between nursery activity and landcover types randomly available in the study area. Generally, female caribou in both parks selected nursery sites with shorter escape distances than provided by unused or random sites, and islands were the feature type most frequently used for nursery activity. Female caribou also used clusters of land features within a shorter distance of one another as compared to random points along the shoreline. Caribou cow-calf pairs typically used areas for nursery activity that were 9.0km (\pm 6.5km, range 2.3-20.6km) in Wabakimi Provincial Park and 10.0km (\pm 6.9km, range 0.7 – 32.6km) in Woodland Caribou Provincial Park from any human recreational disturbance.

The identification of these important characteristics of caribou nursery areas at two different spatial scales provides baseline information that may be used to predict the locations of potential caribou nursery sites both within protected area boundaries and across the broader range of this valued species in northern Ontario. It is suggested that a first iteration spatial model be developed from the outcomes of this study to enable validation and refinement and to enhance the management and understanding of this critical life history requisite (*N. Carr, pers. comm.*).

Title: Movement patterns, habitat selection and connectivity of a forest-dwelling woodland caribou population in NWO

Primary Contact: Tom Nudds, John Fryxell

Graduate Student: Jennifer Shuter

Organization: University of Guelph

Abstract: Both movement and habitat selection patterns have been identified as major determinants of the dynamics and distribution of populations in spatially heterogeneous landscapes, as well as important determinants of population persistence. Individual movement can make a vital contribution to changes in population distribution and density, by adding or removing individuals; altering the outcomes of species interactions; providing crucial genetic variability; and rescuing populations from extinction. However, despite broad acknowledgement of the importance of movement as a key driver of population dynamics in heterogeneous landscapes and a large body of theoretical work that attempts to explore this role, the empirical understanding of movements across landscapes and between spatially disjunct groups remains limited.

Habitat selection and landscape pattern are factors that are likely to exert a strong influence on individual movement, as well as the population-level distribution of an organism within a given landscape. Area-restricted search theory predicts that an individual will spend more time in areas where resources are plentiful and less in areas where resources are scarce and it is generally assumed that there is a positive relationship between the extent of use that a given area receives and the quality of the resources and conditions associated with it. The spatial configuration of the combination of resources and conditions that comprise suitable habitat can affect individual movement behaviour, movement-dependent population processes and spatial population structure. For organisms like the forest-dwelling woodland caribou (*Rangifer tarandus caribou*) that exhibit seasonal differences in habitat selection, the distribution of seasonally significant habitats and the ability of organisms to move between them are likely to be important for population persistence. Measures of “connectivity” (i.e., the extent to which movement is facilitated or impeded by landscape

characteristics) provide a means for assessing how an organism's movement might be affected by the composition and configuration of the landscape it inhabits.

The purpose of this project is to develop a better understanding of how seasonal changes and individual variation shape the ways in which forest-dwelling woodland caribou that live near the southern margin of the ecotype's continuous range in northwestern Ontario, move and select habitat. I am also examining whether and how behaviours at different temporal and spatial scales determine the spatial structure of the caribou population that currently persists. Specifically, I am using satellite telemetry data gathered from 34 individuals collared from 1995 to 2000, to focus on:

1. Determining whether the average space use patterns exhibited by collared individuals are consistent with a general ecological definition of "migration" and if so, determining whether there is evidence for partial and/or differential migration and whether population and individual level patterns in migration distance are consistent with a conditional or fixed basis for this migration characteristic.
2. Evaluating whether the general "ecological migrations" exhibited by collared individuals are produced by movements that are consistent with the more strictly defined "behavioural migrations". In other words, I am testing whether there is evidence for clear switches between "migratory" and "encamped/ station-keeping" that occur during the course of the annual cycle. I am also testing whether such switches exhibit similar timing between years (consistent with anticipatory migration) or whether they exhibit significant annual variability (consistent with facultative migration) and if the evidence supports the latter, I intend to test whether variability in environmental conditions such as snow depth and vegetative growth are associated with these differences in timing.
3. Evaluating whether the results of season-specific habitat selection analyses performed using a random selection of location points (i.e., a conventional approach), differ from analyses that adopt area-restricted search based assumptions and incorporate intensity of "use" (i.e., the relative tortuosity/linearity of individual movement), in terms of both model performance and evidence for selection/avoidance of specific landscape attributes.
4. Determining whether incorporating the relative connectivity of suitable winter habitat (in relation to suitable summer range) improves the predictive power of resource selection functions derived for winter habitat. (*J. Shuter, pers. comm.*)

Quebec (7)

Title: Impacts of human activities on woodland caribou in managed boreal forests

Primary Contact: Jean-Pierre Ouellet (UQAR), Claude Dussault (MRNF), Réhaume Courtois (MRNF), Martin-Hugues St-Laurent (UQAR)

Organization: University of Quebec in Rimouski, Ministry of Natural Resources and Wildlife, Quebec

Abstract: The boreal forest is one of the largest land ecosystems on the planet. Shaped in the past by natural disturbances (fires, windfall, epidemics), it is now more often transformed by man-made disturbances. One of the most significant, logging, is always present in the southern boreal forest and

the southern boundaries of the logging areas are advancing rapidly. The home range of woodland caribou, an “umbrella” species in the boreal forest, has retreated northward as logging moves north: about 70% of the population in Canada is declining. The objective of this research program is to improve understanding of human disturbances (logging, roads and cottages) on woodland caribou. Several aspects of the traditional logging model (juxtaposition of harvest areas, harvesting with protection of regeneration and soils, access to the land, etc.), as practiced in Quebec in recent decades, have been identified as potential causes of the population decline and retreat of the woodland caribou range. Recent work has shown that caribou respond to the presence of harvested areas by increasing their movements and the area of their home range, and by avoiding the disturbed environments. Caribou that remain in highly fragmented environments have a lower survival rate. To rectify this problem, new silvicultural methods are suggested to protect the woodland caribou herds. One of these is to maintain 250-km² blocks of forest and concentrate logging. This strategy is aimed at preserving some of the habitats used by the caribou until the harvested areas become attractive again for this species. Various silvicultural techniques are practiced on sites to be harvested with a view to restoring the forest landscape quickly to a composition and structure similar to what existed before harvest. Some of these techniques include harvesting with protection of small merchantable stems, harvesting with protection of high regeneration and soils, commercial thinning and partial cutting. These new harvesting strategies in black spruce stands would, in theory, help to preserve woodland caribou populations. We must admit, however, that the changes caused by logging could increase the risk of predation. Since 2004, we have conducted GPS telemetric monitoring of about twenty caribou in two study areas located north of Saguenay-Lac-Saint-Jean. Some preliminary findings show an impact of human activity on caribou habitat selection. The size and cover of the residual forests play a role in the usage patterns of harvested areas. Our work emphasizes the importance of having a forest management plan that will restore suitable habitats rapidly, protect large mature forests and spread logging over time, to maintain a minimum of essential habitats at all times for woodland caribou (*R. Courtois, pers. comm.*)

Title: Effect of forest management strategies on predation of woodland caribou

Primary Contact: Réhaume Courtois (MRNF), Jean-Pierre Ouellet (UQAR), Daniel Fortin (U. Laval) and Christian Dussault (MRNF, UQAR)

Organization: Ministry of Natural Resources and Wildlife, University of Quebec in Rimouski

Abstract: Woodland caribou are in difficulty almost everywhere in North America. For this reason, it has been designated endangered in Canada and vulnerable in Quebec. Its precarious position can be largely explained by habitat changes, especially from logging. Logging gives humans and predators more access to the territory, concentrates caribou in remaining habitats, creates suitable habitats for black bears and attracts alternate prey for wolves, including moose. These phenomena are likely to intensify predation of caribou by wolves and black bears. The Charlevoix herd is a good illustration of the precariousness of woodland caribou. Although located in a world biosphere reserve, this community is still one of the most fragile in Quebec because of predation by wolves and black bears. GPS tracking of caribou in the Charlevoix herd was introduced in April 2004. We used this monitoring to study the indirect effects of logging on caribou predation. So little is known about these impacts that our ability to provide proper guidance for management plans remains limited. This research aims to clarify the influence of logging on interaction between wolves, bears and caribou in the boreal forest. We simultaneously monitored these three species of large mammals with GPS and VHF telemetric collars to understand how they interact and share space and habitats, and particularly to assess how habitat changes influence these interactions. One of the innovative features of the study is the simultaneous tracking of several species of large mammals in harvested areas to understand the

impact of habitat changes on trophic interaction, use of space and habitat selection in a system with predators (black bears, grey wolves) and prey (caribou). We also determined the causes of mortality for young caribou. Habitat selection by the species was studied by telemetry and we tagged more than 50 new-born calves to determine their survival rate and causes of mortality. The preliminary findings show the influence of roads on caribou range. Mature coniferous forests were sought by caribou in winter; in spring and summer, peatlands, dry barrens and harvested areas were preferred. Black bear monitoring showed that areas harvested 6 to 20 years ago were sought in summer and provided the most food biomass. Between 40 and 80% of the calves died and black bears were mainly responsible for these deaths. Logging therefore has a beneficial impact on black bears and a negative impact on caribou. At the end of the project, we will model the interaction between the species based on habitat development scenarios. This information will enable us to validate the management plan and suggest alternate management methods. The information collected during the study will guide future decisions on forest and wildlife management plans. The project is being conducted jointly by researchers from UQAR, the Quebec Wildlife Research Branch (*MRNF – Secteur Faune Québec*) and Laval University. (*R. Courtois, pers. comm.*)

Title: Impact on woodland caribou of logging practices under the Quebec-Cree agreement

Primary Contact: Vincent Brodeur (MRNF), Pierre Drapeau (UQAM), Réhaume Courtois (MRNF)

Organization: Ministry of Natural Resources and Wildlife, Quebec, University of Quebec in Montreal

Abstract: Not much is known about the distribution of woodland caribou in northern Quebec. The current data suggests low abundance and we do not know whether native harvesting involves woodland herds or barren ground caribou. Moreover, under the Quebec-Cree agreement, mosaic (patch) harvesting will be used throughout the territory governed by the agreement; the land is allocated under forest management contracts. This strategy of dispersed logging is particularly favourable to border species like moose. However, such forest management practices do not appear appropriate for species in mature and overaged forests, as is the case for woodland caribou. For this species, a dispersal strategy inspired by the natural disturbances in the boreal forest (fires, insect infestations, windfall) appears more promising for creating landscapes where large blocks of disturbed forest are adjacent to large mature forests. It is therefore probable that the current standards will cause habitat changes that may negatively affect caribou. It is difficult, at the moment, to draw conclusions as to what kinds of effects this type of land management scenario will have on the long-term preservation of woodland caribou in northern Quebec. Given the significant changes that will occur in the habitat of this ecotype in the coming years, it would appear urgent to simultaneously document current land use in northern Quebec and the impact on caribou range of the forest practices stipulated in the Quebec-Cree agreement. An inventory program was conducted by the MRNF¹ to locate the main herds and describe their winter habitats. In addition, GPS tracking of 20 females was initiated in January 2004 to document caribou dispersal in the area and analyze their seasonal use of habitats. This monitoring will continue in the coming years and will assess the impact of mosaic (patch) harvesting as described in the Quebec-Cree agreement (dispersal of harvested areas, 200-m wooded strips of land along streams at least five m wide, etc.) on the use of the space by woodland caribou. The results of this research project will have major impacts on the level of population and habitat management for this vulnerable ecotype, as well as on forest management. It will locate the herds of woodland caribou in the James Bay region and describe the habitats they use on a seasonal basis. This information will make it possible to implement population and habitat management measures that are suited to each herd and to measure the impacts of the Quebec-Cree agreement on the preservation of woodland caribou. Forest management that is better suited to caribou requirements

will be suggested to maintain the current population level and prevent the disappearance of this ecotype from the James Bay area. (*R. Courtois, pers. comm.*)

Title: Monitoring the impact on woodland caribou of reconstruction of Highway 175

Primary Contact: Christian Dussault (MRNF, UQAR) and Jean-Pierre Ouellet (UQAR)

Organization: Ministry of Natural Resources and Wildlife, Quebec; University of Quebec in Rimouski

Abstract: Highway 175 in the *Réserve faunique des Laurentides* (Laurentian wildlife reserve) will be rebuilt with two lanes in each direction. Among the main environmental issues for this project are the barrier created and fragmentation caused by the road, which could compromise conservation of the Charlevoix woodland caribou herd. According to the scientific literature, this species is greatly affected by linear structures like roads. The right-of-way width for the new road will be tripled and there will be more traffic. The reconstruction of Highway 175 may not only increase the risk of collision with this species but also limit its dispersal in the environment. We fear that caribou would become more confined to the eastern side of the highway and, with the greater local abundance, become more vulnerable to predation by wolves and other animals. The overall objective of the project is to monitor the impact of reconstruction of Highway 175 on woodland caribou and their interaction with wolves. The specific objectives include: 1) identification of the spatial and temporal factors that influence the probability that a stretch of road (paved highways and logging roads) will be crossed or frequented; 2) assessment of changes in movement patterns following the changes to Highway 175; 3) study of survival probability according to home range parameters such as habitat, presence of predators, roads and other human disturbances; 4) investigation of the main periods of activity (annual and circadian) near roads and along power transmission lines to facilitate measures to reduce accidents with these species; 5) observation of the time of year and time of day when the risk of collision is the highest; 6) selection of measures to mitigate road accidents involving these species (e.g., wildlife crossings); 7) modelling of population dynamics, including road mortality. A better knowledge of movements and the habitats used will help to guide developments and mitigation measures to limit the highway's impact on these species. We will also tag 10-month-old caribous to see if dispersed individuals are more likely to be affected by the highway. This project, to begin in the winter of 2006-2007, will meet several conditions of the Ministry of Sustainable Development, Environment and Parks, environmental order 923-2005 for reconstruction of Highway 175. (*R. Courtois, pers. comm.*)

Title: Interaction between wolves, caribou and moose in managed boreal forests

Primary Contact: Daniel Fortin

Organization: University of Laval

Abstract: This research is intended to clarify the influence of logging on direct and indirect interaction between wolves, caribou and moose in the boreal forest. This information is important for the development of management programs for woodland caribou. The scientific community has agreed that caribou need to adopt avoidance strategies for predators and other Cervidae in order to survive. However, the impact of habitat changes on the relationships between caribou, moose and predators is not well-known. We will monitor these three species of large mammals simultaneously with GPS collars to understand how the species interact and share space and especially to see how

habitat changes influence their interaction. We are particularly interested in the hypothesis that logging may lead to apparent competition between moose and caribou because of wolf predation.

It is essential to understand predators' hunting behaviour to be able to anticipate the impact of predation on coexistence with prey. When a predator feeds on several types of prey, an increase in the density of one type of prey may lead to extinction of the others through interaction with their common predator. Such indirect interaction between types of prey constitutes an "apparent competition" and would be foreseeable in the wolf/caribou/moose system in the managed forests on the North Shore where this study is being conducted. Logging may increase the moose population by creating habitats that are more suitable to them. The resulting numerical response of wolves may lead to more frequent interaction between wolves and caribou. These changes in the nature of trophic interaction may eventually render woodland caribou locally extinct. The validity of this hypothesis depends on the wolves' numerical and behavioural reactions to their prey, but knowledge of the mechanisms governing the relationships between caribou, moose and wolves remains fragmentary. Our study of the species' use of space will help to partly clarify this hypothesis.

The project will i) determine whether wolf movements are favourable to meeting with moose or caribou, ii) clarify the impact of logging on wolf movement patterns and hence on meeting probabilities and iii) determine the behavioural reaction (movement patterns and habitat use) of caribou and moose to the spatial range of wolves and to logging changes.

The simultaneous study of environment use by three species of large mammals is an unusual feature of this research. Relatively few studies have assessed the role of direct and indirect interaction between large mammals in a managed forest ecosystem. Moreover, our understanding of trophic interaction remains limited because most predator/prey studies assume that the individuals at one or the other of the trophic levels are stationary. Tracking the three species with GPS collars will enable us to consider the spatial and temporal dynamics of both the predators and their prey and to improve our understanding of predator/prey interaction. We will then be in a better position to assess the challenge of protecting woodland caribou in managed forests.

Title: Habitat selection by woodland caribou: Identification of variations in movement patterns and habitat selection

Primary Contact: J.P. Ouellet

Organization: University of Quebec in Rimouski

Abstract: This project will observe changes in movement patterns or habitat selection (dispersal) by female caribou and compare the characteristics of the sites frequented. This will enable us to see whether females travel away from disturbed environments and whether this phenomenon is influenced by their reproductive success. The study area is located in the Réserve des Laurentides (Laurentians wildlife reserve) and in Saguenay. This project will use the data from caribou monitoring in these two areas. The overall objective of this study is to establish the site fidelity of female caribou, based on the level of environmental disturbance (loss and fragmentation) and their reproductive success. Site fidelity will be determined according to two time scales: seasonal (summer, rut, winter, calving) and annual. The main variables used are distance between locations in different successive years, size of home range, and extent of movement according to changes in the environment. Reproductive success will be assessed in a parallel study of mothers and young caribou (15). This monitoring began nearly two years ago. The telemetric data will be collected over a three-year period.

Title: Use of space, physical condition and demographics of caribou in Quebec and Labrador: From the individual to the metapopulation

Primary Contact: Steeve D. Côté

Organization: University of Laval

Abstract: Since the 1950s, caribou herds in North America have been defined and named according to the location of their calving grounds. This method of describing herds appears appropriate for short-term management decisions. However, over more extensive time and space, the herd may not be the most efficient conservation unit. Metapopulation theory may prove useful for long-term conservation of caribou. In the Quebec-Labrador Peninsula, caribou herd ranges overlap, but their demographics and ecological characteristics are very different. Observations suggest that exchanges have occurred between neighbouring herds of the woodland, barren ground and mountain caribou ecotypes. It is important to be aware of the long-term impacts on caribou conservation of these overlaps of populations and ecotypes. Quebec-Labrador provides a unique opportunity to test the predictions of the metapopulation theory applied to caribou conservation. The northern caribou in Quebec-Labrador constitute a large-scale example of an ecosystem involving only one ungulate and in which some populations are migratory, others sedentary. At the moment, it is still difficult to predict the demographics of large ungulate populations, be they in rich, variable African savannas or in poor, stable Arctic deserts. Our study of the use of space, physical condition and demographics of four caribou populations of three different ecotypes will improve understanding of the mechanisms that govern these large ungulate populations. The study area for this project will be the vast Quebec-Labrador region north of parallel 52°N, from the boreal forest to the Arctic tundra. A special feature of this project will be access to a considerable database compiled mostly since 1985 and never analyzed. The project will also have access to some data from the 1970s. The two additional years of data collection will guide possible comparisons with previous years. Our project is therefore a unique opportunity to update information on the status of northern caribou at this crucial time in its evolution throughout the Quebec-Labrador Peninsula.

Newfoundland/Labrador (4)

Title: The behavioural ecology of the Gaff-Topsail Caribou Herd on their summer range

Student: Soulliere, C.

Organization: Memorial University of Newfoundland Organization

Abstract: none available

Title: Developing a statistical model using caribou populations data from insular Newfoundland

Student: Pechham, D.

Organization: Memorial University of Newfoundland

Abstract: none available

Title: Population genetics of woodland caribou (*Rangifer tarandus caribou*) on the island of Newfoundland

Primary Contact: Steven Carr

Graduate Student: Corinne D. Wilkerson

Organization: Memorial University of Newfoundland

Abstract: A 2223 base pair sequence of mitochondrial DNA from the control (dloop) region and the cytochrome *b* gene was sequenced for 233 Newfoundland caribou (*Rangifer tarandus caribou*). Phylogenetic analysis identified 32 haplotypes structured into four distinct clades or haplogroups. Analysis using a hierarchical AMOVA revealed there is little genetic differentiation among defined herds, although there is some regional differentiation of the Avalon Peninsula from the rest of the island. Caribou on the Avalon Peninsula are genetically depauperate and distinct, possibly as a result of founder effects. A Nested Clade Analysis identified several significant phylogeographic associations of caribou haplotypes which are due to restricted gene flow with isolation by distance, contiguous range expansion, and long distance colonization possibly coupled with subsequent fragmentation or past fragmentation followed by range expansion. Most Newfoundland caribou show close relationships to woodland caribou in Quebec, and a small subset show close relationships to woodland caribou in Labrador. Distant genetic relationships confirm that Newfoundland caribou did not successfully interbreed with populations of Eurasian reindeer (*Rangifer tarandus tarandus*) introduced from Norway. The whole mitochondrial genome for one Newfoundland caribou was sequenced (16,359 bp) for use in developing a multi-species, microarray-based DNA sequencing strategy for biodiversity studies.

Title: Impact of the Trans-Labrador Highway on satellite-collared woodland caribou of the Mealy Mountain caribou in eastern Labrador

Primary Contact: Jim Schaefer

Organization: Trent University

Abstract: none available

Yukon

Title: Conservation Assessment and Strategy for Caribou of the Y2Y Region

Primary Contact: James Bergdahl

Organization: Yukon to Yellowstone Conservation Initiative

Abstract: none available