ASSESSING THE IMPACTS OF HELI-SKIING ON THE BEHAVIOUR AND SPATIAL DISTRIBUTION OF MOUNTAIN CARIBOU (*RANGIFER TARANDUS CARIBOU*)

by

Katharina Jacqueline Huebel

B.Sc. Thompson Rivers University, 2008

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

Master of Science

in

Environmental Science

Thompson Rivers University

Spring Convocation 2012

Thesis Supervisory Committee

____

Dr. Thomas E. Dickinson, Supervisor

____

Dr. Karl Larsen, Committee Member & Coordinator of MSc. (Environmental Science) program

____

Dr. Darryl Carlyle-Moses, Committee Member

____

Dr. Bruce McLellan, External Reader

This thesis by Katharina Jacqueline Huebel was defended successfully in an oral examination on April 10th, 2012 by a committee comprising:

____

Bruce McLellan, External Reader

____

Dr. Thomas E. Dickinson, Supervisor & Dean of Science

____

Dr. Karl Larsen, Committee Member & Chair of M.Sc. (Environmental Science) program

____

Dr. Darryl Carlyle-Moses, Committee Member

____

Dr. Andrew McKay, Chair of the examining committee

This thesis is accepted in its present form by the Office of the Associate Vice President, Research and Graduate Studies as satisfying the thesis requirements for the degree Master of Science, Environmental Science.

…………………………………………

Dr. Donald Noakes, Interim Associate Vice President, Research and Graduate Studies

ACKNOWLEDGEMENTS

I would like to thank my supervisor Tom Dickinson for his extensive guidance and support throughout the last years. Thank you to my committee members Karl Larsen and Darryl Carlyle-Moses for giving helpful advice. Thank you Bruce McLellan for acting as my External Examiner, and for providing me with a large dataset on caribou locations, that gave me the opportunity to ask a unique set of questions in combination with heli-skiing data.

I want to thank Mike Wiegele for enabling long-term cooperation between MWHS and TRU for this research project. This project was only possible with data made available on heli-skiing activities. I also appreciate the additional financial support provided by MWHS. Thank you for welcoming me numerous times in Blue River with great accommodation and many helping hands. The supportive and approachable MWHS employees made sure it was an enjoyable stay every time, and even gave me the chance to go heli-skiing! Special thanks to Adam Brown for providing me with MWHS GIS data and always offering advice on developing research questions. Thank you to Rick Kunelius for introducing the MWHS wildlife management procedures to me and continuously giving valuable recommendations on my project.

A special thank you to Mike Campbell, for sitting down with me for many hours on his own time to explain GIS applications that were new to me, and brainstorming for new ideas using spatial analyses.

Thank you to NSERC for providing me with an IPS scholarship that greatly enhanced my research possibilities.

My personal thanks go out to my family and friends. Although my family was puzzled at times how it can take so long to complete this degree, they continued to be extremely supportive! Thank you for your patience!! Thank you to my friends for always being there for me and encouraging me to get things done!

ABSTRACT

Mountain caribou (*Rangifer tarandus caribou)* are listed as endangered in Canada, with isolated subherds only remaining in British Columbia and parts of northern Idaho. A loss of old-growth forest habitat has caused a decline in their range, making them more likely to be disturbed by backcountry recreational activities such as heli-skiing. This study investigated whether an interaction between heli-skiing and Mountain Caribou could be detected. The detectability of caribou from helicopters indicated that caribou are often not detected when within close proximity to active skiing. Data on the behavioural responses of caribou that were recorded by Mike Wiegele heli-skiing personnel between 1996 and 2010 were analysed. The relationship between the type of responses and the frequency of ski run usage was examined. Responses were not higher in areas subject to more frequent skiing, but overt behavioural responses to heliskiing were documented. Three GIS analyses were performed on GPS data from 25 caribou collared between 1996 and 2007 to determine any spatial effects of skiing activity on how animals use their range. The first test examined habitat use near ski runs. Actual numbers of GPS locations within suitable habitat near ski runs were more than expected. The second test determined the distance established by caribou between themselves and ski runs with different intensities of use. More than an expected number of locations were found close to frequently skied runs; while fewer than expected locations were found close to runs not skied. The third test compared caribou's rate of movement within zones skied frequently and less often. There was no significant difference in the degree of movement in areas skied heavily or not. Results of these analyses suggest that caribou in the area were not directly displaced by heli-skiing activities during the years studied, but avoidance at finer scales than I measured is possible. It appears as if 'Best Management Practices' that enforce closing areas to skiing upon detection of caribou may be helpful in reducing conflicts with caribou; however, mountain caribou in this study area have likely habituated to more than 40 years of skiing. Continued avoidance management, more specific research on short-term reactions to heliskiing and with herds in other areas are suggested to ensure a coexistence of caribou and heli-skiing.

Keywords: *Rangifer tarandus caribou*, heli-skiing, backcountry recreation, disturbance, habitat specialist, GIS.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1. INTRODUCTION

The importance of biodiversity, which can be defined as the totality of genes, species and ecosystems within a region (World Resources Institute et al. 1992), is well-documented and not easily overstated. Besides its intrinsic value, biological diversity has countless ecological and anthropogenic values. Biodiversity allows the natural world to sustain itself and provides for basic human needs.

In spite of a wide recognition of the importance of conserving the variability of all living organisms, biodiversity and the abundance of animals has rapidly declined all across the globe, with the world's mammals being no exception (Hoffmann et al. 2011). Within the last 500 years, more than 70 mammal species have gone extinct (IUCN 2011). A large number of the remaining mammal species are now considered to be rare, threatened or endangered.

By definition, an endangered species is "in danger to become extinct in the foreseeable future throughout all or a significant portion of its range" (U.S. Fish & Wildlife Service 2011). Conservation efforts are generally needed to stabilize populations of endangered species in order to ensure continued survival (COSEWIC 2012). Recovery plans are constructed to provide specific management actions to assist these efforts. For species listed as endangered under a federal endangered species act, legal actions are provided to ensure implementation of recovery actions.

In Canada, the "Species at Risk Act" (SARA) was proclaimed in June 2003 (Species at Risk Public Registry 2008). It currently recognizes 860 species at risk, of which 52 are terrestrial mammals (Species at Risk Public Registry 2011).

Many of the species appearing on the endangered species list share a number of characteristics, which make them vulnerable to changes in their environments, and ultimately cause them to become threatened. A common trait found among animal species at risk is a tendency towards a K-selected survival strategy (Pimm et al. 1988).

Shared characteristics among K-selected species include late reproductive maturation, low reproductive rates and high survival rates (Pianka 1970). A K-selected strategy of survival makes animals highly density-dependent and means that if populations suffer extreme losses, they do not recover but become endangered. K-selected species often live near their carrying capacity, since they depend on the availability of resources. While no animal is completely "K-selected", a tendency towards this life strategy is often found in endangered species (Pimm et al. 1988).

Another common life history trait found among many endangered species that overlaps with K-selection is that of specialization, since specialist species are less tolerant to environmental changes than generalist species. The concept of specialization is itself based on the concept of an 'ecological niche'- "what a population needs to ensure survival in a certain environment, as well as how it impacts that environment" (Chesson 2000). Specialist species have a narrower niche width than generalists, and hence are more sensitive to changes in that niche. While specialization enables species to function better within a certain kind of habitat, generalist species function more consistently between a broader range of habitats. Environmental changes explain why specialist species are now commonly found on the endangered species list.

One of the most iconic endangered animals found in Canada is the mountain caribou (*Rangifer tarandus caribou*). Mountain caribou exist only in the South-eastern part of British Columbia and small parts of Idaho (Hummel & Ray 2008). An ecotype of the more common woodland caribou subspecies, it is yet another example of an animal that has likely become endangered due to particular life history traits.

Certain aspects of the biology of mountain caribou such as a specialized winter diet and low recruitment rates make them highly susceptible to population declines. Being a K-selected species, caribou have a lower reproductive rate than other ungulates such as deer and moose, and therefore cannot deal as well with losses within their populations (Brade 2003). Mountain caribou cows mostly produce single offspring, and rarely give birth to more than six calves during a lifespan (Hunter 1972). The fact that mountain caribou are habitat specialists and their resources during the winter months are spatially limited adds to the adversity of their habitat and tenuous nature of their life history.

The specialized winter diet of mountain caribou consists mainly of arboreal lichen (*Bryoria sp*. and *Alectoria sp*.), which are low in protein, but high in calories that caribou need to sustain themselves through the cold winter months (BC Ministry of Environment, Lands, and Parks 1999). Their foraging needs are high, as a grown caribou on average consumes lichen at approximately 40 g per kilogram of its body weight per day (Goward & Campbell 2005). Arboreal lichen grows very slowly, and is found predominantly in forests that are at least 125 years old (BC Ministry of Environment, Lands and Parks 1997). Since old forest ecosystems have the most developed lichen communities, mountain caribou are highly dependent on large tracts of old-growth forest in high elevation mountainous regions. Adaptations to this constraint on their habitat include large, snow-shoe like feet that allow mountain caribou to distribute their weight on snow and reach areas that other ungulates and predators cannot (BC Ministry of Environment, Lands, and Parks 1999).

In the late winter period, the snowpack builds high enough to raise mountain caribou, enabling them to reach arboreal lichen. Mountain caribou therefore spend the late winter in these high-elevation old-growth forests feeding on lichen, and descend into lower elevations when the snow melt to feed on spring plant material, predominantly grasses, sedges and forbs. Mountain caribou cows move up into higher elevations again in late spring to have their calves in order to avoid predators. During summer, mountain caribou slowly follow the melting snow and move back into higher elevations to feed, but as fall arrives they descend again into low-elevation forest until the snowpack has consolidated. Throughout their history, this distinctive elevational migration has likely allowed mountain caribou to successfully avoid predators and food competitors.

However, with increasing human access into high-elevation forests, mountain caribou's dependency on a special habitat niche now places them at risk of extinction. Logging and mining activities, increasing human settlement as well as wildfires have caused these old-growth forests to become far less abundant. The loss and fragmentation of old-growth forests has caused suitable habitat for mountain caribou to become more limited, also making them more likely to be killed by predators and to be disturbed by recreational activities such as snowmobiling and heli-skiing (Brade 2003).

While the mountain caribou is one of the most studied wildlife species in BC (Mountain Caribou Science Team 2005), a significant gap still exists in the understanding of the underlying factors contributing to its decline. One such factor is mechanized winter recreation, which various scientific studies have identified as a major threat to mountain caribou (BC Ministry of Environment, Lands, and Parks 1999; Simpson & Terry 2000; Forbes 2002; Brade 2003). Backcountry winter recreation poses a risk for displacement from critical winter habitat as well as for direct harassment. Relative to other winter backcountry recreation activities, snowmobiling has been considered the greatest threat to mountain caribou. Increasingly powerful snowmobile machines have allowed users to gain more access into high elevation areas, causing snowmobile use to overlap with caribou range. Moreover, snowmobilers may also indirectly impact mountain caribou by creating compact pathways for predators, so they can reach areas previously inaccessible due to the deep snow (Oberg 2001). Furthermore, disturbances may result in the unnecessary expenditure of energy which could tip the balance needed to survive extreme conditions (Brade 2003).

Heli-skiing is considered by some to be less threatening to mountain caribou since direct disturbance by helicopter is spatially removed and limited in time, as is the likelihood of coinciding with skiers who generally prefer steeper terrain (Brade 2003). Nevertheless, commercial heli-skiing operations do require a vast terrain and therefore have the potential to displace mountain caribou into less preferred habitat. Because of this, commercial operators are supposed to adhere to a protocol of action designed to minimize disturbance.

In a review on potential threats to mountain caribou, Simpson and Terry (2000) identified a lack of studies clearly documenting the impacts of backcountry activities on mountain caribou and point out that no scientific reports have specifically addressed the effects of heli-skiing. A number of studies have, however, focused on helicopter disturbance of other ungulate species, such as the responses of mountain goats to helicopter disturbance (Cote 1996) and the responses by Dall’s sheep to helicopters (Frid 1996).

These studies generally show that ungulate response varies according to factors such as size, scale and intensity of the disturbance, and also historical exposure in the area.

While it is clear that a potential for helicopters to disturb mountain caribou exists, studies determining the magnitude of impacts by heli-skiing in an area and its overall implications to the survival of populations are needed to improve future management strategies.

THESIS OBJECTIVES

One main objective of this thesis was to provide a background on how to evaluate the Best Management Practices previously put in place to protect mountain caribou and their habitat from disturbances associated with heli-skiing.

Another objective was to use existing data to test hypotheses about the impact of heli-skiing on the behaviour of mountain caribou.

For statistical testing, it was proposed that heli-skiing activities in the study area do not cause mountain caribou to display overt behavioural reactions. If the null hypothesis that heli-skiing does not cause mountain caribou to react overtly is supported, then I predicted that behavioural indicators of stress, such as fleeing to escape terrain (as recorded for mountain goats by Penner, 1988) would not be correlated with measures of the intensity of heli-skiing.

The third objective was to use existing data obtained to monitor caribou populations to test hypotheses about the impact of heli-skiing on their possible spatial displacement. Again, for testing it was proposed that heli-skiing activities in the study area do not displace mountain caribou into less preferred habitat. If the null hypothesis that heli-skiing activities do not displace mountain caribou from their preferred habitat is supported, then I predicted that the tendency of mountain caribou to remain in or leave highly suitable habitat would not be correlated with various measures of the intensity of heli-skiing.

REFERENCES

BC Ministry of Environment, Lands and Parks . 1997. Toward a Mountain Caribou Management Strategy for British Columbia. Wildlife Branch.

BC Ministry of Environment, Lands, and Parks. 1999. Mountain Caribou.

Brade, B. 2003. Management of Motorized Access in High Elevation Mountain Caribou Habitat. Ministry of Water, Land, and Air Protection.

Chesson, P. 2000. Mechanisms of maintenance of species diversity. Annual Review of Ecology and Systematics. **31:** 343-358.

COSEWIC. 2012. Background. Retrieved October 5th, 2011 from http://www.cosewic.gc.ca/eng/sct6/sct6_3_e.cfm#hist

Cote, S. 1996. Mountain Goat response to helicopter disturbance. Wildlife Society Bulletin. **24:** 681-685.

Forbes, R. 2002. Disturbance effects of human activities on rangifer tarandus habitat implications for life history and population dynamics. Polar Geography. **26:** 171-186.

Frid, A. 1996. Responses by dall's sheep to helicopter disturbance: Preliminary data from the southwest Yukon. Caprinaea News.

Goward, T., and J. Campbell. 2005. Arboreal Hair Lichens in a Young, Mid-elevation Conifer Stand, with Implications for the Management of Mountain Caribou. The Bryologist. **108:** 427-434.

Hoffmann, M., Belant, J., Chanson, J., Cox, N., Lamoreux, J., Rodrigues, A., Schipper, J., and S.Stuart. 2011. The changing fates of the world's mammals. Philosophical Transactions of the Royal Society- Biological Sciences. **366:** 2598-2610.

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

Hunter, T. 1972. British Columbia's Natural History. Victoria, BC: BC Department of Recreation and Conservation.

IUCN. 2011. IUCN Red List of Threatened Species, Version 2011. Retrieved October 5th, 2011 from www.iucnredlist.org

Mountain Caribou Science Team. 2005. Mountain Caribou Situation Analysis.

Oberg, P. 2001. Responses of Mountain Caribou to Linear Features in a West-Central Alberta Landscape. M.Sc.Thesis. Department of Renewable Resources. University of Alberta. Edmonton, Alberta. 126 pp.

Penner, D. 1988. Behavioural Response and Habituation of Mountain Goats in Relation to Petroleum Exploration at Pinto Creek, Alberta. Biann. Symp. North. Wild Sheep and Goat Council. **6:** 141-158

Pianka, E. 1970. On r- and k-selection. American Naturalist. **104:** 592-597.

Pimm, S., Jones, H., and J. Diamond. 1988. On the risk of Extinction. The American Naturalist. **132:** 757-785.

Simpson, K., and E. Terry. 2000. Impacts of Backcountry Recreation Activities on Mountain Caribou. Ministry of Environment, Lands, and Parks .

Species at Risk Public Registry. 2011. A to Z Species Index. Retrieved October 5, 2011, from Species at Risk: http://www.sararegistry.gc.ca/sar/index/default_e.cfm?stype=species&lng=e&index=1&osid=&common=&scientific=&population=&taxid=0&locid=0&desid=0&schid=0&desd2=0&

Species at Risk Public Registry. 2008. Background. Retrieved October 5, 2011, from Canada's Strategy: http://www.sararegistry.gc.ca/approach/strategy/background/default_e.cfm

U.S. Fish & Wildlife Service . 2011. Glossary. Retrieved October 4, 2011, from Endangered Species : http://www.fws.gov/midwest/endangered/glossary/index.html

World Resources Institute, IUCN, and UNEP. 1992. Global Biodiversity Strategy Guidelines for Action to Save, Study and Use Earth's Biotic Wealth Sustainablyand Equitably.

CHAPTER 2. SPECIES DESCRIPTION, STUDY AREA AND DATA SOURCES

MOUNTAIN CARIBOU

Although mountain caribou are widely acknowledged as an ecotype of the woodland caribou subspecies, much confusion remains about the different types of caribou, and references to mountain caribou are often non-complementary. While some distinguish mountain caribou to be all caribou that live in the mountains of western North America (Hummel & Ray 2008), others refer to mountain caribou as only a small part of woodland caribou within British Columbia, small parts of northern Idaho and north-eastern Idaho (Kinley & Apps 2001).

The caribou species (*Rangifer tarandus*) is separated into three distinct subspecies in Canada. Populations inhabiting tundra habitats belong to the barren-ground caribou subspecies (*Rangifer tarandus groenlandicus*) and Peary caribou subspecies (*Rangifer tarandus pearyi*) and woodland caribou (*Rangifer tarandus caribou*) colonize mainly boreal and mountain habitats (Mountain Caribou Science Team 2005). Within British Columbia, the woodland caribou subspecies is further divided into three ecotypes (BC Ministry of Environment, Lands, and Parks 1999). These ecotypes are referred to as the boreal caribou, northern caribou, and mountain caribou. Figure 1.1 displays the distribution of the three ecotypes (Knowledge Management Branch). Mountain caribou (*Rangifer tarandus caribou*) are distinguished from other ecotypes not by genetics, but mainly by biological and behavioural characteristics such as upslope migrations.

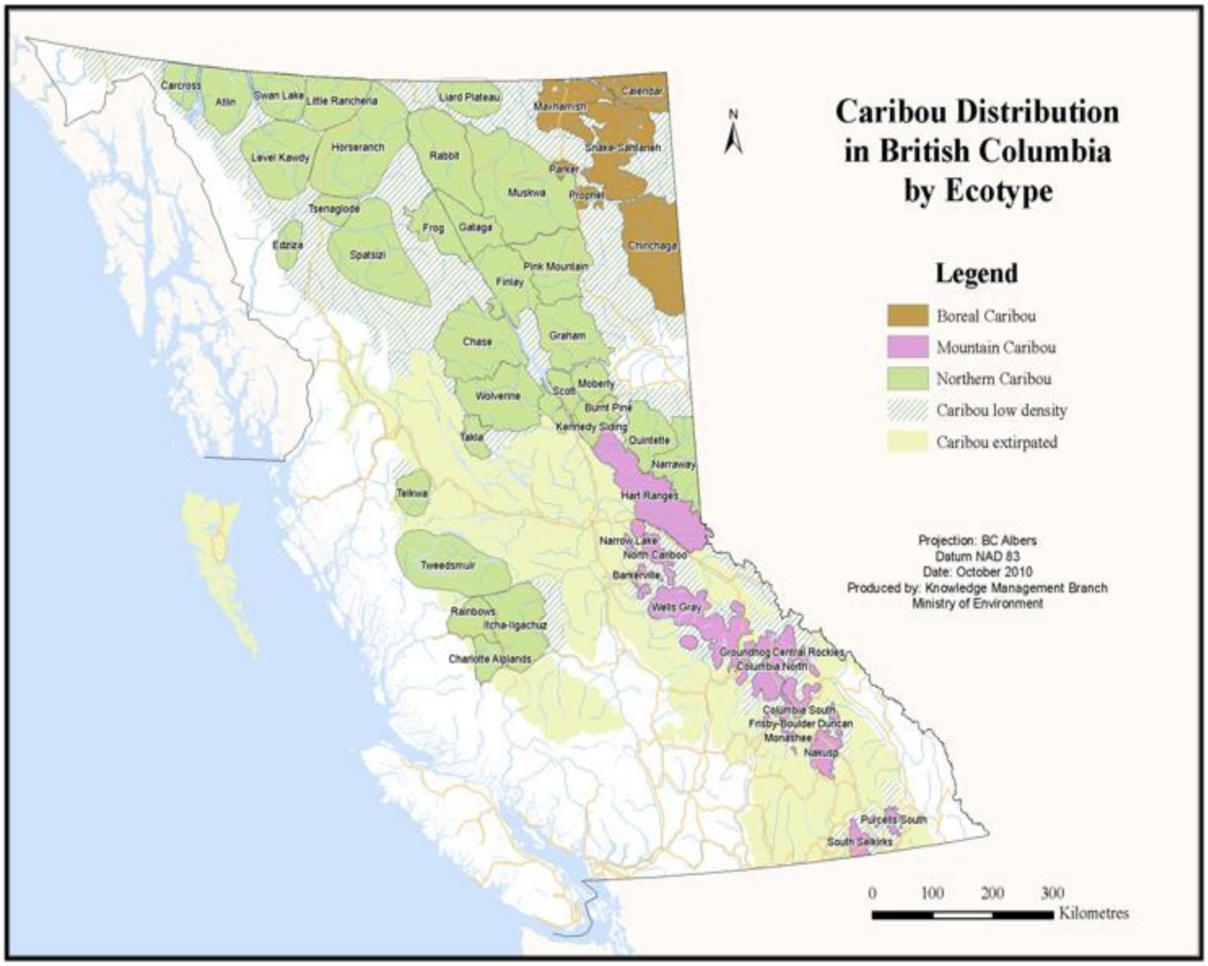


Figure 1.1 Distribution of three ecotypes of Mountain Caribou in British Columbia (Source: Knowledge Management Branch, Ministry of Environment).

Mountain caribou were abundant in southeastern British Columbia during the early 20th century but had declined within their historic range by the 1980s (Bergerud 1978; Seip 1990). Historical and current distribution, based on a 2005 estimate (Mountain Caribou Science Team, 2005) of mountain caribou is depicted in Figure 1.2.

Figure 1.2 Historical and present distribution of mountain caribou within Canada and the United States (Source: U.S. Fish and Wildlife Service, 2011)

Hunting limits on mountain caribou used to be generous, but due to a decline in populations, restrictions were periodically imposed throughout the mid 1900's in different areas (BC Ministry of Environment, Lands and Parks 1997). In the early 1960s, it was also first recognized that not only hunting was having an effect on mountain caribou. Due to increasing resource use, mainly timber harvesting in the 1950s, extensive habitat loss and fragmentation had occurred.

Increased access to higher elevations through the use of roads has raised the ability for predators to reach caribou in areas that were previously inaccessible to them, increasing natural hunting pressures. As a result of extensive habitat loss, mountain caribou populations have been broken down into a number of small subherds. This can be detrimental to species survival, since interactions are possible within a subpopulation, but highly limited or impossible with other subpopulations (Mountain Caribou Science Team 2005). It was recently estimated that 1,883 animals persist in 18 sub-populations within British Columbia, compared to approximately 2,500 animals in 1995 (BC Ministry of Environment 2009). Some subpopulations have declined by more than 50% within the last 10 years, and only 16 of the 18 subpopulations were found to remain in 2010 (van Oort et al. 2011).

A Recovery Implementation Plan, which provides actions to protect mountain caribou and their habitat, aims at recovering all mountain caribou herds within their distribution in British Columbia to the more stable 1995 population level. A 14-member science team was established in 2005 through the Species at Risk Coordination Office (SaRCO) to advise on actions necessary for a successful recovery (BC Ministry of Environment 2009). Measures suggested to be required by the Science team include the protection of habitat from logging to ensure food sources, as well as associated road building to limit hazards. Predator control is also suggested through removal of predators in conjunction with a reduction of moose and deer near herds of caribou, because they support higher predator populations. Potential trans-location of animals from stable herds to less stable ones and management of winter backcountry recreation in upper elevations to limit stress has also been suggested if some smaller populations are to remain.

Importance of Protecting and Studying Caribou

Why is it so important to conserve mountain caribou populations in the first place? Plainly said, there are stable woodland caribou found across the North, and the loss of the mountain caribou ecotype would not mean the extinction of a species. Yet an extensive recovery implementation plan has been constructed, and expensive conservation efforts are directed towards saving mountain caribou.

Based on ethical reasons alone, protecting mountain caribou can be justified. The American endangered species act presumes that endangered species have a right to be in this world, apart from what value or service they offer to humans (Petulla, 1988). The sole reason to protect a species based on its inherent right to live and to preserve biodiversity should therefore be sufficient. Furthermore, specialist species generally decline and generalist species thrive in changing environments. A negative effect of that may be an increasing functional homogenization and reduction of species diversity, raising the need for conservation of specialist species such as mountain caribou.

Mountain caribou provide utilitarian value as they play a fundamental role within their ecosystem. For example, they disperse the nitrogen fixed by arboreal lichens throughout their habitat. Old-growth forest ecosystems continue to suffer under the pressure of human demands with logging reaching higher elevations. Since mountain caribou use a range of habitats within this ecosystem and are sensitive to ecological disturbances, they are sometimes considered to be an indicator species (Kinley, 1999). The decline of mountain caribou has been cited to signal changes in the interior cedar-hemlock forest in British Columbia (Morris, 2002).

Mountain caribou have also been referred to as an umbrella species. Umbrella species generally require large suitable habitat that provides requirements for other species (Carignan & Villard, 2002). Supporters of the umbrella species concept suggest the protection and restoration of mountain caribou populations will benefit a range of other species with similar habitat requirements. Virginia Thompson of the North Columbia Environmental Society pointed out in a recent news article that “mountain caribou recovery is not a single species issue” (Thompson, 2011). A report released in 2007 by environmental stewardship group “Forest Ethics” revealed that at least 21 vertebrate and invertebrate species at risk occupy the same range as mountain caribou (Dulisse, 2007). In addition, high elevation habitats contain species that are emblems of unspoiled wilderness, such as grizzly bears (*Ursus arctos horribilis*) and wolverines (*Gulo gulo*). These species, they say, will ultimately gain from conservation efforts directed towards mountain caribou.

Hence, studying human impacts on mountain caribou populations to protect caribou and their habitat may be recognized from a broader perspective as an effort to protect other species as well.

STUDY AREA DESCRIPTION

Figure 2.1 shows the general project study area, including parts of Wells Gray Provincial Park. The town of Blue River and surrounding areas are incorporated into this study area, with parts of the Cariboo mountain ranges on the West side of Highway 5 North, as well as parts of the Monashee mountain ranges on the East side of Highway 5 North.

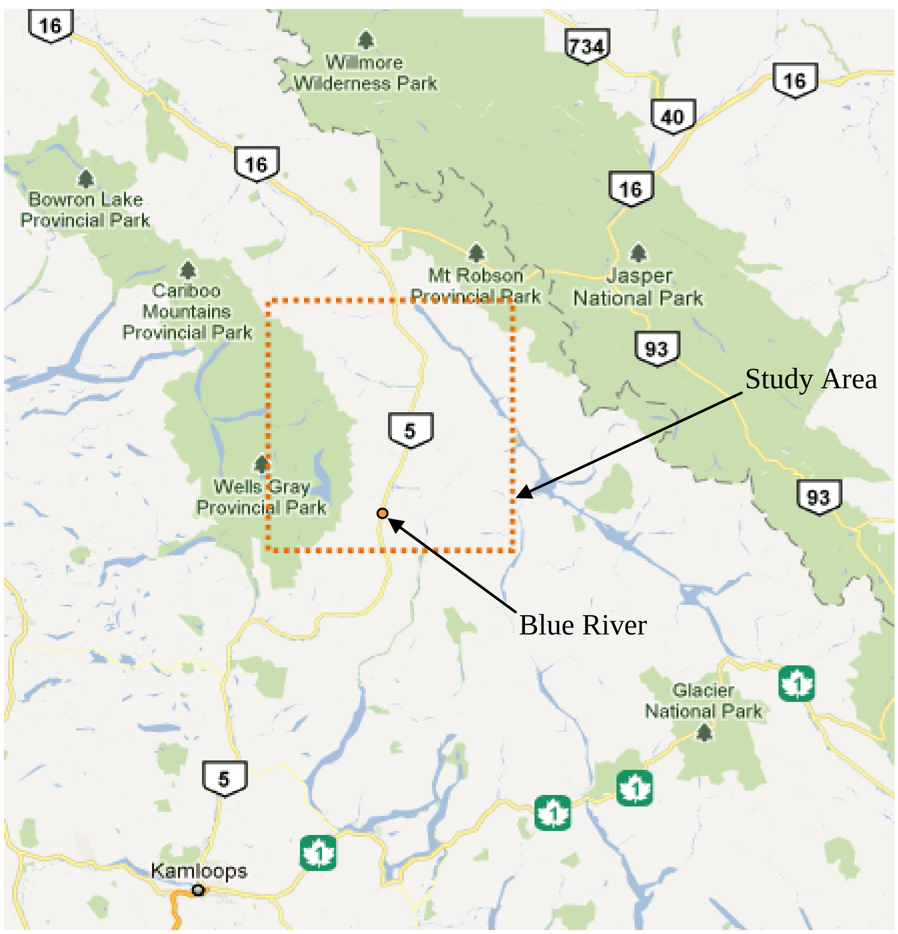


Figure 2.1 General study area (dashed line), ranging between 52˚57'N, 51˚50'S, 118˚41'E, and 120˚28'W (Source: composite of Google maps)

Terrain Features and Caribou Habitat

The study area is dominated by valley bottoms of the wet ICH (Interior Cedar Hemlock) biogeoclimatic zone, high slopes with wet cold Engelman-Spruce-Subalpine-Fir (ESSF) forest, and Alpine Tundra (AT).

The ICH biogeoclimatic zone (from 49˚ to 54˚ 15´N) occurs at low-mid elevations between 400 and 1500m (Ketcheson et al. 1991). It is characterized by interior, continental weather with cool winters. Landscapes are predominantly upland coniferous forest, with a large diversity of tree species. Western red cedar and western hemlock are most common, while White Spruce, Engelmann Spruce, and Subalpine Fir are also abundant. Ecological factors of this zone that are beneficial to mountain caribou are the old-growth forests, meadows and narrow valleys. Caribou spend their late summer/early fall in this zone, before moving up into higher elevations of the ESSF zone in winter.

The ESSF biogeoclimatic zone is located below the Alpine Tundra, at elevations from 1500 m to 2300 m (Coupe et al. 1991). The ESSF is characterized by steep and rugged mountain terrain, and long, cold winters. At lower and middle elevations, this zone is dominated by forest, with Engelman Spruce being the most common tree species. Upper elevations mostly include parkland with subalpine fir, as well as open meadow. Extensive old-growth forest of the subalpine parklands provides caribou with arboreal lichen in winter.

The alpine tundra biogeoclimatic zone (AT) lies above the ESSF zone, and is characterized to be cold and windy with little frost-free days in the year (Pojar & Stewart 1991). It is mainly treeless aside from krummholz in lower elevations, and is dominated by shrub vegetation. Since some lichen also exists in the alpine, caribou do migrate upwards into this zone to winter.

While forests in the area provide caribou with valuable habitat, much of it is now fragmented due to past logging and mining activities in the area. During the 1960 and

1970s, logging practices had reached into subalpine areas (Blue River Tourism Group 2007), and caused a reduction in valuable mountain caribou habitat. The Wells Gray caribou population, last estimated to be approximately 490 animals (2006), covers a range of 9405 km^2 (Knowledge Management Branch 2010).

Management Practices Employed to Protect Caribou from heli-skiing

Mike Wiegele Heli-Skiing (hereafter MWHS) is located in Blue River, a small town 230 kilometres North of Kamloops, British Columbia. The heli-skiing operation is situated along Highway 5 North heading towards Jasper. The resort lies at an elevation of 690 m (Mike Wiegele Heli-skiing 2011).

The ski resort was founded in the early 1970s by Mike Wiegele. It includes a wide range of facilities: 22 log chalets, a main lodge, as well as an additional facility located 45 kilometres North of Blue River. A total of 12 helicopters are used for heli-skiing and include four Bell 212 two-engine helicopters, seven A'stars, and a Bell 407- although helicopter configuration is subject to change year to year.

Skiing takes place in elevations of approximately 1,000 m to 3,500 metres. Most landing spots used to drop off guests are at a height of approximately 2,500 metres. During their stay at the resort, most guests ski about 17,000 metres per day, which equals an average of 8 to 10 runs.

The operating area, covering 485,640 hectares, encompasses portions of the the Cariboo and Monashee mountain ranges, with over 1,000 mountain peaks. High alpine glaciers as well as forested valley glades exist and provide depths of up to 10 metres of snow each year. Within this terrain, there are an estimated 825 individual ski runs, 8 fuel sites, a landing strip, and 3 weather stations.

Heli-skiing operators have recognized the risk of exposing caribou to potential disturbance. As part of its "Best Management Practices", an 'Alert and Closure Protocol' (Kunelius 2009) has been used at MWHS since 2006 in order to guard against impacting Mountain Caribou when heli-skiing. This protocol requires that a "Closure" is applied when caribou are observed on or in close proximity to a ski run, in order to divert traffic away from the area for 24 hours. An “Alert” is applied when caribou are within 500 metres of a run, but not on it, or if tracks on a run are observed. An Alert means pilots and guides are notified to watch out for caribou when heli-skiing in or flying over the area and select a ski strategy to avoid potential displacement. After a closure is lifted, an automatic Alert will exist the day after for helicopters flying within 500 metres of that area. If a caribou is detected, the pilot at site immediately calls it in to the dispatcher and the sighting is recorded. Subsequently, any required actions are taken.

In addition, detailed observations, including animal group size and behaviour, have been recorded by MWHS pilots and ski guides for more than 15 years. These were recorded by guides on monitoring forms, compiled at the end of each skiing day during the guide’s meeting, and then stored in a database which was updated weekly by one of the guides. Locations for wildlife sightings were then entered into Google Earth for future reference. Rick Kunelius, wildlife biologist based out of Banff, has been summarizing the findings for the past 20 years, and has given training sessions for the guides to encourage consistent recording of all sightings.

DATA SOURCES

GPS telemetry data

Mountain caribou capture and telemetry data gathered as part of the Columbia Mountains Caribou Project (McLellan pers.comm. 2008) were made available for this research under a memorandum of understanding with Thompson Rivers University. The dataset contains over 14,000 GPS telemetry locations for winter months (December to April). It was set up in 1996, and has been updated until 2007, which is when GPS collaring in the area was terminated. A total of 23 caribou were collared during winter months over this period of time. Details on collaring times, sex and age of individuals and general location can be found in Appendix A. The most caribou wearing collars were 11 animals in 2003. Animals were collared for a minimum of 1 and a maximum of 4 years, while the majority of animals were collared for about 2 years before they either lost collars, the collars stopped working, or the animal died. How frequently GPS locations were documented varied among the different GPS collars used. During the earlier years (~1996-2000), caribou were fitted with Lotek 1000 collars, with an average 3-5 locations recorded per day. Lotek 2200 collars, as well as Televilt Proscrec 900 collars were used from about 2002 to 2007. Televilt Proscrec 900 gave mainly 2-4 locations/day, while the Lotek 2200 provided up to 12 locations per day.

DOP (Dilution of Precision) values, obtained as part of the telemetry data set, were used as an indicator of the accuracy of GPS locations. DOP values are a measure of the quality of GPS points, and can be affected by the number of satellites and their position in the sky (Bossler 2010). Small DOP values mean high accuracy due to a bigger distance between satellites, and high DOP values do not provide accurate GPS locations due to a smaller distance between satellites. A DOP value of 1 may be considered as ideal, 1-5 excellent, 5-10 moderate, 10-20 fair, and values above 20 as poor (Person 2008). For this study, any GPS locations with a DOP value over 10 were eliminated from the dataset to ensure better accuracy of point locations. However, some GPS locations do not have information on DOP values in the dataset provided, and therefore some uncertainty with accuracy of GPS point locations remained.

Helicopter flight data

Information on helicopter flight tracks and landing locations was made available by MWHS. This consisted of several different forms of data. One data is existing shapefiles for use within a GIS program to be used for spatial analysis. These shapefiles include information on ski run locations, ski zone boundaries, fuel locations, and other major landing spots (Figure 2.2)

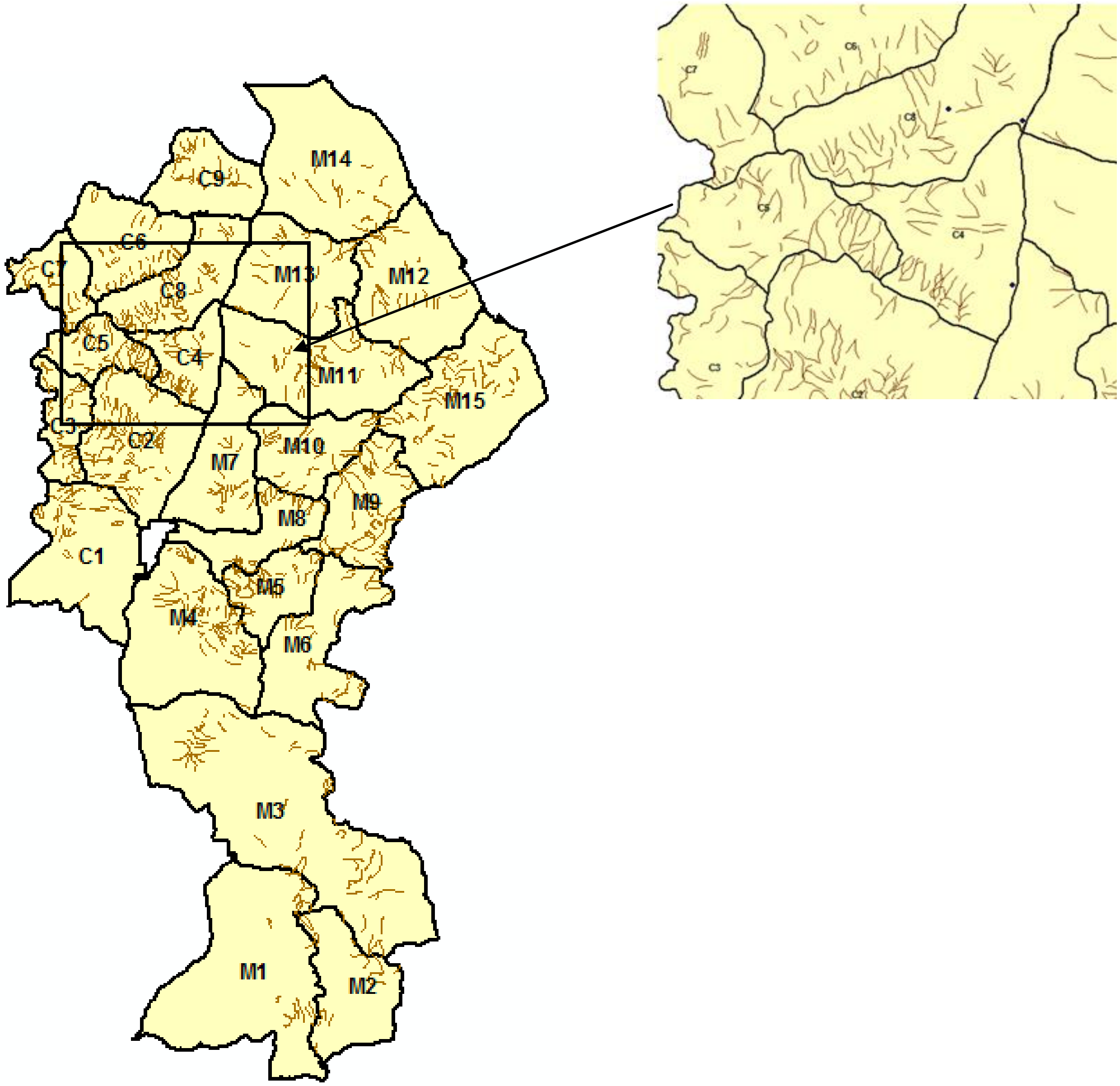


Figure 2.2 Mike Wiegele Ski Zones, displaying 825 ski runs (C1 –C9 for Cariboo mountain range, M1-M15 for Monashee mountain range). (Source: MWHS)

These data were used as a basis for the main part of the GIS work done for this project. Summaries of how often each ski run was skied/month for each season were also provided in hard copy, from which data were then entered into the existing ski run GIS shapefiles. These were vital for determining the intensity levels of individual ski run usage.

Access was also given to the `Blue Sky` mapping program used at MWHS to map real-time helicopter locations during skiing days. Flight track data are automatically stored with Blue Sky, and flights on individual days can be retrieved at a later time. This presented an opportunity to go back in time and determine when helicopters were close to collared animals. However, Blue Sky was not installed at MWHS until 2006, after collaring of animals within the ski terrain had already terminated, and could therefore not be put to use. For that reason, MWHS provided helicopter flight data in hard copy, which was used by the company to track helicopter locations prior to the use of Blue Sky.

Mike Wiegele Caribou sightings

The third principal data source consisted of all the mountain caribou sightings made at MWHS, and compiled since 1992. These were recorded by guides on monitoring forms, compiled at the end of each skiing day during the guide's meeting, and then stored in a database that was updated weekly by one of the guides. The wildlife monitoring form used by guides and pilots to record mountain caribou sightings evolved over the years, and therefore some information recorded within the sightings database differs among years. Core information that was always recorded includes: date, species, number of animals, UTM coordinates, general descriptive location, aspect, elevation, observer, ski zone, and general text fields for notes. Information on the estimated observer distance from the animals and more detailed behavioural responses by caribou has only been added to the monitor form in the past 5 years. A field to document the human action taken in order to avoid "displacement" of animals was also added. Due to time constraints, wildlife information noted by guides and pilots is often estimation.

Recently, additional fields have been added to document the type of helicopter from which observations were made, and whether or not there was evidence of snowmobile activity in the area. All wildlife observations were plotted using Google Earth and annual records were overlaid to provide visual reference over time.

Caribou sightings were entered into ArcGIS by adding XY data using the existing UTM coordinates given for each sighting. Sightings which occurred between 1992 and 2010 were displayed on the existing ski zone map (Figure 2.3).

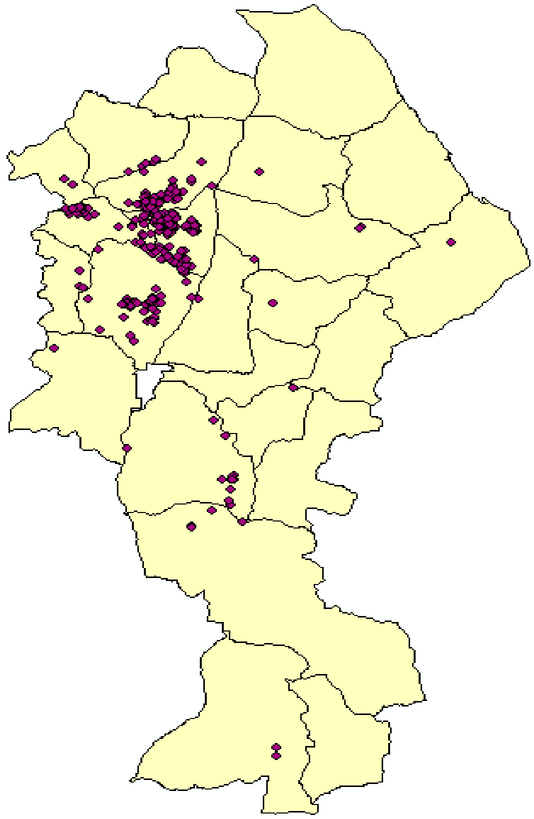


Figure 2.3 Occurrence of caribou sightings within Mike Wiegele ski terrain, from 1992 to 2010 (Source of data: MWHS)

The accuracy of MWHS caribou sightings was limited by several factors. When guides or pilots detect caribou they are most often not directly overhead of caribous' position, and cannot simply use the helicopter's GPS instrument, requires that the positions had to be estimated. "Best Management Practices" require that heli ski activity does not displace animal activity and minimizes disturbance. As soon as an animal was sighted the helicopter diverted away from the animal. At the end of the day, ski guides brought up the Google Earth image and obtained geographical coordinates and elevations from the estimated point. In early years, sightings were plotted on 1:50,000 topographical maps on which ski runs had been drawn. Precision could not be guaranteed, but each observation was reviewed with the guide who plotted it whenever possible.

Habitat Suitability Model

A caribou habitat suitability model was obtained from the Ministry of Environment (Surgenor person. comm. 2010) The late winter habitat polygons were extracted (Figure 2.4) and used to differentiate between preferred and less preferred habitat for Mountain Caribou in further analyses. Habitat suitability is based on elevation, tree age and slope. Elevations of 1750- 2100 m, and tree age classes 8 (141-250 yrs) and 9 (>250 yrs) are considered suitable for late winter caribou habitat use. Slopes <50% are considered high, 50-60 % moderate, and >60 % low suitability matches for caribou habitat.

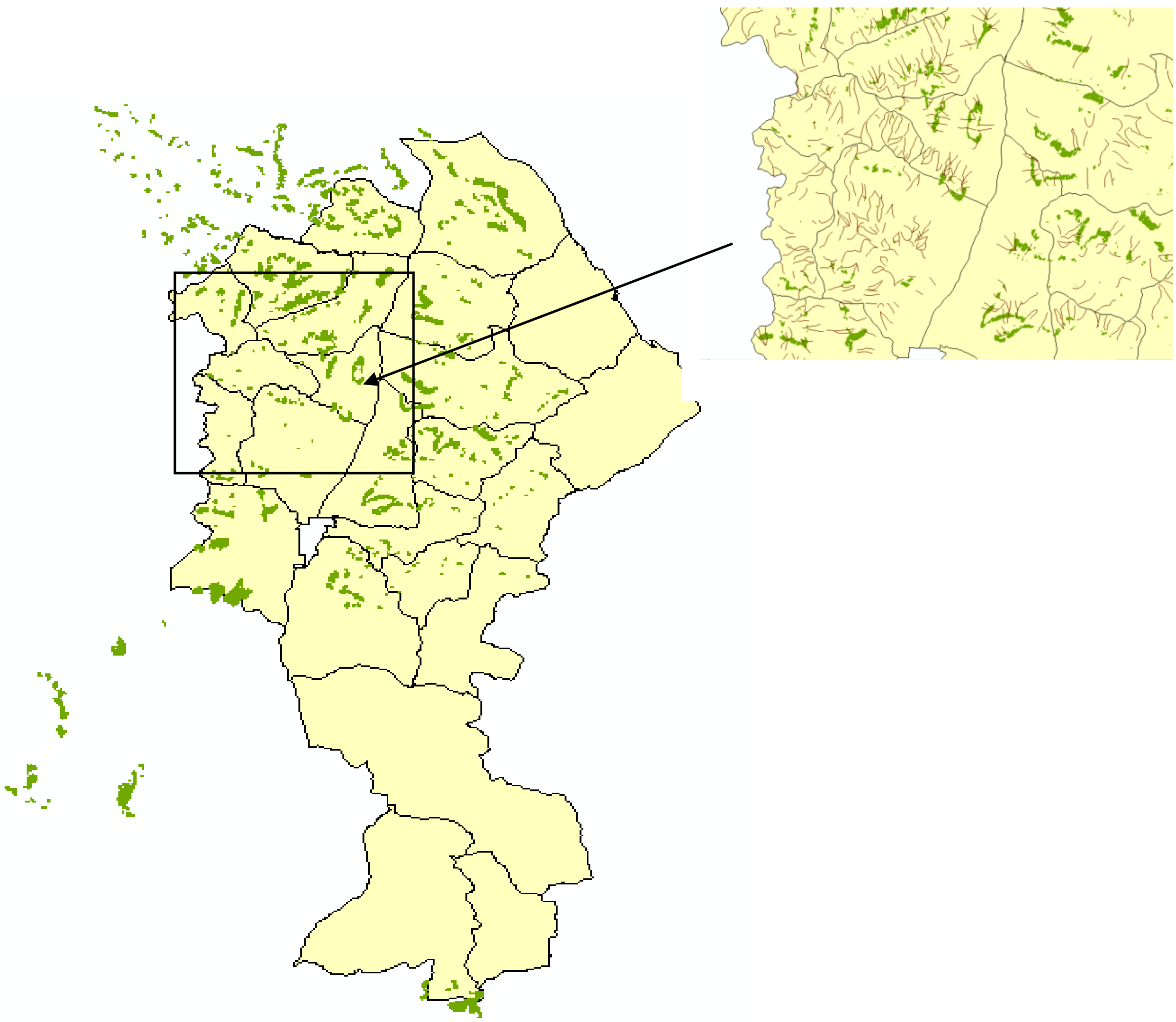


Figure 2.4 Caribou Late Winter Habitat Suitability Model, displaying suitable habitat patches in dark green over Mike Wiegele ski zones (Source of data: MoE)

GENERAL DATA ANALYSIS

Introduction to Geographic Information Systems (GIS) methods

Spatial data were exclusively managed within ArcMap 9.3, the main application of ArcGIS, a geospatial processing program developed by “esri” (Esri n.d.). ArcMap was used for basic and more advanced map-based tasks including map viewing, analysis and editing. Prior to any detailed geographical analysis, the dataset containing GPS telemetry locations was overlayed with the existing ski zone and ski run layer by adding the GPS telemetry dataset with UTM coordinates as XY data within ArcMap (Figure 2.5).

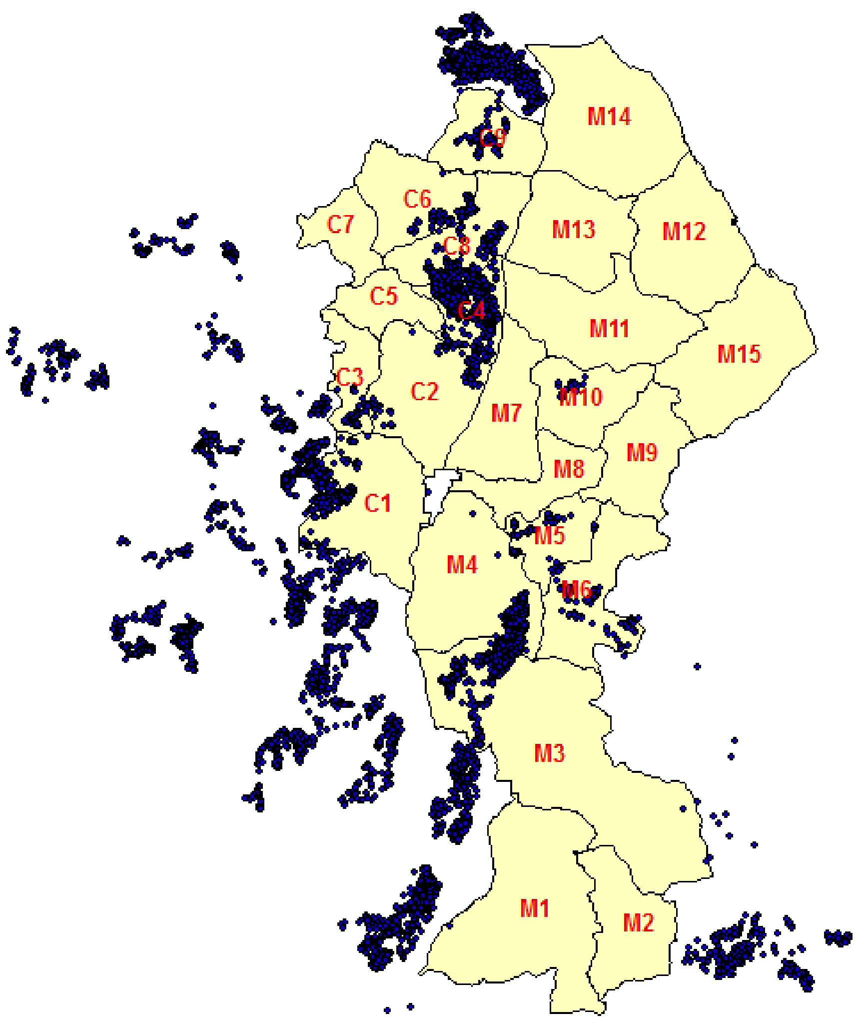


Figure 2.5 GPS location points obtained from caribou collared during 1996-2007 (Source of data: MoE)

Of the more than 14,000 caribou GPS locations for late winter, over 9,000 were outside of the MWHS ski terrain, and approximately 4,000 locations fell within the ski terrain. Figure 2.6 also shows MWHS 24 ski zones. Ski areas West of highway 5 near Miledge Creek had the highest potential of skiers coinciding with caribou (labelled ski zones C4, C8 and M4), since the area does not only provide valuable habitat for caribou, but prime skiing. Approximately 1,500 caribou locations were within these two frequently skied zones.

Within the MWHS ski terrain, snowmobiling also occurs frequently, although most is in the periphery. This study focused on the impacts of heli-skiing on mountain caribou only, and recognizes that these occur within an area where snowmobiling concurrently takes place. The influence of snowmobiling itself was not investigated but may have a strong influence on the areas used by caribou.

Statistical Data Analysis

All data collected by MWHS and the CMCP were spatially explicit, permitting statistical testing using GIS. Statistical analysis of tabular results included G tests of independence and Fisher's exact tests for smaller samples performed using Microsoft Excel®, as well as Analysis of Variance completed with the use of R version 2.3 statistical software. Specific hypotheses are described as relevant in each part of the study.

REFERENCES

BC Ministry of Environment, Lands and Parks . 1997. Toward a Mountain Ca ribou Management Strategy for British Columbia. Wildlife Branch.

BC Ministry of Environment, Lands, and Parks. 1999. Mountain Caribou .

BC Ministry of Environment. 2009. Mountain Caribou Recovery Implementation Plan, Update to the Mountain Caribou Progress Board.

Bergerud, T. 1978. The status and management of caribou in British Columbia. B.C. Fish and Wildlife Branch Report, Victoria.

Blue River Tourism Group. 2007. Area Description. Retrieved July 17, 2011, from Blue River & Avola: http://www.blueriverbc.ca/visitor_info/area-info.htm

Bossler, J. 2010. Manual of Geospatial Science and Technology. Boca Raton: CRC Press.

Carignan, V., and M. Villard. 2002. Selecting indicator species to monitor ecological integrity: a review. Environmental Monitoring and Assessment. **78:** 45-61.

Coupe, R., Stewart, A., and B.Wikeem. 1991. Engelmann spruce-subalpine fir zone, SpecialReport Series No.6. In D. a. Edited by Meidinger, Ecosystems of British Columbia (pp. 223-236). Victoria: BC Ministry of Forests.

Dulisse, J. 2007. Connected to Caribou- A Mountain Caribou/Species at Risk Co occurence Analysis. Forest Ethics.

Esri. n.d. Esri products: ArcGIS. Retrieved June 28,2011, from: http://www.esri.com/products/index.html

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

Ketcheson, M., Braumandl, T., Meidinger, D., Utzig, G., and D. Demarchi. 1991. Interior cedar hemlock zone. Ecosystems of British Columbia. BC Ministry of Forests,Victori. Special Report Series No. 6: 167-181.

Kinley, T. 1999. Mountain Caribou.Victoria : Wildlife Branch, Ministry of Environment, Lands and Parks .

Kinley, T., and C. Apps. 2001. Mortality patterns in a subpopulation of endangered mountain caribou. Wildlife Society Bulletin. **29:** 158-164.

Knowledge Management Branch. 2010. Caribou distribution by ecotpe in BC. Retrieved July 16, 2011, from Wells Gray: http://www.env.gov.bc.ca/wld/speciesconservation/caribou_by_ecotype.html

Knowledge Management Branch, Ministry of Environment. n.d. Caribou Distribution in British Columbia by Ecotype. Retrieved June 14, 2011, from Caribou in British Columbia: http://www.env.gov.bc.ca/wld/speciesconservation/caribou_by_ecotype.html

Kunelius, R. 2009. Alerts and Closures- Procedures. (Mike Wiegele Heli-skiing Manual).

MC Lellan, B. 2008. person.comm. Mountain caribou capture and telemetry data from the Columbia Mountains Caribou Project. Kamloops, BC.

Mike Wiegele Heli-skiing. 2011. Our Story. Retrieved February 12, 2001, from Mike Wiegele Helicopter Skiing: http://www.wiegele.com/ourstory.html

Morris, M. 2002. An Exclusive Interview with Santa Claus on Reindeer and Mountain Caribou. Parks Canada.

Mountain Caribou Science Team. 2005. Mountain Caribou Situation Analysis.

Person, J. 2004. Writing your own GPS Applications: Part 2. Causes of Precision Error.

Petulla, J. 1988. American environmental history. 2nd Edition ed. New York: Macmillan.

Pojar, J., and Stewart, A. 1991. Apline Tundra Zone. In D. a. Edited by Meidinger, Ecosystems of British Columbia, Special Report Series No. 6 (pp. 263-274). Victoria: BC Ministry of Forests.

Seip, D. 1990. Ecology of Woodland Caribou in Wells Gray Provincial Park. Ministry of Environment.

Surgenor, J. person. comm. 2010. Caribou Habitat Suitability Model. BC Ministry of Environment. Kamloops, BC

Thompson, V. 2011. Mountain Caribou recovery not a single species issue: NCES. Revelstoke: Revelstoke Times Review.

U.S. Fish and Wildlife Service. 2011. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Southern Selkirk Mountains Population of Woodland Caribou (Rangifer tarandus caribou. Federal Register.

Van Oort, H., McLellan, B., and R. Serrouya. 2011. Metapopulation or predictable pattern of extinction? Animal Conservation. **14:** 231-232

CHAPTER 3. DETECTABILITY AND RESPONSES OF MOUNTAIN CARIBOU TO HELI-SKIING

INTRODUCTION

The conservation of ungulate species such as caribou, for which forage availability is limited during winter months and predation risks are high, requires that energetic costs be controlled (Safford 2004). Helicopter skiing has the potential to cause stress in mountain caribou, due to a similar geographical use of high elevation forests during winter (Simpson & Terry 2000, Mountain Caribou Technical Advisory Committee 2002, Hamilton and Pasztor 2009). Stress caused by skiers on the ground or helicopter noise could have long-term effects on reproduction and survivorship; hence, recreation has long been of concern with continuously declining population trends (Miller and Gunn 1979, Simpson & Terry 2000). Studies clearly illustrating direct behavioural responses made by caribou towards varying disturbances are increasingly needed; particularly as winter backcountry recreation is growing in popularity and gaining more access across British Columbia. Since responses may differ among caribou herds depending on historical exposure to disturbance, a comparison among existing studies would be valuable (Mclellan, person. comm. 2010). However, the lack of studies documenting direct behavioural effects of heli-skiing to mountain caribou prevents such evaluation. Nonetheless, some studies (Foster et al. 1983, Cote 1996) have looked at responses of caribou and some other wildlife to aircraft, vehicular, and direct human disturbances.

This chapter focuses on immediate responses of mountain caribou to heli-skiing disturbances near Blue River, BC. The main objectives of this chapter are:

1) To determine the detectability of caribou within Mike Wiegele Heli-Skiing (MWHS) ski terrain, based on past occurrence data.

2) To determine the relationship between levels of heli-skiing activity and behavioural responses of mountain caribou.

Energetic Cost related to Human Disturbance

Studies suggest that stress might affect caribou survivorship since flight responses may result in high energetic costs during times when reserves are limited (Calef et al. 1976, Freeman 2008). The behavioural adaptations of mountain caribou make them most vulnerable during winter. Weight losses of up to 20 % have been recorded in caribou during winter months (Bergerud 1974).

Low body reserves in female arctic caribou during fall and winter has been documented to cause embryonic absorption after breeding (Russell et al. 1998). Embryonic mortality might also be related to a trade-off mechanism ensuring proper lactation for the current calf during winter before investing in new offspring, especially when proper nutrition is low. Another study on prenatal-mortality in caribou from the Porcupine Herd in Yukon and Alaska pointed out that stillbirth and abortion might contribute significantly to the number of calf deaths (Roffe 1993). If female mountain caribou are nutritionally weakened during winter months similarly to arctic caribou and additionally stressed, this could potentially cause an increase in the number of stillbirths and abortion. Ultimately, if this is the case for mountain caribou, this can lead to consequences in recruitment, and can substantially affect population persistence.

The upslope migration that mountain caribou undertake in the early-through mid-winter (depending on herd) puts an additional strain on their energy reserves. Despite the fact that caribou are well adapted for winter locomotion with large splayed hooves, the energetic cost of movement increases with greater snow depth. Elevational movement is necessary to distance themselves from predators that do not have the ability to walk on deep snow (Festa-Bianchet et al. 2011). However, due to increased human access into higher elevations via snowmobile tracks and roads, predators have also found ways to reach caribou to hunt in higher elevations. Intuitively, this puts caribou at a greater risk for predation and elevated energetic costs due to increased escape efforts. Snowmachines and aircrafts could potentially also be perceived as predators and elicit a flight response, thus causing caribou to move excessively. It has been suggested that disturbance stimuli can affect animal fitness and population dynamics in a similar matter than predation risk due to elevated stress responses (Frid et al. 2002).

Research on the direct physiological reactions of mountain caribou in response to disturbances is limited. An early study conducted on reindeer (the same species as caribou) found that extensive running during cold winter months promoted pulmonary disorders (Calef et al. 1976). Freeman (2008) studied the stress responses in mountain caribou caused by motorized backcountry recreation, specifically snowmobiles and helicopters. Using a stress hormone analysis that measured fecal glucocorticoids, she found high levels of stress hormones in the scat of mountain caribou located in areas extensively used for snowmobiling and heli-skiing, and found that hormone levels can remain elevated following these recreational activities.

Heart rate responses towards helicopter disturbance has not been measured on caribou, but one study conducted on mountain sheep (*Ovis Canadensis*) in south-western Alberta indicated that sheep heart rates increased by as much as 120 bpm after running for 2-15 seconds when helicopters were less than 250 metres above ground level (McArthur et al. 1982). Similar cardiac responses in caribou due to frequent heli-skiing exposure could potentially affect overall health conditions since energy reserves are already low during winter months.

Behavioural Responses to Human Disturbances

Signs of distress and anxiety in caribou have been associated with ground as well as air disturbances (Simpson & Terry 2000). A number of studies have been conducted on barren-ground caribou in northern Canada, where human disturbances are increasingly common, and include ground disturbances associated with oil development and seismic lines, as well as aircraft overflights.

One study conducted in northern Yukon and Alaska found that strong panic reactions in a large number of barren-ground caribou occurred when fixed-wing aircrafts and helicopters flew at an altitude less than 60 metres (Calef et al. 1976). It also noted that caribou display a higher percentage of strong escape reactions when disturbed by aircraft during calving season and in early winter, at altitudes up to 150 metres. Their general recommendation was to fly at a minimum of 150 metres during migrations and at a minimum of 300 metres during other times to avoid causing a severe response.

Similar recommendations were given in studies conducted on other ungulate species. Cote (1996) reported that mountain goats were adversely affected if helicopters flew within 500 meters, and recommended restrictions for helicopters flying within 2 km of mountain goat habitat. Foster & Rahs (1983) analysed the responses of mountain goats to helicopter disturbance using categories of overt responses in North-western British Columbia. They found that factors which influence the degree of responses include the distance of the disturbance, geographic area, cover availability, and degree of awareness.

Miller and Gunn (1979) reported various factors influencing flight responses of Peary caribou to helicopter disturbance in a study conducted in the Northwest Territories. These included group size and type, wind direction in relation to the helicopter, previous herd activity and terrain. In a later study, they also found that calves were more excited than adults and this lead to a general elevated response by the group (Miller & Gunn 1981).

Another study, conducted on Grant's caribou in interior Alaska during calving season, found only mild short term reactions to jet overflights, and no increased movements of cow-calf pairs (Lawler et al. 2005). Similarly, low-level jet fighter overflights were not found to be related to calving success and calf survival in Labrador (Harrington & Veitch 1992). An earlier study conducted on the same caribou herd found no significant impact on daily activity levels or distance moved, and only a brief overt reaction towards the low-level jet fighters was noted (Harrington & Veitch 1991).

Responses towards aircraft disturbances by caribou appear to vary among studies, but are mostly short-term, mild, and do not extensively affect caribou survival or diurnal activities. Variation among studies might be due to differences among habitats where caribou were studied, since caribou within forested habitat have more protection compared with caribou in open terrain. Additionally, the number of historical flights may play an important role, since caribou potentially habituate and react less to aircrafts (Wolfe et al.2000).

Other studies have shown that ground disturbances can also cause varying degrees of responses by caribou. The responses of barren-ground caribou towards a moving vehicle were observed in the Yukon (Horejsi 1981). Panic responses to a pick-up truck included running away, jumping, and raising of tails. The study concluded that caribou react to vehicles mostly based on the speed of the approaching vehicle.

A study in Norway focused on the behavioural responses of wild reindeer to direct provocation by snowmobiles and skiers (Reimers et al. 2003). Fright distance (the distance between the human observer and herd center point at the moment individuals group together as fright response) and flight distance (the subsequent distance between the observer and herd at the moment of flight) were measured when animals encountered different sources of disturbance. While provocations by skiers and snowmobiles overall resulted in similar responses, reindeer were more easily disturbed by snowmobiles and detected them earlier, but reacted stronger when provoked by skiers, with longer flight distances. Mean distance moved for snowmobiles was 660 m, while mean distance moved for skiers was 970 m. The study also pointed out that flight distances were longer when reindeer were lying at the time of provocation than if they were grazing. The actual mean flight distances observed differed from that found in caribou in Newfoundland (Mahoney et al. 2001), that recorded much shorter fright distances (net flight distance of 65 m versus an average of 400 m in Norway). This difference might be due to the fact that in Newfoundland, caribou were located within more forested habitats and might have become more habituated to snowmobiling in the area. As mentioned, the historical exposure to heli-skiing, as well as the terrain can play a major role in determining the responses of individual caribou. Hence, different studies show different results, and conclusions should only be drawn for the studied population and based on their historical background towards disturbances.

Mike Wiegele heli-skiing (MWHS), a heli-skiing operation in Blue River, BC provided a unique opportunity to examine at the response behaviour of one mountain caribou herd towards this kind of disturbance. More information on the MWHS operation can be found in Chapter 2. MWHS started operating 40 years ago; therefore, many generations of caribou have lived their lives with heli-skiing. However, some caribou in this area are historically less often exposed to disturbances than others, as some mainly inhabit Wells Gray Provincial Park East of the MWHS ski tenure and only occasionally move into ski terrain.

"Best Management Practices"

Caribou conservation strategies have large potential consequences for heli-ski operators. In order to minimize potential disturbances to caribou associated with heli-skiing, an 'Alert and Closure Protocol' (Kunelius 2009) has been used at MWHS since 2006 as part of their 'Best Management Practices'. As described in Chapter 2, this protocol requires that a "Closure" is applied when caribou are observed on, or in close proximity to, a ski run in order to divert traffic away from the area for 24 hours. An "Alert" is applied when caribou are within 500 metres of a run, but not on it, or if tracks on a run are observed.

The 'Alert and Closure Protocol', however, relies on mountain caribou being detected, since only when a sighting occurs the area is avoided. If caribou are not seen, they are not avoided. For this reason, the question arises how detectable mountain caribou are within the ski terrain. Detectability of mountain caribou can possibly be attributed to be a factor of group size and tree cover, so these types of factors play an important role in how well ski guides and pilots are able to detect caribou within the ski terrain. If detectability can be quantified, it can be determined how effective these Best Management Practices are in terms of minimizing how frequently skiing activities and caribou coincide. An essential part of examining how efficiently heli-ski operations avoid disturbances towards caribou is therefore to determine how often caribou are or are not detected when flying or skiing close to them.

Behavioural Responses

Mountain caribou sightings, made at MWHS when caribou were detected during flights or skiing, have been recorded by guides and pilots and made available for this study. Caribou recordings from 1992 to 2009 contained information on the number of animals observed, location and general behaviour notes. Pilots and guides at MWHS have been briefed about making accurate observations and have years of experience flying and skiing in this terrain, as well as reporting wildlife sightings (Kunelius person. comm. 2009). These data allowed for an examination of the responses caribou made towards heli-skiing. Only visual observations of animals were considered, and recordings of caribou tracks were not used.

The type of caribou responses observed by the MWHS team was related to three variables associated with heli-skiing. The first one of these variables was the type of helicopter used while making the observation. This might have an effect on the response, since larger helicopter machines such as the Bell 212 are louder than smaller machines, such as the Bell 407 or the A-star (Figure 3.1).

Bell 212 A-Star Bell 407

Figure 3.1 Three types of helicopters available for heli-skiing tours at MWHS. Bell 212 is the largest, and the Bell 407 the smallest helicopter in terms of passenger seats (Source: MWHS)

The second variable tested for its effect on the direct response by mountain caribou was whether the observation was made by skiers or from the helicopter while overflying or landing. A potential difference of responses could exist since helicopters are much noisier than disturbances from the ground, but possibly also since ground disturbances may be associated with predation as opposed to disturbances from the air.

The third variable tested for its effect on the direct responses made by mountain caribou was the type of habitat where sightings occurred. More specifically, I examined whether caribou responded differently when sighted within forested habitat as opposed to open terrain. Since caribou are prey animals, the possibility of caribou being more frightened in open habitat with less escape terrain exists. Dense forest provides caribou with cover not only from predators, but human disturbances as well.

METHODS

Determining detectability

To determine the detectability of mountain caribou, the incidents where skiing took place in close proximity to caribou were examined. These incidents were identified using GPS locations of caribou, provided by the Columbia Mountains Caribou Project (McLellan pers.comm. 2008). Provided data contained over 14,000 GPS telemetry locations for winter months (December to April) from 1996 to 2007 for 23 female caribou. More details on the GPS capture and telemetry dataset can be found in Chapter 2.

Although radio collar data have been available since 1996 and flight routes since 1990, only three years of data (2002, 2003, and 2004) where both for caribou habitat use and helicopter flight paths were recorded were available, since flight path data was recorded on paper before 2006 and not kept on file for all years.

Ski areas West of highway 5 near Miledge Creek had the highest potential of skiers coinciding with caribou (ski zones C4, C8, and M4, Figure 2.5, Chapter 2), since the area provides valuable habitat for caribou as well as prime conditions for skiing. Approximately 1,500 caribou locations were within these frequently skied zones. Of those, just over 1,000 caribou locations were from 2002-2004, and these were filtered from the entire GPS telemetry set to use for the visibility analysis.

Daily flight summary sheets with hourly helicopter locations (refer to Appendix B for an example) were analysed to determine those dates helicopters were within 500 metres of mountain caribou. For the three years examined, each day of skiing was compared to collared caribou habitat use on the same day. This was done by mapping out caribou locations individually for each day using GIS.

For each day, the helicopter flight sheets were inspected to find out if GPS locations appeared to be in the same general area as was skied that day. Ski runs an individual helicopter flew to and from on a specific day were mapped out and highlighted, and a general flight path used to access those ski runs was also constructed.

To re-construct flight paths of previous years, a number of generally used flight tracks, drawn out by long-term employed pilots, were used. These general flight paths can only be considered an estimation of how helicopters were flying one a specific day in the past, since some variation exists between individual pilots and flight routes are usually dependent on weather conditions on that day. Pilots generally stay lower in elevation during flights from one run to the next and within valleys; therefore, assumptions made on how helicopters were likely flying on a certain day are valid. To account for some inconsistency, a 500m ``buffer`` technique was applied all around the ski runs to minimize the variation to some extent.

A digital contour model, called a TIN (triangulated irregular network), was made available by MWHS. A TIN model represents three-dimensional surfaces as a set of triangles (Peucker et al. 1977). When re-creating exact flight paths, the TIN was used to apply the rule of flying within valleys by following contour lines. To draw the flight paths in GIS, a digitizing tool was used to follow through from the flight's starting point to each ski run skied, then between ski runs and fuel stations, and back to landing sites. Only those flight paths of helicopters flying in the area close to collared animals on a specific day were actually drawn out. An example of one day's helicopter flight path is shown in Figure 3.2

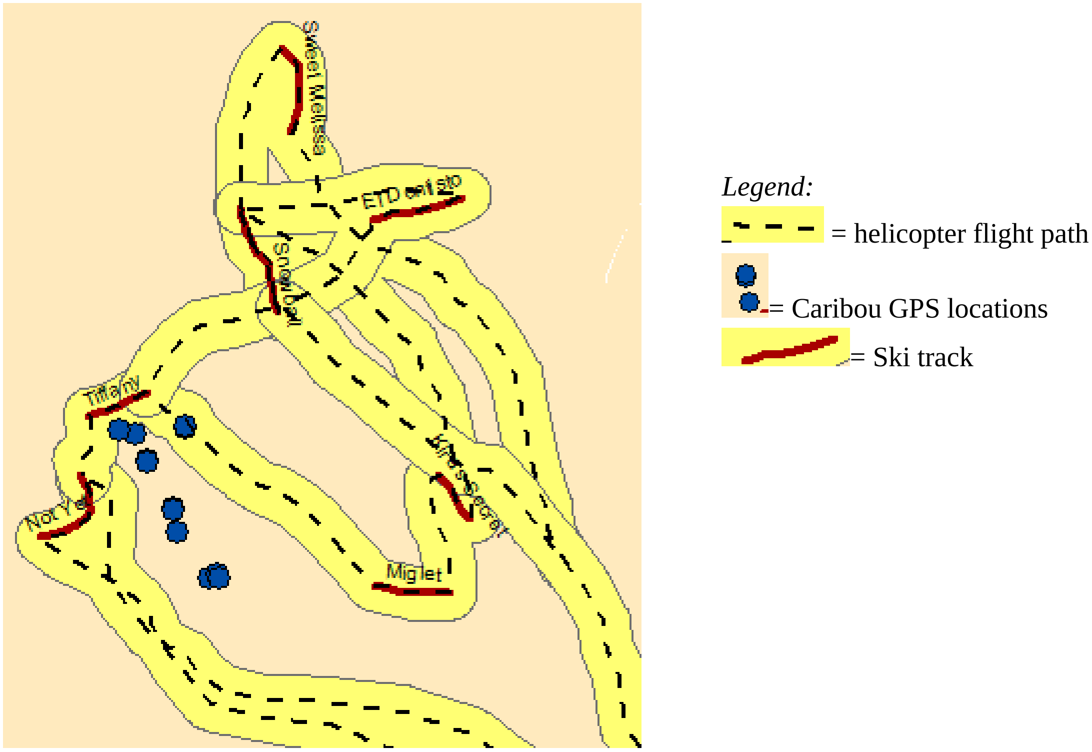


Figure 3.2 Example of helicopter flight path made between ski runs on one day (on April 15th, 2002) and GPS locations for one caribou for the same time period (Source: composite of MWHS and MoE)

The 500m zone created to limit variation among flight paths also served as a detection envelope when considering the pilot's visibility during helicopter flights. If GPS locations fell within this 500m zone, the caribou were considered to be within visibility of pilots. After processing helicopter flight sheets for all three years, and mapping out the flight paths and GPS locations available, a total of only 15 days were found where GPS locations were within the 500m zone of a ski run or flight line on that specific day. For these 15 days, the wildlife monitoring database was checked to see whether a sighting for caribou had occurred.

A recording of caribou on a day where flying or skiing was within 500 metres of collared caribou was considered a 'hit', and incidents where no recording occurred was considered a 'miss'. The total number of hits and misses were then determined and reported as a percentage. It was assumed that for the years studied no bias towards looking for caribou and finding their locations occurred, since no protocol to watch out for caribou existed at that time. Observations made were only recorded out of interest of the company, and not yet a requirement for management purposes.

In order to determine whether forest cover had a significant influence on how well caribou can be avoided, the detectability of caribou within open terrain was compared to within forested areas. The number of sightings made within open and forested terrain was determined, as well as an "expected" number of sightings in each. The expected number was derived from the percentage of GPS collar locations within each habitat category. GPS locations were limited to the time of the day when skiing took place (between 8 am and 4 pm). Open vs. forested habitat was distinguished using tree ages on forest cover maps provided by the BC Ministry of Forests. The distinction between forested and open habitat was possible by delineating polygons with different tree age classifications. According to the BC classification scheme, tree age class 0 refers to no trees, and all other tree ages can be considered to be forested habitat. Open habitat (tree age=0), and forested habitat (tree age≥1) were graphed. Sightings recorded by MWHS were displayed over the forested and then the non-forested map layers, to find out how many sightings took place in each category. GPS collar locations from 1996 to 2007 were also displayed, to provide the expected number of sightings within each category. This number was divided by the total number of GPS locations to obtain a percentage.

Evaluating Behavioural Responses

In order to determine whether mountain caribou react overtly to heli-skiing, observations made by MWHS pilots when a caribou was sighted over the past ten years were analysed. The number of sightings recorded each year between 1996 and 2010 were counted using the database described in Chapter 2, to examine the general trend of number of sightings recorded over the past years. Only actual sightings were used for this, and sightings of caribou tracks were excluded.

I also examined how the type of the responses recorded over the same years varied. This was done by first classifying the responses provided by the guides and/or pilots into one of three categories (Figure 3.3, 3.4, and 3.5), adapted from a scale used by Penner (1988) to classify mountain goat behavioural responses.

Figure 3.3 Category of “low” behavioural response made by caribou in response to heli-skiing. No significant change in movement. If resting, remain rested, and possibly tilting of head towards helicopter.

Figure 3.4 Category of “moderate” behavioural response made by caribou in response to heli-skiing. A change in movement from resting to standing, standing to walking, but no major unrest in the group dynamic.

Figure 3.5 Category of “high” behavioural response made by caribou in response to heli-skiing. A drastic change in movement from standing and feeding to running away, abandoning area completely, and possibly splitting up group.

I examined the relationship between the type of response and the frequency of use of the ski run by first categorizing each of the 825 ski runs into one of four skiing intensity categories: none, low, med, and high. (None) refers to zero usage during the month before the sighting, (low) refers to 1-40 times a group skiing specific runs, (medium) refers to 40-80 times of skiing specific runs, and (high) refers to more than 80 times of skiing specific runs. Daily ski run usage data for individual ski runs for the past years were not available, hence the ski run usage per month when sightings took place were used as an estimate.

To examine any effect of the type of helicopter on the response of caribou, helicopter use data from the past years were analyzed to determine which machine was being used when observations took place. The relationship was tested using a Fisher's exact test. The same was done to determine whether observations were made from the air or on the ground, and another Fisher's exact test was employed.

I determined whether mountain caribou react differently towards helicopter disturbance within open or forested habitat to investigate the importance of cover, by examining locations of mountain caribou sightings recorded by MWHS. The same forest cover map as used for the previous analysis was displayed to distinguish between open habitat and forested habitat (tree age 0 and 1= open, all other tree ages= forested). Caribou sightings were overlaid on open and forested areas and the sightings in each were counted. The total size of area for all open habitat patches and the total size of area for all forested habitat patches were determined. These were used to get an expected number of sightings for each category, based on the percentage of area of each over the total area of all habitats. Another Fisher's exact test was employed to test for the significance of the difference between actual and expected number of sightings in open and forested habitat.

RESULTS

Figure 3.6 shows the trend of number of mountain caribou sightings at MWHS over the past years in relation to the ski run usage at MWHS. An increase in the number of caribou sightings is apparent, while the skiing level activities appear to have levelled off around the mid 1990s.

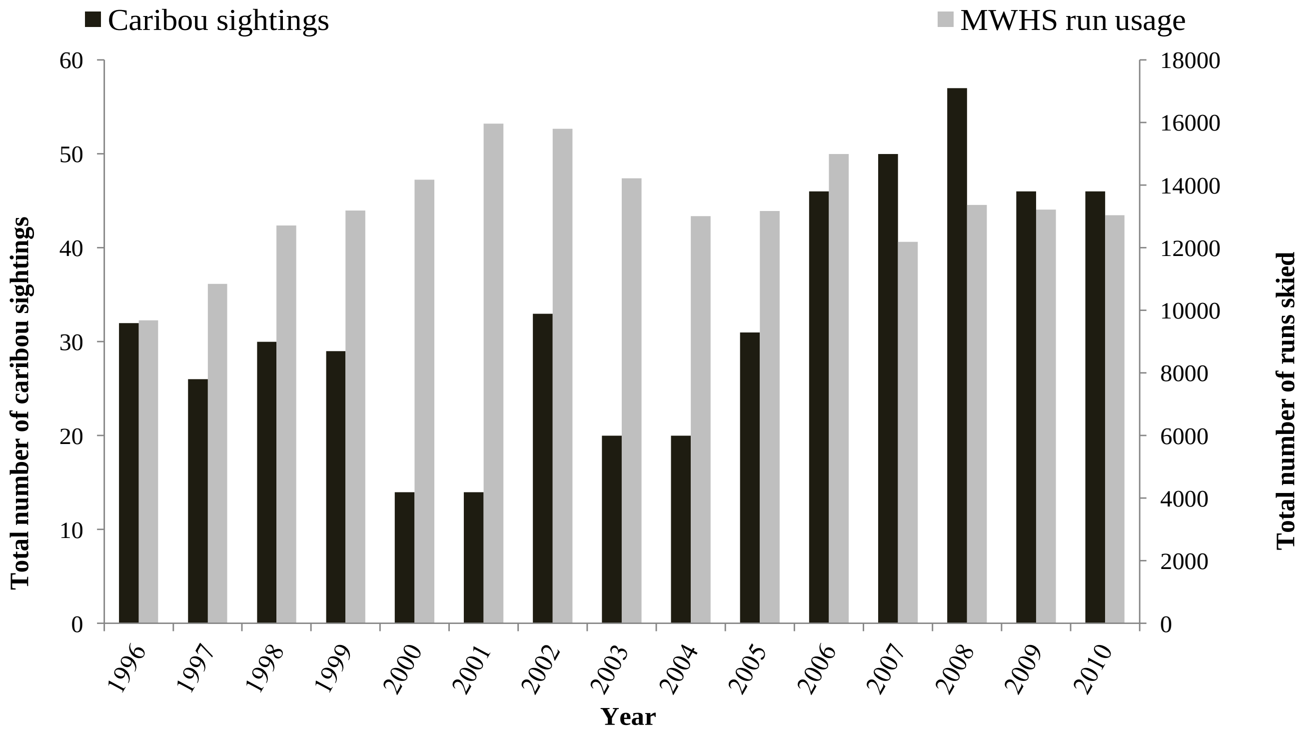


Figure 3.6 Trend of number of mountain caribou sightings at MWHS in relation to MWHS ski run usage from 1996 to 2010.

Detectability

As noted, despite thorough examination of three years of data, only 15 days were found where collared caribou were within 500 meters of a run skied on that particular day. For 6 of the 15 days, observations for caribou were made, and for 9 of 15 days no observations were recorded. On an individual run basis, on 40 % of occasions when caribou were within close proximity to ski runs, they were detected (CI 0.18-0.67, binomial test, P=0.37, 95%, Power=0.99).

The second test examined the sightability of mountain caribou within open compared with forested habitat. Figure 3.7 depicts the locations of MW sightings within each habitat category. Figure 3.8 depicts the GPS collar locations based on the telemetry dataset from 1996 to 2007.

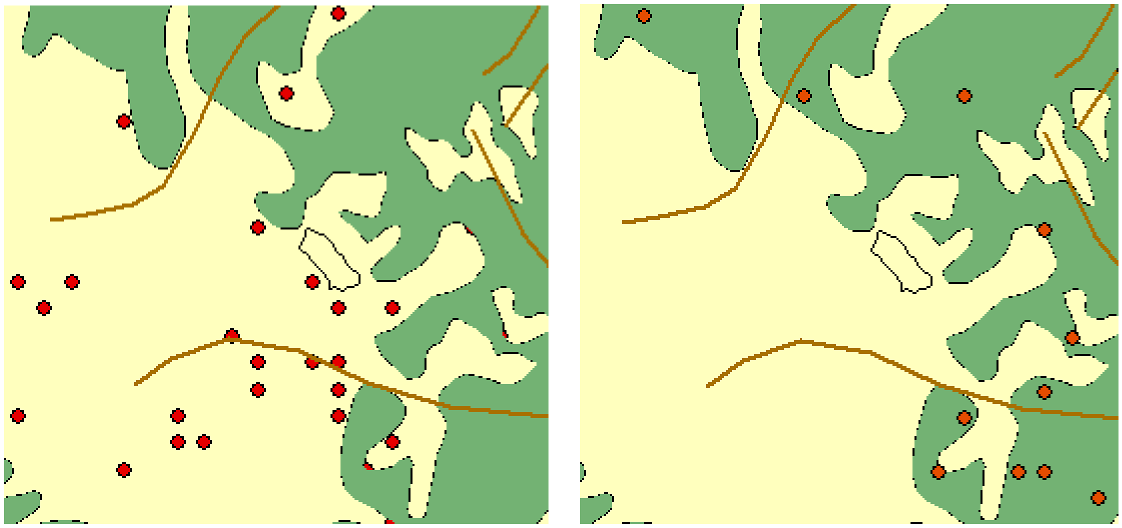


Figure 3.7 Map illustration of MW sightings within open habitat on the left, and MW sightings within forested habitat on the right. Total numbers for each category were counted (Source: composite of MoE and MWHS)

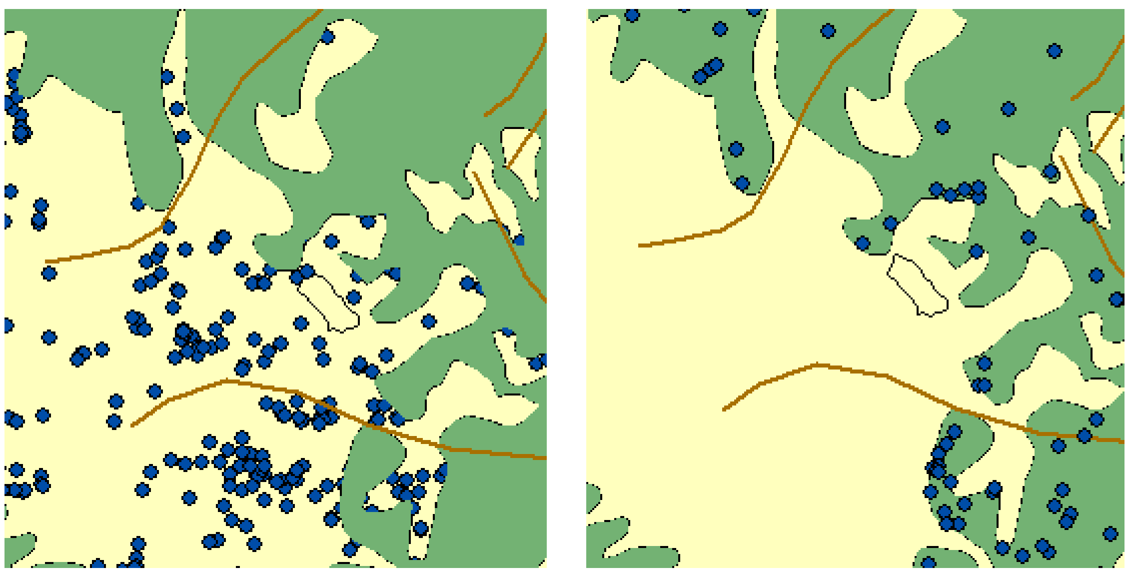


Figure 3.8 Map illustration of GPS collar locations within open habitat on the left, and GPS collar locations within forested habitat on the right (Source: MoE)

The number of sightings recorded within open areas totalled 206 (54%), while the number of sightings within treed areas was 177 (46%). The number of GPS locations within treed areas was 10811 (77%), while the number of GPS locations within open areas was 3280 (23%). Proportionally more sightings ($G= 345, df=1, p<0.01$) occurred in open areas, despite fewer GPS locations being within open areas.

Responses

Table 3.1 shows the relative proportions of different caribou responses recorded after 2003 when a new protocol was introduced that distinguished between three classes of response intensities. Only some of the observations recorded between 2003 and 2009 had remarks on responses of caribou (151 in total). In general, there was no tendency for moderate and high responses to be recorded more frequently in later years. Moderate and high responses combined (49%) were almost equal to the number of low responses (51%).

Table 3.1 Number of caribou observations over the past years in categories of response type

Year	**low**	**moderate**	**high**	**Total**
2003	7	7	2	16
2004	9	5	1	15
2005	15	9	0	24
2006	19	18	1	38
2007	10	10	5	25
2008	8	7	3	18
2009	9	6	0	15
Total	**77**	**62**	**12**	**151**

Figure 3.9 shows the number of sightings recorded by MWHS in relation to the area where the sightings took place. The total number of sightings does not equal the total in Table 1 since for some of the earlier years no detailed skiing data were available.

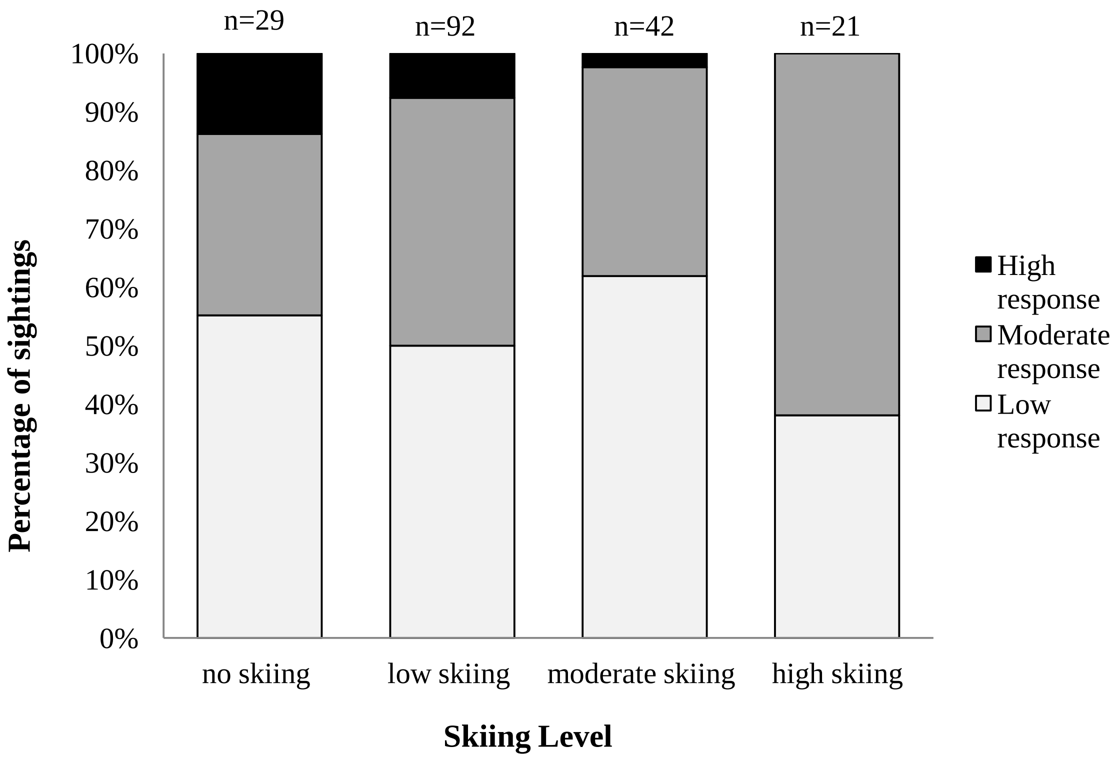


Figure 3.9 Proportion of sightings within categories of response type versus the general skiing in the area.

Observations in the high responses category did not get more frequent with increasing skiing (p=0.16, FET), thus caribou located in areas skied more heavily did not respond more than in areas less disturbed by skiing.

The relative frequency of different sighting categories made from a Bell 212 helicopter (8 low responses, 3 moderate, and 1 high), from a Bell 407 helicopter (14 low responses, 2 moderate, and 2 high), and from an A-Star helicopter (7 low responses, 0 moderate, and 0 high) were similar (p=0.62, FET).

The proportions of different responses recorded from the air (28 low responses, 2 moderate, and 0 high,) and from the ground (6 low responses, 0 moderate, and 3 high) did vary (p=0.0068, FET).

The frequency of different responses made when disturbed within open terrain (50 low responses, 45 moderate, and 5 high) differed from those made when disturbed within forested habitat (68 low responses, 22 moderate responses, and 4 high) significantly (p=0.0045, FET).

DISCUSSION

Since monitoring surveys have shown that the herd in this area was slightly declining over the course of the study, the apparent increase in the number of caribou sightings at MWHS is not likely due to an increase in the number of animals in the area, but rather an artefact of an increased awareness due to better, more intensive training of observers. Two important events that brought increased awareness into action are an environmental stewardship agreement made in 2003 (Best Practices for Sustainability Committee, 2003), and the introduction of the Alert and Closure Protocol in 2006 following the signing of a memorandum of understanding regarding management of heli-skiing and snowcat skiing in mountain caribou habitat in 2005 (BC Ministries of Agriculture and Lands, Environment, Tourism, Sports and the Arts and BCHSSOA 2005). After the protocol was implemented, more sighting records were logged.

Due to the low number of incidents with geographical overlap of caribou and heli-skiing, the visibility of mountain caribou in skiing terrain cannot be precisely estimated, but results suggest that many if not most caribou within 500 m of active heliskiing are not seen. One explanation of low-coincidence of collared caribou and heli-skiing being in the same location at the same time is that caribou are displaced from areas of active skiing. This effect cannot be dismissed in any following interpretations. However, the low number of incidents of overlap for the studied years may also be an artefact of low numbers of GPS collar locations available in areas where frequent skiing took place. As mentioned in Chapter 2, of the 14,000 late winter caribou locations, only around 4,000 locations were within MWHS ski terrain. Collaring of caribou in this area was not aimed at studying caribou’s responses to heli-skiing, but rather to study their general habitat use and responses to logging practices and different levels of predation. Approximately 1,500 locations were within areas where frequent skiing took place (ski zones C4, C8 and M4), and for the time period of 2003-2004 studied for the visibility analysis, over 1,000 locations were found in these areas.

Despite low numbers of incidents (15) where collared caribou were within a 500 m impact zone while skiing took place, the visibility analysis showed that mountain caribou are often not detected since most collared caribou were not observed when they were within 500 meters of helicopters.

It can be concluded with some confidence that mountain caribou are more visible to pilots when in the open as opposed to within dense forest terrain. Since mountain caribou feed on arboreal tree lichen, they spend a large amount of time among dense trees where they are not easily detected by pilots, although their sightability in the late winter by biologists doing censuses is > 90% (Wittmer et al. 2005). The significant difference between actual and expected number of sightings based on the number of GPS locations within each habitat category also suggests that many animals were not detected when present. Many factors could be responsible for the failures to detect: snow and wind often limit visibility and require observers to have a greater vigilance for hazards, and pilots and guides are much more interested in conditions related to skiing and safety than caribou.

The responses made by caribou as observed by MWHS varied greatly. While on some occasions caribou continued to bed and did not appear to change behaviour in response to helicopters, on other occasions caribou fled and increased movement. As noted earlier, other studies also show varying responses of caribou towards aircrafts (Calef et al. 1976, Lawler et al. 2005, Reimers & Colman 2006). The variation among observations may be explained by a number of different factors. The age of the individual caribou might contribute to the response, as some caribou might have habituated to heli-skiing more than others. Additionally, some caribou might be more habituated to skiing than others, as some only cross ski zone boundaries from Wells Gray Provincial Park occasionally.

My results support the conclusion that mountain caribou reacted more severely when disturbed from the ground versus from above. It is probable that caribou associate ground disturbances with predation, but not aircraft disturbances. It could also reflect habituation to the common aircraft noise in the area. A study conducted on grizzly bears (*Ursus arctos*) in southeast British Columbia also found that bears responded more strongly to people on foot than to aircrafts (McLellan & Shackleton 1989). The study also found that grizzly bears in open habitats responded more to ground-based human activities than did bears in cover.

Similarly, caribou in my study area showed greater reactions to aircraft when in open than in forested areas. This could be due to the fact that they feel less protected when surprised within open terrain with less escape opportunities, and fleeing costs may be avoided if closer to refuge. A review of ungulate flight responses to human disturbances suggests ungulates perceive greater risk when disturbed in open habitats (Stankowich 2008). Increased flight initiation distances when farther from refuge has also been observed in a number of other species such as woodchucks (*Marmota monax*) and their distance from burrows (Bonenfant & Kramer 1996) and bighorn sheep (*Ovis canadensis*) and their distance from rocky slopes (Papouchis et al. 2001).

Caribou in the MWHS terrain did not react differently to the types of helicopters, likely because caribou have made similar experiences with all types of machines and therefore treat them equally. They also might have habituated to the noise level, since some caribou likely experience helicopter noise on a daily basis.

The fact that caribou did not respond more strongly towards heli-skiing within areas used more frequently is possibly because caribou located in these areas are used to encountering heli-skiing and may have become habituated. On one hand, it might be expected that caribou would respond more severely when disturbed in a frequently skied area. This could be because caribou may be more alert as they are often disturbed. If caribou have not been habituated in these areas to the noise level and skiing activities, then it could be the case that animals in these areas show increased readiness, as they are more frequently exposed to danger and may feel chronically stressed. As their energy budget would be lowered with increased flight responses to heli-skiing, less energy could be saved for flight responses to actual predators. If, however, caribou do become habituated to heli-skiing activities over time, the opposite may be the case. In areas skied frequently throughout the winter season, caribou may be more habituated and will react less as in areas where skiing is not as frequent. Based on the results presented here, the latter may be the case with this study herd.

Visible responses as those investigated here are, however, only one indicator of potential stress in caribou in response to heli-skiing. While immediate behavioural responses may indicate how animals react overtly, it does not necessarily give insight into physiological levels of stress. A stress hormone level analysis as the one conducted by Freeman (2008) would provide a more detailed look at how caribou respond physiologically to helicopter disturbance. In her study, both snowmobiling and heli-skiing resulted in elevated levels stress hormones in caribou. It is possible that while my study herd did not appear to react overtly to heli-skiing in 51 % of the occasions as observed by MWHS, stress hormone analyses could indicate levels of stress. If this was the case, effects on reproductive success (Roffe 1993; Russell et al. 1998) or elevated cardiac rates such as described by McArthur et al. (1982 on mountain sheep), could potentially be affected.

Cortisol or other stress-related hormones were not investigated for this study, and hence no conclusions can be drawn about whether mountain caribou have been physiologically stressed by heli-skiing or not. Indeed, half of the time caribou did show a reaction greater than ‘low’, so this possibility should be examined. Results of this study do indicate that caribou incur some costs from their reactions. It is, however, vital to acknowledge that stress should also be measured by more than visible reactions alone; hence further studies in this area determining stress hormones would be valuable.

REFERENCES

BC Ministries of Agriculture and Lands, Environment and Tourism, Sports and the Arts. 2005. Memorandum of Understanding regarding Management of Helicopter and Snow cat skiing in Mountain Caribou Habitat. British Columbia Helicopter and Snowcat Skiiing Operators Association (BCHSSOA).

Bergerud, A. 1974. Decline of caribou in North America following settlement. Journal of Wildlife Management. **38:** 757-770.

Best Practices for Sustainability Committee. 2003. Stewardship of Mountain Ecosystems. BC Helicopter and Snowcat Skiing Operators Association.

Bonefant, M., and D. Kramer. 1996. The influence of distance to burrow on flight initiation distance on the woodchuck, Marmota monax. Behavioural Ecology. **7:** 299-303.

Calef, G., DeBock, E., & Lortie, G. 1976. The reaction of barren-ground caribou to aircraft. Arctic. **29:** 201-212.

Cote, S. 1996. Mountain Goat response to helicopter disturbance. Wildlife Society Bulletin. **24:** 681-685.

Festa-Bianchet, M., Ray, J., Boutin, S., Cote, S., & Gunn, A. 2011. Conservation of caribou (Rangifer tarandus) in Canada: an uncertain future. Canadian Journal of Zoology , 89, 419-434.

Foster, B., and E. Rahs. Mountain Goat Response to Hydroelectric Exploration in Northwestern British Columbia. Environmental Management. **7:** 189-197

Freeman, N. 2008. Motorized Backcountry Recreation and Stress Response in Mountain Caribou (Rangifer tarandus caribou). Vancouver: University of British Columbia.

Frid, A. and L. Dill. 2002. Human-caused Disturbance Stimuli as a Form of Predation Risk. Conservation Ecology. **6**: 11-26.

Hamilton, D. and C. Pasztor. 2009. A Guide to Commercial Backcountry Skiing Standard Operating Practices for Ski Run Development, Helicopter Landing and Pickup Site Development, and Snow Trail Development in Mountain Caribou Habitat. Submitted to Species at Risk Coordination, Ministry of Environment, Victoria.

Harrington, F. H., and Veitch, A. M. 1991. Short-term Impacts of Low-level Jet Fighter Training on Caribou in Labrador. Arctic. **44:** 318-327.

Harrington, F., and Veitch, A. 1992. Calving Success of Woodland Caribou Exposed to Low-Level Jet Fighter Overflights. Arctic. **45:** 213-218.

Horejsi, B. 1981. Behavioural Response of Barren Ground Caribou to a Moving Vehicle. Arctic. **34:** 180-185.

Kunelius, R. 2009. Alerts and Closures- Procedures. (Mike Wiegele Heli-skiing Manual).

Lawler, J. P., Magoun, A. J., Seaton, T. C., Gardner, C. L., Boertje, R. D., Ver Hoef, J. M., and P.A. Del Vecchio. 2005. Short-term impacts of military overflights on caribou during calving season. Journal of Wildlife Management. **69:** 1133-1146.

Mahoney, S., Mawhinney, K., McCarthy, C., Anions, D., and S. Taylor. 2001. Caribou reactions to provocations by snowmachines in Newfoundland. Rangifer. **21:** 35-43.

MacArthur, R., Geist, V., and R. Johnston. 1982. Cardiac and Behavioral Responses of Mountain Sheep to Human Disturbance. Journal of Wildlife Management. **46:** 351-358.

McLellan, B. and D. Shackleton. 1989. Immediate Reactions of Grizzly Bears to Human Activities. Wildlife Society Bulletin. **17**: 269-274

Mc Lellan, B. 2008. person.comm. Mountain caribou capture and telemetry data from the Columbia Mountains Caribou Project. Kamloops, BC.

McLellan, B. person. comm. 2010.

Miller, F. L., and Gunn, A. 1979. Caribou and muskoxen response to helicopter harassment, Prince of Wales Island 1976-77. Edmonton: Canadian Wildlife Service.

Miller, F., and Gunn, A. 1981. Play by Peary caribou before, during and after helicopter harassment. Canadian Journal of Zoology. **59:** 823-827.

Mountain Caribou Technical Advisory Committee. 2002. A Strategy for the Recovery of Mountain Caribou in British Columbia. BC Ministry of Water, Land and Air Protection. Victoria, BC.

Papouchis, C., Singer, F., and W. Sloan. 2001. Responses of desert bighorn sheep to increased human recreation. Journal of Wildlife Management. **65**: 573-582.

Penner, D. 1988. Behavioural Response and Habituation of Mountain Goats in Relation to Petroleum Exploration at Pinto Creek, Alberta. Biann. Symp. North. Wild Sheep and Goat Council. **6:** 141-158

Peucker, T., Fowler, R., Little, J., and D. Mark. 1977. Digital Representation of Three dimensional surfaces by triangulated irregular networks (TIN). Department of Geography. Burnaby, BC: Simon Fraser University.

Reimers, E., and J. Colman. 2006. Reindeer and caribou (Rangifer tarandus) response to human activities. Rangifer. **26:** 55-71.

Reimers, E., Eftestol, S., and J. Colman. 2003. Behaviour Responses of Wild Reindeer to direct Provocation by a Snowmobile or Skier. Journal of Wildlife Management. **67:** 747 754.

Roffe, T. 1993. Peri-natal mortality in caribou from the porcupine herd, Alaska. Journal of Wildlife Diseases. **29:** 295-303.

Russell, D., Gerhart, K., White, R., and D. Van de Wetering. 1998. Detection of early pregnancy in caribou: Evidence for embryonic mortality. Journal of Wildlife Management. **62:** 1066-1075.

Safford, K. 2004. Modelling critical winter habitat of four ungulate species in the Robson Valley, British Columbia. BC Journal of Ecosystems and Management. **4:** 1-13.

Simpson, K., and Terry, E. 2000. Impacts of Backcountry Recreation Activities on Mountain Caribou. Ministry of Environment, Lands, and Parks.

Stankowich, T. 2008. Ungulate flight response to human disturbance. A review and meta-analysis. Biological Conservation. **141:** 2159-2173.

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

Wolfe, S., Griffith, B., and C. Wolfe. 2000. Response of reindeer and caribou to human activities. Polar research. **19:** 63-73.

CHAPTER 4. AN ANALYSIS OF SPATIAL EFFECTS OF HELI-SKIING ON MOUNTAIN CARIBOU

INTRODUCTION

For over 25 years, mountain caribou (*Rangifer tarandus caribou*) populations have declined across their range (Van Oort et al. 2011). Caribou have been extirpated from much of their historical range, making it crucial for conservation purposes to determine what drives their movements. Habitat loss and alterations have been attributed as a major factor resulting in large-scale habitat displacement. How disturbances associated with winter backcountry recreational activities have affected mountain caribou is less well understood, particularly as it may involve heli-skiing. While a number of reports have identified the potential of displacement associated with heli-skiing (Simpson &Terry 2000, Brade 2003, Cichowski et al. 2004, Mountain Caribou Science Team 2005, Hamilton & Pasztor 2009), there is a lack of studies focused on this specific topic. Because displacement due to disturbance could result in energetic costs as well as limiting animals' access to critical food resources, studying the spatial relationship between mountain caribou and heli-skiing may lead to a better understanding of some of the underlying factors causing their continued decline.

The purpose of this chapter was therefore to determine whether heli-skiing disturbances have caused recent (<10 yrs) displacement of mountain caribou. A variety of GIS analyses were performed to investigate the spatial relationship between skiing and GPS-collared caribou in the area.

Natural Movement Patterns in Mountain Caribou

As a central part of habitat selection, food availability naturally drives daily movement of caribou (Apps & Kinley 2000, Terry et al. 1996). During summer, mountain caribou feed on a variety of grasses, forbs and shrubs, that are abundant and accessible (Seip 1990).

As mountain caribou focus their winter diet primarily on arboreal lichen, they need access to areas that provide sufficient old growth trees. Much of this winter diet is becoming less abundant, and so caribou have been forced to abandon areas in which they used to feed, in search for other food sources. Both natural (e.g. wildfire) and anthropogenic (e.g. logging, agriculture, urbanization) factors have contributed to large-scale loss of old-growth trees across much of the species' range (Franklin et al. 2002, Apps & McLellan 2006). Young forest stands do not provide caribou with the amount of lichen they need to sustain through winter.

One study conducted in Newfoundland during the early 1990s supports the conclusion that woodland caribou generally avoid clearcuts. The study found that some woodland caribou abandoned areas in response to nearby clear-cutting (Chubbs et al. 1992). Of 35 caribou studied, 15 individuals were found to maintain greater distances from clearcut areas than they did before cutting took place.

Habitat fragmentation, the disruption of a continuous area of one kind of vegetation into smaller subunits (Lord & Norton 1990) has likely contributed greatly to suitable caribou habitat becoming less abundant. Fragmentation of habitat can also result in a separation of herds, when distances between suitable patches become too great. In fact, herds of mountain caribou in British Columbia only show very limited mixing (Wittmer et al. 2005).

Habitat fragmentation can also potentially affect predator-prey systems by increasing habitat quality for other ungulate species and therefore increasing the number of predators (Seip 1992). This can result in a higher predation rates on caribou. Predator avoidance is an important behavioural trait. Besides lichen availability, an important attribute of old-growth forest is that they generally have a smaller number of elk, moose and deer to support predators (Cichowski et al. 2004), so the loss of old-growth forest mixes predators with caribou.

Backcountry recreation activities such as heli-skiing require a vast terrain in high alpine areas essential to caribou, and thus also have the potential to impact habitat use of caribou (Simpson & Terry 2000, Mountain Caribou Technical Advisory Committee 2002, Brade 2003, Wilson & Hamilton 2003, Mountain Caribou Science Team 2005). Elevated movement due to heli-skiing disturbances is possible, and, as described in Chapter 1, may result in higher energy expenditures. However, while short-term responses of mountain caribou towards heli-skiing might affect their health, an important question is also whether heli-skiing displaces mountain caribou from preferred habitat. Such disturbance might effectively lower the quality of an otherwise suitable piece of habitat. Studies that have tested whether displacement of mountain caribou in response to heli-skiing occurs on a large-scale are lacking (Simpson & Terry 2000). Many studies have, however, focused on other disturbances and the geographic responses of mountain caribou, as well as on those of related species.

Geographic Responses of Mountain Caribou to Human Disturbances

Research on long-term spatial effects of human disturbances on caribou has produced varying results, and therefore conclusions are often contradictory. Some studies have focused on impermanent human disturbances, while others have paid more attention to the impact of permanent anthropogenic features on caribou. Studies related to permanent structures and their impact on caribou movement are more common.

In northeastern Alberta, a GIS crossing analysis was used to investigate whether roads and seismic lines act as barriers to movement of woodland caribou (Dyer et al. 2002). Rates of caribou crossings were compared between areas with actual roads and seismic lines, and areas with simulated roads. The 36 collared woodland caribou tested during 12 months revealed that seismic lines were not barriers, while roads with moderate traffic volumes did act as a barrier, especially during later winter when traffic was more frequent.

Similar findings resulted from a study conducted on mountain caribou in west-central Alberta (Oberg 2001). Distance buffers and compositional analysis were used to relate GPS telemetry data from two winters (1998-2000) to these linear features. The study found no significant avoidance to seismic lines, but indicated that caribou avoid streams to a maximum distance of 250 m, and roads to a maximum distance of 500 m.

A study conducted on wild reindeer (*Rangifer tarandus*) in southcentral Norway found no direct barrier or aversion effects caused by a power line transecting their range (Reimers et al. 2007). Aerial and ground observations made over 22 years showed that reindeer crossed and grazed underneath the power line. These results contrast with other studies conducted on reindeer responses to similar power lines. One such study was also carried out in southcentral Norway, and used lichen biomass as an indicator of reindeer use near roads and power lines (Vistnes et al. 2004). The researchers found that reindeer did graze on both sides of a winter-closed road, but another winter-closed road in combination with two parallel roads resulted in less migration and different grazing patterns. These results were consistent over more than 20 years for three different study herds.

Differences among studies on permanent structure effects may be due to other confounding factors that contribute to daily reindeer movement, such as natural risk factors or surrounding habitat quality. Nevertheless, it seems that permanent structures have the potential to cause habitat avoidance in reindeer. No study has documented whether heli-ski runs are a potential barrier to caribou movement. Heli-ski runs are not man-made structures like roads, and do not exhibit the same kind of traffic volumes. Therefore, it is unlikely that ski runs act as a movement barrier. Further, it has also been documented that linear developments such as oil pipeline right of ways might actually enhance caribou habitat by providing an easy way of travelling and movement corridor (Eccles & Duncan 1986). Thus, it is possible that mountain caribou could use heli-ski runs as movement corridors, but this remains to be tested. However, the same might be the case for predators, as ski runs may allow for easier movements for some predators that are able to reach higher elevations in winter.

Studies on the spatial effects of transitory disturbances associated with snowmobiling and heli-skiing activities are also somewhat limited. The former has received more attention, since snowmobiles directly disturb caribou and also provide increased access into high elevations, thus increasing the likelihood of predators reaching high elevations by using snowmobile tracks as movement corridors. Therefore, snowmobiling has the potential to displace mountain caribou from habitat, if disturbances are frequent and if predation risk is increased.

Seip et al. (2007) compared six different census blocks near Prince George, BC to determine whether caribou have been potentially displaced due to snowmobiling activity (Seip et al. 2007). Three years of data revealed that significant numbers of caribou were found on all five census blocks with no or low snowmobiling. However, no caribou were found on the sixth census block, which experienced intensive snowmobiling activities. A Resource Selection Function (RSF) showed that the census block contained high quality habitat and should have supported approximately 75 caribou. Hence, the study concluded that the intense snowmobiling had caused complete displacement of caribou from suitable habitat, and suggested that snowmobiling should be restricted in high quality mountain caribou winter habitat.

Other studies have also found displacement of mountain caribou from snowmobile activities. Simpson (1987) assessed the effects of snowmobiling for a herd of mountain caribou near Revelstoke, BC from 1981 to 1985. He compared caribou habitat use and movements between areas with varying snowmobile use, and found that caribou avoid high use snowmobile areas, and snowmobile closures allowed animals to remain in certain areas. He proposed that caribou avoid high snowmobile use areas based on whether human scent was present, and on the speed and number of snowmobiles. Simpson concluded that caribou might be able to tolerate low uses of snowmobiling in this area, and pointed out that unless activities increase too rapidly, caribou are able to habituate to snowmobiling.

McLellan (2007) examined how caribou use of winter ranges relates to snowmobiling activity in the interior wet-belt mountains of BC. Using telemetry and census data collected over nearly ten years, caribou habitat use was assessed. One prediction, stating that as snowmobiling activity levels increase over time, the proportion of time caribou spent in these areas would decline was not supported. Another prediction, stating that caribou would be located farther from the trailhead in snowmobiling areas as compared to random locations was supported by the majority of study blocks. The last prediction stated that caribou would use areas with snowmobiling less during times and weekdays when activities were highest. This was not supported by the data. While the study shows some displacement over time, it reveals a more complex relationship between caribou habitat use and snowmobiles as suggested by earlier studies.

Spatial responses of mountain caribou towards skiers on the ground have not received as much attention. However, some studies conducted on other ungulates indicate that the potential for displacement by skiers exists. Cassirer et al. (1992) noted that elk moved uphill, to steeper slopes and closer to trees in response to cross-country skiing in Yellowstone National Park. The displacement of 15 elk studied during 1987 and 1988 was usually temporary, and elk returned to the same area shortly after skiers had left. A study conducted in Alberta indicated that cross-country skiing caused elk and moose to move away from trails that experienced high levels of skiing, but displacement did not increase with more skiers (Ferguson et al. 1982). Heli-skiers may have a similar short-term effect on mountain caribou; however, heli-skiing also poses an additional risk of displacement through helicopter disturbance.

Spatial responses of mountain caribou towards aircraft and ground disturbance associated with heli-skiing have not been clearly documented, but likely vary among herds due to their different historical exposure and terrain. Some herds may have habituated to heli-skiing, while others may not have had a chance to adapt yet. Potential habituation towards low-flying aircraft has been suggested in other ungulate species such as the desert mule deer. A study conducted in an area in south-central Arizona where aircrafts traffic is frequent revealed that mule deer did not change habitat in as a result of aircraft overflights for 97 % of the observations made from the ground (Krausman et al. 1986). The height of the aircraft was also not a factor of displacement for the 22 deer studied over a period of 5 months.

My study presented an opportunity to study the spatial relationship between a caribou herd and heli-skiing activities in the area. Mike Wiegele Heli-Skiing (MWHS) in Blue River, BC provided heli-skiing data for the past 10 years. These were combined with existing GPS collar information for the same area and time period, as collected by the Columbia Mountains Caribou Project (McLellan pers.comm. 2008). These data contained over 14,000 GPS telemetry locations for winter months (December to April) from 1996 to 2007 for 23 female caribou. More details on the GPS capture and telemetry dataset can be found in Chapter 2. These kinds of data have never been analysed in combination in this matter, and can potentially give insight into some of the unanswered questions regarding spatial interactions that take place between caribou and heli-skiing.

In this portion of my study, I had three main objectives. The first was to determine at a large geographic scale whether caribou were absent from otherwise suitable habitat near ski runs. To investigate this, I examined the frequency with which caribou were located within close proximity to ski runs. If caribou have been displaced, I expected they would have used areas less often than expected on the basis of habitat availability.

The second objective was to determine whether mountain caribou kept larger distances from ski runs that were skied more frequently. This analysis takes into account that not all ski runs are skied equally as often throughout a ski season, and provides a finer scale look at how caribou in the area responded spatially to heli-skiing activities. If caribou have been displaced by heli-skiing, I expected they would keep greater distances from ski runs used more frequently.

Finally, the third objective was to determine whether mountain caribou were more mobile within areas skied frequently. To examine this, movement rates of caribou located within areas skied frequently were compared to movement rates of caribou located within areas not skied. If caribou were disturbed by heli-skiing, I expected they would have greater movement rates in skied areas.

METHODS

Suitable Habitat Analysis

In order to test whether animals have been displaced from suitable habitat by skiing, I took advantage of an independent classification that was carried out by the BC Ministry of Environment (Surgenor person. comm. 2010). Late winter habitat was deemed suitable for this model if it was at an elevation of 1750-2100m, trees in the area were older than 140 years, and slopes were below 60%. More detail about the habitat suitability model used can be found in Chapter 2.

For this test, MWHS ski terrain zones, all 825 ski runs, and caribou locations (from 1992 to 2006) were simultaneously displayed (Figure 4.1). Locations for 14 animals for which a sufficient number of GPS locations existed were used, and GPS locations for caribou which were not found inside of MWHS ski terrain were eliminated.

In an attempt to remove the bias that could arise from a lack of independence among data points from the same animal, only one GPS location per day was used for each animal within MWHS terrain. To attempt to further avoid systematic bias, a random location was selected for each individual caribou per day.

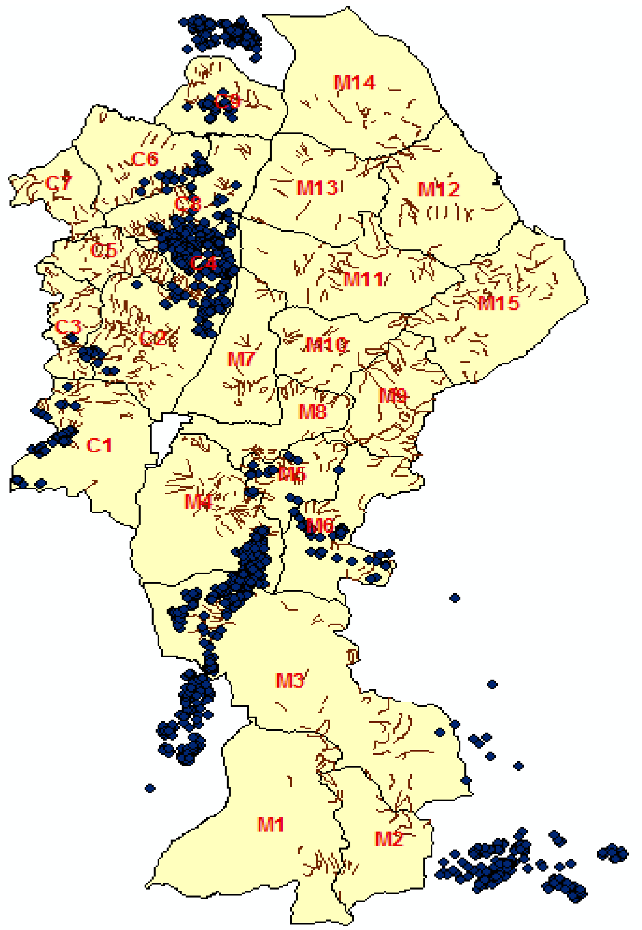


Figure 4.1 GPS locations for 14 caribou, used for suitable habitat analysis. Labels represent MWHS ski zones (C1-9 for Cariboo mountains, M1-15 for Monashee mountains) (Source: composite of MWHS and MoE)

A surrounding circular ‘buffer’ of 500 meters was then used around all ski runs as an inclusive “impact zone”. This zone accounts for the fact that caribou can be affected by the skiers on the ground close to a run, as well as the close noise of helicopters.

The late winter caribou habitat suitability model provided by the Ministry of Environment (as described in Chapter 1) was used to map suitable habitat patches as an overlay to the map layers showing ski runs (with 500 meter impact zone) and caribou locations. This allowed visualization of the areas suitable for caribou within and also outside of skiing impact zones (Figure 4.2).

The actual number of GPS locations located in suitable habitat patches was calculated for areas inside the impact zones as well as outside using appropriate GIS attribute tables (Figure 4.3).

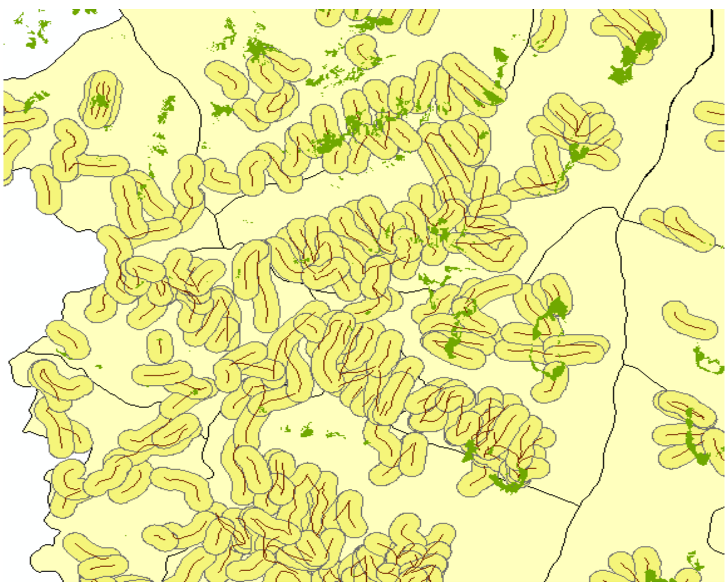


Figure 4.2 Display of suitable caribou habitat (green) in combination with heli-ski runs and surrounding impact zones (yellow).

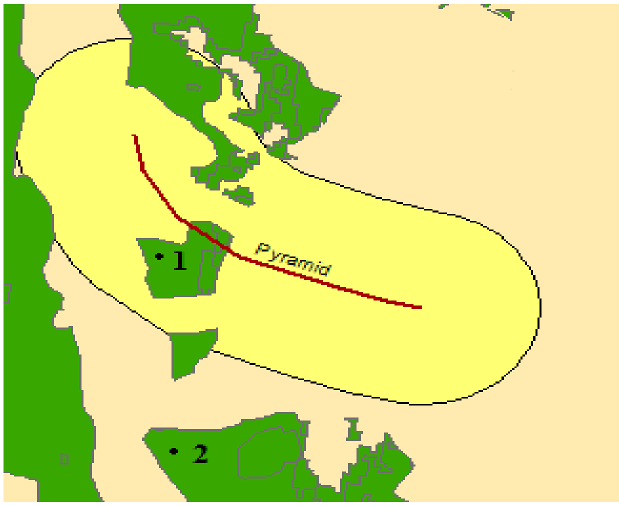
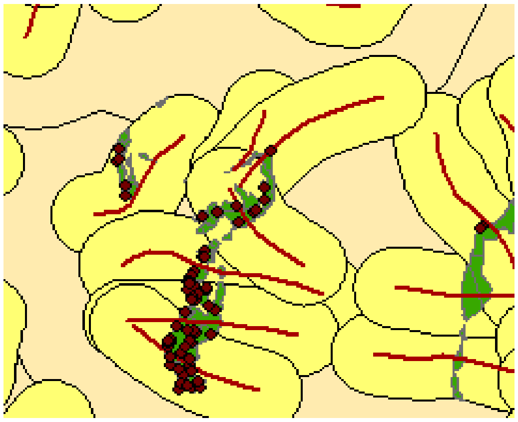


Figure 4.3 Display of suitable habitat use comparison. GPS locations within MWHS skiing impact zones (1) and outside (2) were counted.

Figure 4.4 below depicts the comparison between GPS locations found inside suitable habitat patches. The locations found within skiing impact zones and outside of skiing impact zones were totalled.

1) Inside zone & inside suitable habitat



2) Outside zone & inside suitable habitat

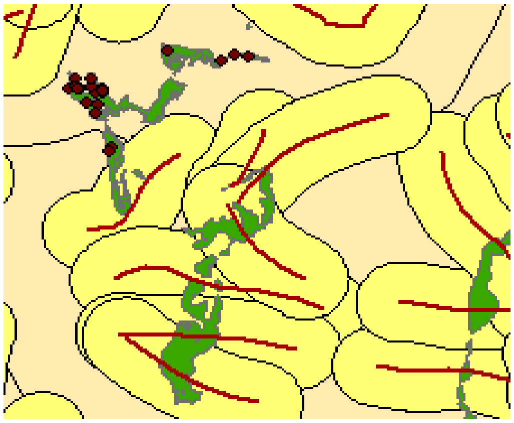


Figure 4.4 GPS data points within skiing impact zones and outside impact zones shown separately, used to determine the number of GPS locations within each.

Next, expected numbers of GPS locations for both inside and outside of impact zones were calculated using querying tools and creating separate shapefiles with ArcMap 9.3. To calculate the area of suitable habitat outside the impact zones, the area of suitable habitat inside the zones was subtracted from the total area of suitable habitat.

Based on these areas, the percent of area of the total MWHS ski terrain area was calculated. This percentage was then applied to the percentage of the total amount of GPS locations examined. Actual and expected numbers of GPS locations within inside and outside of the zones were then compared.

Distance Analysis

In order to limit any annual differences, only one year, 2003, was used for this analysis. Since a sufficient amount of skiing took place and the largest number of caribou were collared (n=21) during 2003, this provided the largest dataset for this analysis. All 825 ski runs were assigned into one of three categories, based on usage during the ski season of 2003 (Dec 2002-April 2003).

Instead of using only one impact zone of 500m as in the previous analysis, multiple distance zones were created for each of the 825 ski runs. Thus it was possible to determine if there was a relationship between the skiing intensity level of the ski runs (none, low, med, and high) and the distance zone occupied by caribou. A total of six distance zones were created and displayed for each ski run (250m, 500m, 750m, 1000m, 1250m, and 1500m, as seen in Figure 4.5).

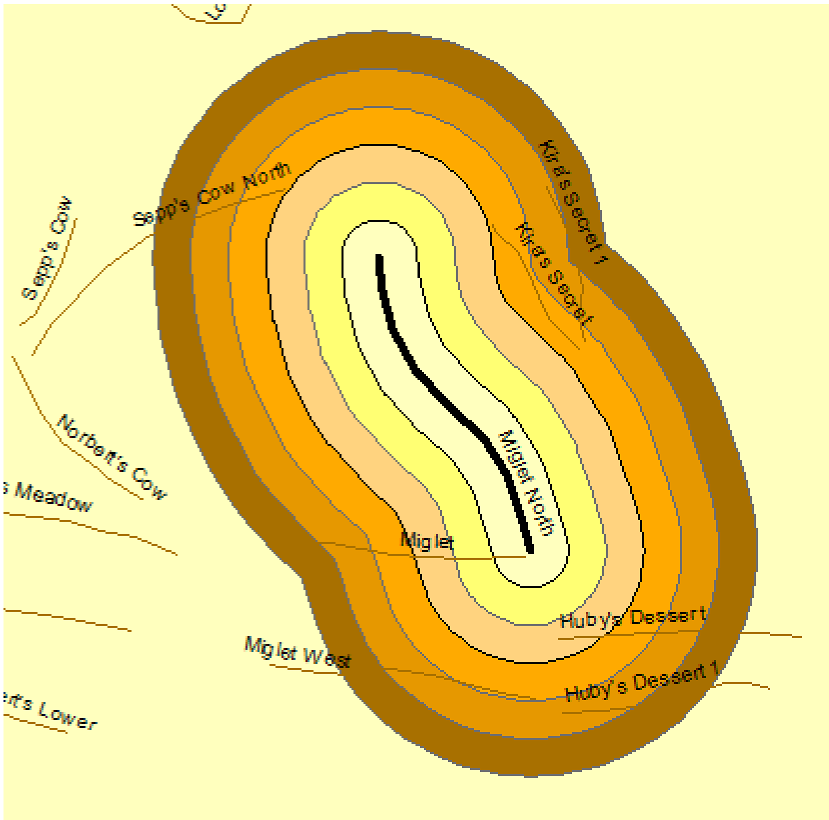


Figure 4.5 Example display of six distance zones in 250 m intervals around one ski run (Miglet North).

The number of GPS caribou locations summarized from the year 2003 was then displayed. The number of GPS locations within each distance zone, for each skiing level, was then counted.

Since many ski runs are located closer than 1.5 km from other runs, some impact zones overlapped. That is, what point located in a 1000 m impact zone for one run could also be in a 500 m zone for a different one. To ensure that GPS location points were not counted twice in this analysis, a process of elimination had to be employed. If a point fell within two impact zones, the point was counted for the ski run that was more frequently skied.

Actual number of GPS locations within each distance zone was then compared with an expected number, which was obtained from a Chi-Square test (based on how often each category occurred).

Movement Rate Analysis

To determine whether caribou were more mobile within areas skied frequently, movement rates of individual caribou were compared. First, distances between consecutive GPS location data points were determined, and a total distance per day was recorded for individual caribou for winter seasons of all years it was collared (total dataset 1996 to 2007). Next, a daily movement rate was calculated by dividing the total daily distance by the total number of hours for which collar information existed each day (see example in Figure 4.6 below). This daily rate would presumably standardize for different periods of time between consecutive locations.

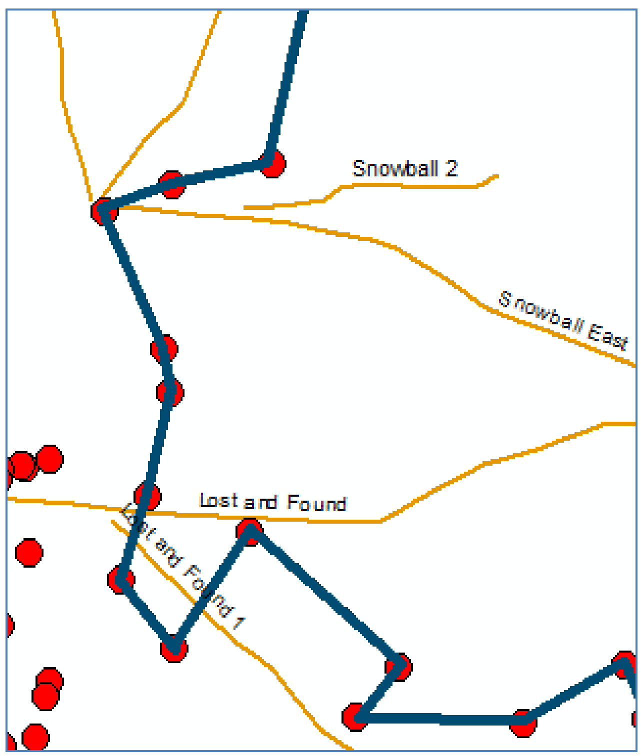


Figure 4.6 Example display of connecting consecutive GPS location points of one caribou collared, to measure daily distance travelled. Labelled lines represent ski runs and names.

For caribou located within MWHS ski terrain, each day was analysed to determine whether the GPS locations were close to an area with no, low-moderate, or high heli-ski use. This was done by applying the previously used method of assigning heli runs with one of the categories based on the collaring year's ski usage. Each heli run was surrounded by a 500-meter impact zone, and caribou locations falling within that zone were considered to be close to a run with the according ski run usage.

Since there were several locations on one day for each animal, a distinction process had to be employed in order to assign all locations of one day to a single heli run usage category. I assigned the highest ski run usage close to locations for each day. Therefore, if one of multiple locations for an animal was within 500 meters of a highly skied run on a certain day, that day was categorized as a "high". If one of muliple locations for an animal were not within 500 meters of a highly skied run but a low-moderate run I assigned a "low-moderate" and similarly for no use.

For this analysis, only GPS locations of caribou that were within each of the three categories of skiing intensity zones at some point during the winter season collaring time span were used. The locations of a number of caribou were located only within one category of skiing area (i.e. only within highly skied, or only within never skied etc.), and those caribou were not considered for this analysis.

A total of 4 caribou were within each kind of skiing area in MWHS terrain and represented the animals used to analyse movement rates in habitat exposed to skiing. All GPS locations outside of the MWHS ski terrain, mainly located within Wells Gray Provincial Park were assigned an automatic "no skiing" since no heli-skiing took place in these areas at any point of time during which the caribou were collared. A total of 8 animals provided sufficient data for Wells Gray Provincial Park and represented the animals used to analyse movement rates in habitat not exposed to skiing.

Several different analyses of variance were conducted to compare movement rates of individual caribou under different conditions. An analysis of variance was used to determine whether, within MWHS terrain, movement rates would differ among individual caribou located in areas with high, moderate and low frequencies of skiing activities. I used R statistical software (version 2.3) for these analyses.

Additional Analyses of Variance were then performed to test if any differences existed among different animals within MWHS terrain regardless of skiing activities. The same was done for caribou outside of the MWHS terrain, to determine whether movement rate differences existed on an individual animal basis, disregarding any skiing factor. At large spatial scale, the degree of movement might be affected at the whole landscape level. To test this, Wells Gray Provincial Park animals were compared with animals within the MWHS terrain to see if their movement rates differed.

RESULTS

Suitable Habitat Analysis

The actual percentage of GPS locations within suitable areas of the impact zones was statistically significant more than expected ($G=10.3$, $df=1$, $p<0.01$; Table 4.1).

Table 4.1 Actual vs. Expected number of GPS locations within suitable habitat inside and outside of skiing impact zones

	Inside zone & suitable	Outside zone & suitable	Total
Area (ha)	9381	14996	24377
% of total area	38.48 %	61.52 %	100 %
Actual # of locations	74	70	144
% of actual locations	51.39 %	48.61 %	100 %
Expected # of locations	55	89	144
% of expected locations	38.48 %	61.52 %	100%

Distance Analysis

There was no significant difference between the distances measured from caribou to ski runs depending on the skiing level (G=14.8, df=10, p>0.10; Table 4.2, Power= 1.0). There appears to be a slight trend towards keeping a greater distance with increasing skiing intensity level. Generally, proportionally larger numbers of caribou locations occurred in the ski zones with greater usage.

Table 4.2 Number of GPS locations within different impact zones as related to general skiing level of the area (expected numbers in italic)

Skiing 2003/04	250 m zone	500 m zone	750 m zone	1000m zone	1250 m zone	1500 m zone	Total
none	18 *(14.75)*	21 *(13.67)*	16 *(20.15)*	10 *(16.19)*	16 *(17.99)*	23 *(21.23)*	104
low/med	12 *(12.63)*	9 *(11.70)*	20 *(17.24)*	17 *(13.86)*	17 *(15.40)*	14 *(18.17)*	89
high	11 *(13.62)*	8 *(12.62)*	20 *(18.60)*	18 *(14.95)*	17 *(16.61)*	22 *(19.60)*	96
Total	41	38	56	45	50	59	289

Movement Rate Analysis

Figure 4.7 shows the general movement patterns of the four animals within MWHS ski area. Most often, movement rates were relatively low ($\bar{x}$ =105 m/hr, SD=108.9). However, animals also showed periodic rapid movements (max. 834 m/hr), as can be seen by the outliers in Figure 4.7. Although mean rates of movement were similar, some animals displayed much greater variability in their movements ($F_{3,498}$= 8.71, p<0.001).

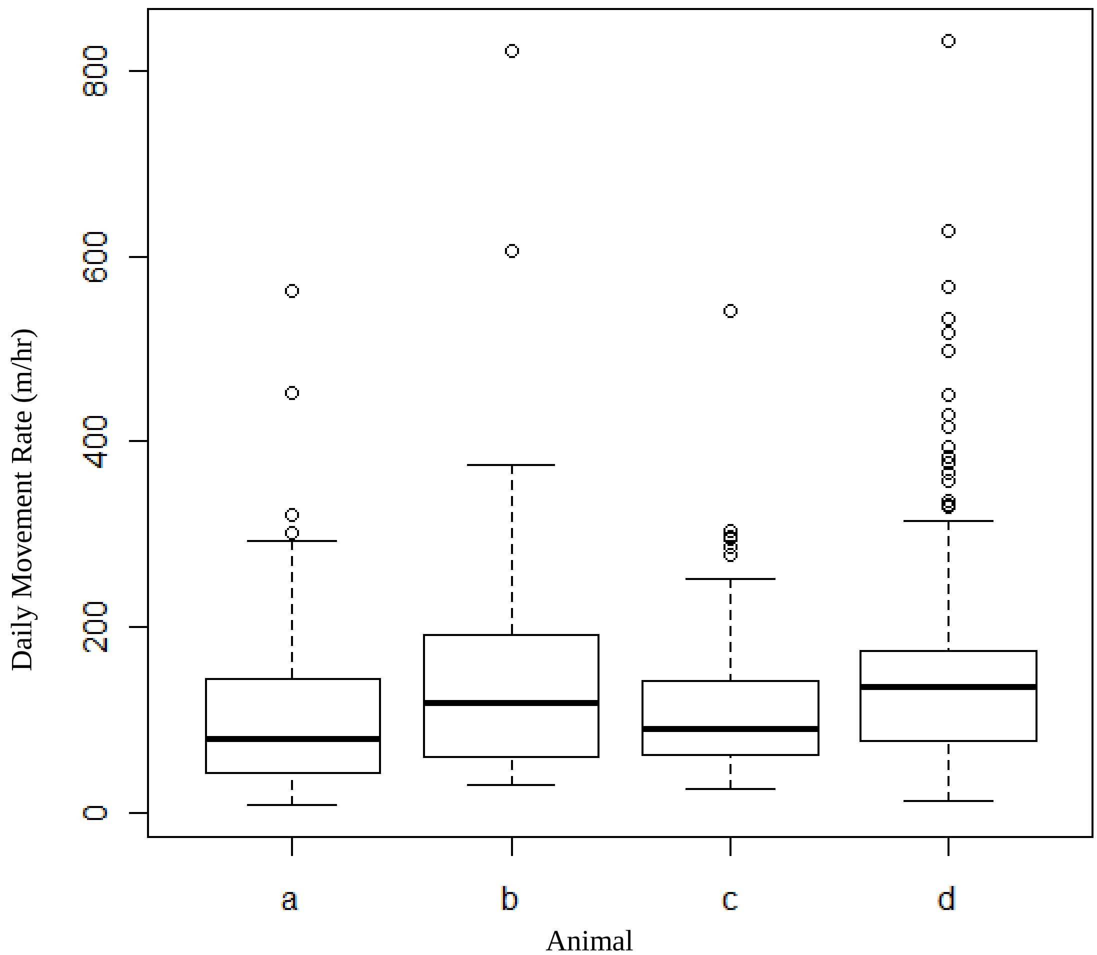


Figure 4.7 Comparison of daily movement rates among 4 different caribou within MWHS ski terrain between 1996 and 2007. (Thick black line=Median, Box=25^{th}&75^{th} quartiles, Whiskers=range, and Circles=outliers, defined as equal to or greater than the 75^{th} quartile plus 1.5 * interquartile range).

One animal was located in a different watershed, and the other three were located in the same area during the period when they were collared. However, if the one animal from the different watershed was left out of the analysis, the difference among individuals still existed ($F_{2,289}$=6.21, P<0.01). Overall, movement rates of animals within MWHS ski zones were related to skiing intensity levels ($F_{2,3}$=6.12,P<0.003). However, results differed significantly among animals. Of the four animals within MWHS ski zones, caribou c showed increased movement within highly skied areas ($F_{2,168}$=11.24, P<0.001), while caribou b did not show increased movement with higher skiing levels ($F_{2,50}$=1.57, p>0.1).

Caribou a showed marginally increased movement with more skiing activities ($F_{2,63}$=3.98, P>0.02), and caribou d showed increased movement with low skiing intensities ($F_{2,218}$=3.32, P>0.03).

A two-way ANOVA showed no significant effect of landscape on individual movements. When combining all MWHS animals to be within a `skied landscape` and combining all WG animals to be within a `not skied landscape`, there was no significant difference in the degree of movement (Landscape= $F_{1,11}$=0.93,P>0.3, Power=0.99, Figure 4.8). Within Wells Gray Provincial Park, there was in fact somewhat greater differences in movement rates ($\bar{x}$=124 m/hr, SD=135.3) than in MWHS terrain ($\bar{x}$=105 m/hr, SD=108.9).

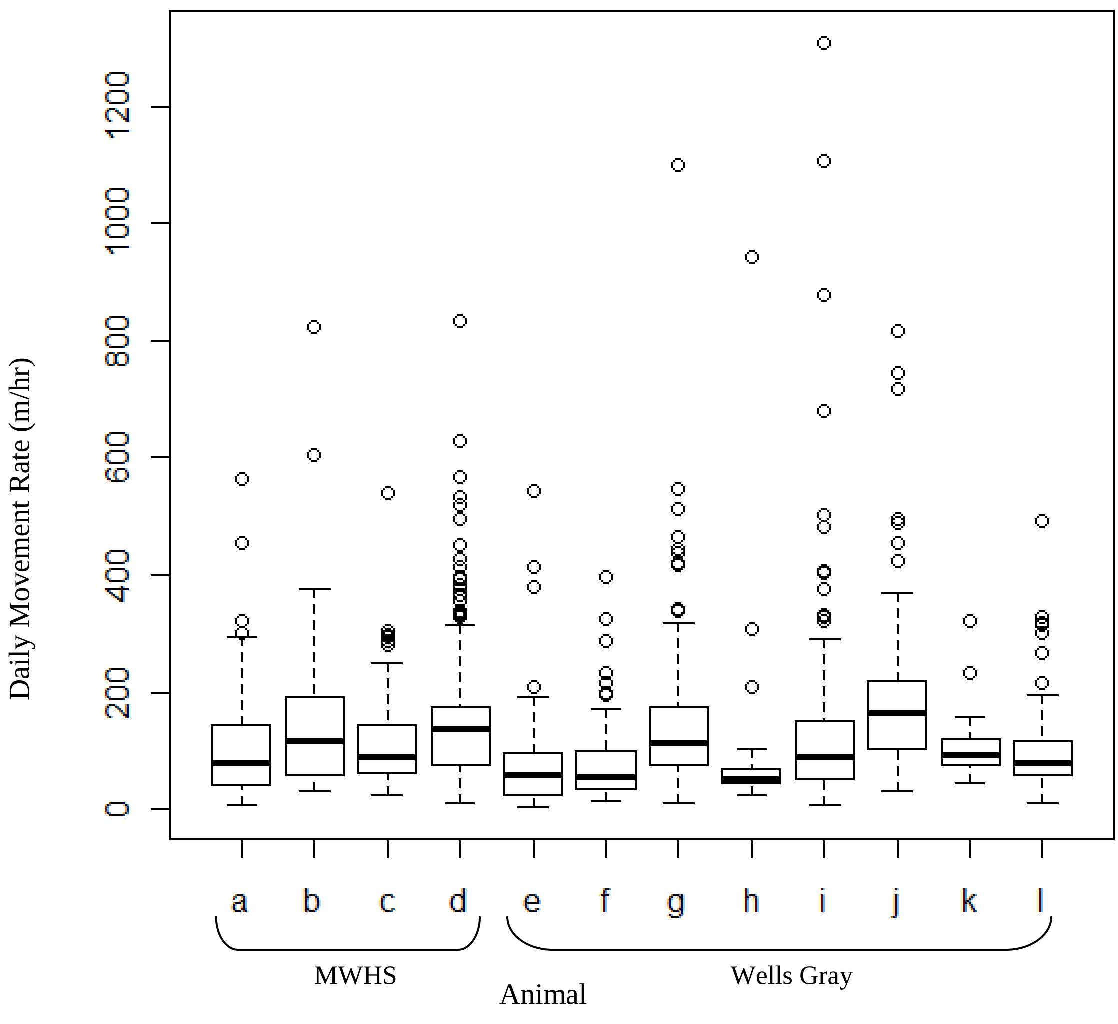


Figure 4.8 Entire sample comparisons of daily movement rates among different caribou within MW ski terrain and WG terrain between 1996 and 2007.

An Analysis of Variance with month added as a variable (December-April) showed that seasonality did not have an effect on the daily movement rate for animals in skiing terrain ($F_{2,4}$=2.20, P>0.06, Power=0.76).

DISCUSSION

The analyses performed here to investigate possible spatial effects of heli-skiing on mountain caribou gave consistent results across several variables and different spatial scales. Despite considerable limitation in the number of data points, each analysis suggests that mountain caribou of this area were not displaced by heli-skiing activities over three successive winters.

The results of the suitable habitat analysis indicate that mountain caribou did not refrain from using suitable habitat near heli-ski runs. Based on the size of the immediate area surrounding ski runs and the number of caribou locations found in various distance zones, caribou were not found significantly less than expected near ski runs.

The analysis of the occurrence of caribou near ski runs suggests that caribou have not moved away completely from suitable habitat surrounding ski runs. While it may be possible that these remaining caribou were temporarily displaced from ski runs while a disturbance takes place, and for some amount of time after, it appears that all caribou do not completely abandon areas. As such, these caribou do not lose the access and ability to forage in areas surrounding ski runs. This contrasts with the complete abandonment of caribou from a mountain block found in response to intensive snowmobiling in Prince George (Seip et al. 2007). If good quality habitat is not avoided near ski runs, habitat choice may be of greater importance than disturbance avoidance. This behaviour might be a form of trade-off (Gill et al. 1996) made to obtain sufficient lichen sources; however, caribou might also be simply attracted to similar habitat features. It also needs to be pointed out that habitat suitability was judged mainly by foraging opportunities and no conclusion can be made on whether caribou displaced from good escape terrain, for example.

The multiple buffer analysis indicated that, when skiing intensities of individual ski runs were factored in, no significant relationship between the distance from ski runs and skiing intensity existed. Hence, caribou did not appear to be displaced by increased levels of skiing in an area. This supports what was found for the first analysis, since caribou apparently used habitat near ski runs, no matter how close or far it was from a frequently used run. The results of this analysis contrast with what was found in the study conducted near Revelstoke, BC on the habitat use and movements of caribou in areas with varying snowmobile use (Simpson 1987). Simpson's study concluded that caribou avoid high snowmobile use areas. Since similar parameters were used in this study, similar results might have been expected. However, avoidance behaviour such as noted in Simpson's study was not found in these analyses.

One explanation for the difference in the spatial responses of caribou might be that caribou do not react to helicopters in the same manner they do to snowmobiles. This may be because their natural predators approach from the ground, as snowmobilers do. Helicopters, on the other hand, may not represent as much of danger to caribou (McLellan pers.comm. 2010). Also, snowmobile use within some areas may be more frequent as opposed to heli-skiing that usually takes place in different areas during a week, as guides change ski terrain with different ski groups. . In my study area, if caribou were displaced by heliskiing, they would likely have to move to areas with intensive snowmobiling, because except for Wells Gray Park, suitable late winter caribou habitat has either one or both of these motorized recreational actives.

The distance analysis indicated that daily movement rates differed significantly among individual animals, with some animals showing higher movement rates with more frequent skiing and some animals with lower movement rates. On a landscape level, with Wells Gray Provincial Park as a "control" with no heli-skiing present, movement rates were similar. Seasonality effects do not seem to be the cause of differences among movement rates. Factors which might explain why some individual caribou seemed to move more in highly skied terrain while others did not might include natural risk factors, or age effects.

Likely, movement rates were highly variable due to snow conditions and food availability. It is probable that caribou move great distances to reach lichen-bearing trees, eat and rest. If snow conditions do not allow for easy movement, daily movement rates will also be lower. Additionally, some predation risk and avalanche risks might explain some of the sporadic great distances moved by caribou on certain days. These factors were not measured for this project, as the main goal was to determine the influence of heli-skiing. The last test demonstrated that heli-skiing had a significant effect on daily movement rates on some caribou and not on others, but on a landscape level, this effect was non-significant.

The non-existent landscape effect may be more important for understanding the spatial patterns of apparent coexistence because it suggests that caribou generally do not respond with greater movement towards disturbances caused by heli-skiing. If this was the case, it would be expected that movement rates would be higher in areas skied heavily. Nevertheless, the last analysis only represents a general view of movement rates in areas skied less and more frequently. It is possible that caribou with low movement rates in frequently skied areas where not there while skiing occurred. The test does not show whether caribou momentarily increase movement rates when being disturbed.

A more detailed look at movement rates of individuals before, during and after a heli-skiing disturbance would provide more precise results. If caribou were to be collared in this area in the future, this sort of test would be highly valuable.

In general, my results contrast with those of other studies that found acute disturbances (such as snowmobiling) cause long-term habitat displacement (Seip et al. 2007, Simpson 1987). However, no study relating heli-skiing to habitat displacement of mountain caribou exists for comparison. It seems my results may be more consistent with results found for studies conducted on other ungulate. One such study concluded that skiers on the ground may have temporarily displaced elk, but animals returned to the same area soon after skiers had left (Cassirer et al. 1992). Heli-skiing in Blue River, BC may have temporarily displaced mountain caribou as mentioned in Chapter 3, but this could not be concluded from the data available for my study. My results show that during three consecutive winter seasons, no long-term, large-scale habitat abandonment occurred in response to heli-skiing in this area during three consecutive winter seasons. This was expected because the area has had heli-skiing for more than 40 years and caribou have been present.

Since there has been heli-skiing in the Blue River area for many decades, habituation is one explanation for the fact that animals have not abandoned their range. This would be consistent with mule deer in Arizona which likely habituated towards continued exposure of low-flying aircrafts (Krausman et al. 1986). Animals available to be caught in the skiing area had been exposed to heli-skiing for generations. If there was an initial impact that displaced caribou, it would likely have been decades ago. If there is a continued impact by skiing, it will likely be expressed by the behavioural response and probable short-term displacement noted in Chapter 3 as well as increased chronic stress levels (Freeman 2008).

REFERENCES

Apps, C. and T. Kinley. 2000. Mountain Caribou habitat use, movements, and factors associated with GPS location bias in the Robson Valley, British Columbia. Columbia Fish & Wildlife Compensation Program.

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

Brade, B. 2003. Management of Motorized Access in High Elevation Mountain Caribou Habitat. Ministry of Water, Land, and Air Protection.

Cassirer, F., Freddy, D., and E. Ables. 1992. Elk Responses to Disturbance by Cross-Country Skiers in Yellowstone National Park. Wildlife Society Bulletin. **20:** 375-381.

Chubbs, T., Keith, L., Mahoney, S., and M. McGrath. 1992. Responses of woodland caribou (Rangifer tarandus caribou) to clear-cutting in east-central Newfoundland. Canadian Journal of Zoology. **71:** 487-493.

Cichowski, D., Kinley, T., and B. Churchill. 2004. Caribou. Accounts and Measures for Managing Identified Wildlife.

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

Eccles, T., and J. Duncan. 1986. Wildlife Monitoring Studies along the Norman Wells Zema Oil Pipeline, April 1985-May 1986. Alberta: Environmental Research Associates prepared for Interprovincial Pipeline (NW) Limited.

Ferguson, M., and L. Keith. 1982. Influence of Nordic Skiing on Distribution of Moose and Elk in Elk Island National Park, Alberta. Canadian Field-Naturalist. **96:** 69-78.

Freeman, N. 2008. Motorized Backcountry Recreation and Stress Response in Mountain Caribou (Rangifer tarandus caribou). Vancouver: University of British Columbia.

Gill, J., Sutherland, W., and A. Watkinson. 1996. A method to quantify the effects of human disturbance on animal populations. Journal of Applied Ecology. **33**: 786-792.

Hamilton, D. and C. Pasztor. 2009. A Guide to Commercial Backcountry Skiing Standard Operating Practices for Ski Run Development, Helicopter Landing and Pickup Site Development, and Snow Trail Development in Mountain Caribou Habitat. Submitted to Species at Risk Coordination, Ministry of Environment, Victoria.

Krausman, P., Leopold, B., and D. Scarbrough. 1986. Desert Mule Deer Response to Aircraft. Wildlife Society Bulletin. **14:** 68-70.

Lord, J. M., and D. Norton. 1990. Scale and the spatial concept of fragmentation. Conservation Biology. **4:** 197-202.

Mc Lellan, B. 2007. Caribou Use of Winter Ranges relative to Snowmobile Activity in the Columbia, Okanagan-Shuswap, and Headwaters Forest Districts. Unpublished report.BC Ministry of Forests and Range Research Branch.

MC Lellan, B. 2008. person.comm. Mountain caribou capture and telemetry data from the Columbia Mountains Caribou Project. Kamloops, BC.

McLellan, B. person. comm. 2010.

Mountain Caribou Science Team. 2005. Mountain Caribou Situation Analysis.

Mountain Caribou Technical Advisory Committee. 2002. A Strategy for the Recovery of Mountain Caribou in British Columbia. BC Ministry of Water, Land and Air Protection. Victoria, BC.

Oberg, P. 2001. Responses of Mountain Caribou to Linear Features in a West-Central Alberta Landscape. M.Sc.Thesis. Department of Renewable Resources. University of Alberta. Edmonton, Alberta. 126 pp.

Reimers, E., Dahle, B., Eftestol, S., Colman, J., and E. Gaare. 2007. Effects of power line on migration and range use of wild reindeer. Biological Conservation. **134:** 484-494.

Seip, D. 1990. Ecology of Woodland Caribou in Wells Gray Provincial Park. Ministry of Environment.

Seip, D. 1992. Factors limiting woodland caribou populations and their interrelationship with wolves and moose in southeastern British Columbia. Canadian Journal of Zoology. **70:** 1494-1503.

Seip, D., Johnson, C., and G. Watts. 2007. Displacement of Mountain Caribou from Winter Habitat by Snowmobiles. Journal of Wildlife Management. **71:** 1539-1544.

Simpson, K. 1987. The effects of Snowmobiling on winter range use by mountain caribou. B.C. Ministry of Environment.

Simpson, K., and Terry, E. 2000. Impacts of Backcountry Recreation Activities on Mountain Caribou. Ministry of Environment, Lands, and Parks.

Surgenor, J. person. comm. 2010. Caribou Habitat Suitability Model. BC Ministry of Environment. Kamloops, BC

Terry, E., McLellan, B., Watts, G. and J. Flaa. 1996. Early Winter Habitat Use by Mountain Caribou in the North Cariboo and Columbia Mountains, British Columbia. Rangifer. Special Issue No. **9**: 133-140.

Van Oort, H., McLellan, B., and R. Serrouya, R. 2011. Fragmentation, dispersal and metapopulation function in remnant populations of endangered mountain caribou. Animal Conservation. **14:** 215-224

Vistnes, I., Nellemann, C., Jordhoy, P., and O. Strand. 2004. Effects of Infrastructue on Migration and Range Use of Wild Reindeer. The Journal of Wildlife Management. **68:** 101-108.

Wilson, S. and D. Hamilton. 2003. Cumulative Effects of Habitat Change and Backcountry Recreation on Mountain Caribou in the Central Selkirk Mountains. Prepared for: BC Ministry of Sustainable Resource Management, Canadian Mountain Holidays, and Pope & Talbot Ltd.

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

CHAPTER 5. CONCLUSIONS AND MANAGEMENT IMPLICATIONS

As an interdisciplinary subject, environmental science recognizes the importance of studying the impacts humans have on their natural surroundings and protecting threatened species and their habitat. The goal to maintain biodiversity is what drives environmental scientists across the globe to investigate underlying factors contributing to the decline of a species. Which species require the most conservation efforts is often a topic of debates. It is however, widely acknowledged that specialized species are more vulnerable to changes in their environment than generalist species (Clavel et al. 2010; Baskin 1998) and hence require attention. It is frequently reported that generalist species are actually replacing specialist species in a variety of ecosystems. Hence, it is essential to protect the habitat of habitat specialists in order to protect them from population decline. This includes limiting habitat loss and fragmentation, as well as protecting areas from disturbances which might cause species to abandon habitat. Studies investigating which disturbances can act as a drive for displacement are therefore essential.

This particular study focused on mountain caribou, a habitat specialist species found only in small subherds across the interior wet belt of British Columbia. While recovery actions have been put in place over the past years to stabilize populations, numbers continue to decline. Scientific research studying the contributing factors causing this decline is wide-ranging. Habitat loss and predation have been attributed to be the main concern and received most attention, and studies on mountain caribou life history and habitat needs are vast (Kinley 1999; Seip 1990; Terry et al. 2000; Apps et al. 2001). Since the decline of mountain caribou became more evident in the mid-1900s, studies have also been conducted on human impacts on already vulnerable caribou herds, mainly associated with logging and mining. In more recent years, winter backcountry recreation has been identified as an additional human pressure, yet quantitative research on the degree at which these activities impact caribou herds are still scarce. A need for studies clearly documenting behavioural and spatial responses of mountain caribou towards recreational activities such as snowmobiling and heli-skiing over a number of years exists. This need was a major drive for my research project; more specifically to evaluate best management practices put in place to protect mountain caribou from heli-skiing.

SUMMARY OF RESEARCH FINDINGS

For my study, heli-skiing data were made available from a commercial operator and caribou location data were made available from a long term study that monitored the species' biology. The two independently generated data sets allowed me to investigate a possible relationship between the two. While a number of limitations existed due to the nature of the data, a number of tests could be applied to determine direct behavioural and long-term spatial effects of heli-skiing on mountain caribou.

The detectability of mountain caribou within ski terrain was investigated, because an existing "Alert and Closure Protocol" relies heavily on sighting caribou in order to avoid them. Results suggest that caribou are often missed when flying over an area. It appears that caribou are not easily detected by casual observers when located in high elevations during winter seasons. Biologists doing caribou censuses see a much higher proportion of animals than heliskiing personnel.

The direct behavioural responses of mountain caribou towards heli-skiing activities were also analysed. Responses to helicopters observed by MWHS varied among different observations. In 51 % of incidents, caribou responded slightly by only moving their heads towards the helicopter but remaining rested, while on some days, caribou responded in panic and fled the area. Caribou did not react differently to helicopter disturbances when exposed in areas that were skied more frequently. While there might be an effect in a long-term response, short-term flight responses appear to be similar across all MWHS ski zones.

Several different spatial GIS techniques were applied to the existing GPS telemetry location data points within MWHS ski terrain in order to determine whether caribou were potentially displaced from suitable habitat due to heli-skiing over the years analysed. Movement rates of mountain caribou were also compared across different ski zones.

A suitable habitat analysis showed that mountain caribou in MWHS terrain used suitable foraging habitat near heli-ski runs more than expected based on the size of the area. Caribou did not refrain from using suitable habitat near ski runs. No sign of long-term displacement during the studied time frame from MWHS heli-skiing zones exists. These results are vital, since in other studies, complete abandonment of caribou has been observed in response to snowmobiling.

A distance analysis showed that with increased skiing levels of individual ski runs, the distance kept by caribou from ski runs did not increase. Hence, caribou have not been displaced by higher frequencies of skiing in an area. This is a significant outcome, as it reaffirms what the first test showed. . Within MWHS terrain, it appears that mountain caribou have not been permanently displaced by heli-skiing over the study time period. Since heli-skiing has been frequent in the area for many years before the time frame studied, it is not known if caribou were initially displaced when skiing began and only a small number of habituated individuals remain to be studied.

A movement rate analysis showed that most often, daily movement of mountain caribou in the study area was relatively low. However, animals in MWHS ski terrain as well as within Wells Gray Provincial Park showed high variability in movement rates and occasionally showed much greater movement. On a landscape level, caribou were not moving more in areas exposed to skiing. A variety of different factors might explain the variability in daily movement rates found among individual caribou. Heli-skiing can be excluded on a landscape level, as caribou within a non-skied landscape show similar variability. Seasonality, which could have an effect due to the sporadic uphill movements caribou undergo during early winter, was also excluded. Gender could also be excluded to be a factor influencing the daily movement rate of these caribou, since all caribou analysed for MWHS were females, and yet variability was high. Likely, environmental conditions including weather, predation and food availability account for most of the variability among daily movement rates. These factors could not be controlled or tested for this project. Overall, while the main findings of this study are spatially limited and retrospective, they show that mountain caribou in Blue River, BC:

1) did not get displaced from areas exposed to heli-skiing between 1996 and 2007
2) only showed minor behavioural responses to helicopters during this time frame

LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

A major limitation of this study is that mid-term reactions (ie. 0 to 24 hrs) of GPS collared caribou to heliskiing could not be measured. I only had access to visual observations by ski industry personnel of the immediate responses of caribou (< 1 minute) and GPS locations of caribou, a habitat map, and ski run locations for season-long analyses. Thus my analyses were limited to immediate reactions and longer-term, more general displacement. Because in Chapter 3 I found that out of more than 1000 caribou locations in the most heavily skied portion of the study area, only 15 (< 1.5%) were within 500 m of active heliskiing, that short-term avoidance was probable. This scale of displacement should be further investigated as, combined with notable immediate reactions (49% of the observations), the major effect of heliskiing on these likely habitatuated animals is short-term reactions and displacement.

Another limitation of this study is that that it was not possible to separate the effects of heli-skiing from those of snowmobiling that occurs over much of the same and adjacent terrain. Responses of caribou to heli-skiing studied here are therefore specific to animals located in areas exposed to both heli-skiing and snowmobiling, despite the fact that heli-skiing impacts were the focus. If caribou were displaced by heliskiing, it is likely that they would have to move to areas of greater snowmobiling. Caribou may respond quite differently to heli-skiing as they do to snowmobiling. More research on heli-skiing impacts, conducted on other caribou herds which have never been exposed to snowmobiling, would be valuable for comparison.

Additionally, the effects of disturbances on behaviour and movement of caribou cannot be distinguished from natural factors such as predation, as natural factors cannot be controlled when studying animals in their natural surroundings. The effects of heli-skiing are likely much less significant than habitat quality, snow cover and predation. A great importance to conduct more research on heli-skiing remains, since when combined with other factors, it may contribute to an overall effect, potentially causing the decline of the species towards extinction. If more is known about the impact heli-skiing has on mountain caribou, more comprehensive studies can be conducted that compare human disturbances and their relative importance for conservation measures.

Furthermore, as mentioned in Chapter 3, immediate behavioural responses as investigated for this study are only one indicator of stress, and physiological indicators were not studied. While it appears that some caribou in the study area did not increase energy expenditure due to heli-skiing as they rarely fled, this does not necessarily mean these animals were not stressed. A detailed stress hormone level analysis would provide a detailed look at potential physiological stress factors related to heli-skiing in the area, and may be valuable to conduct as a follow-up to this study on this specific herd.

Finally, this research was based on data collected after heli-skiing had occurred in the area for many years. Hence, the study does not show whether displacement of caribou had already occurred, since no reliable data for previous years existed, and I was left to study the few remaining individuals. Results of this study should not be extrapolated to areas where there has not yet been heli-skiing.

KEY CONTRIBUTIONS OF RESEARCH

This study provides the first quantitative research showing that no major displacement occurs in the area where heli-skiing has been done for many years. This supports anecdotal data collected by MWHS over the years that caribou are found in areas with heliskiing. This study suggests that pressure from government and non-governmental organizations towards limiting the disturbance from heli-skiing companies in areas where heli-skiing is already being done may (or may not) be less important than other factors. As a result this project will be valuable for future management considerations and assist in creating a clearer picture of how commercial winter backcountry recreation and caribou may interact and even possibly co-exist. The findings of this study suggest that existing best management practices put in place to protect mountain caribou from heli-skiing in the area may be effective even if they are based on observing caribou, when most are not seen.

MANAGEMENT IMPLICATIONS

In terms of the Best Management Practices already in place for heli-skiing, a number of additional considerations can be made based on the results of this research:

Since the visibility analysis clearly showed that caribou are much easier detected within open terrain, observers need to show “extra diligence” when skiing or flying over densely forested areas, as caribou might be present but not visible. Heli-skiing frequently takes place through trees, and during mid-day when caribou may be bedding down to ruminate, making this an important point to consider for future skiing. Also, since the likelihood of detecting caribou increases when flying over an area more than once, this needs to be kept in mind. Continued awareness training for pilots and guides is essential for a successful “Alert and Closure Protocol”.

Caribou appear to react more overtly to skiing on the ground compared to being disturbed from above. Hence, one way to potentially limit the number of instances where skiers run into caribou on the ground would be to make a few higher elevation flyovers over the ski terrain every morning of a ski day. While it may be unfeasible to fly over the entire ski terrain to look for caribou, it may be possible to fly over a specific ski run to be skied next and check for caribou, before dropping of skiers at the top. Perhaps more importantly, responses of caribou to skiers vs. helicopters showed that the closure of areas of skiing may be more important than diverting flights to avoid disturbances. This supports the procedures suggested by existing Best Management Practices.

Also, extra care needs to be taken when accidentally running into caribou. Since they react more when disturbed on the ground, and in open terrain, it may be helpful to make sure they have a direct way to get back into protected, forested terrain and not to cut them off and cause an escape into open, possibly avalanche prone terrain.

While no trends were observed based on displacement, conclusions are limited somewhat by relatively small numbers of animals with usable data, as well as assumptions made on daily independence of data points. Although several other studies have used similar criteria to classify continuously generated GPS points, the criteria have not been rigorously validated. It is important to consider caribou when planning new ski runs, involving any kind of expansion of runs, or additions. For future ski run developments, it is highly recommended to focus on areas that do not represent prime caribou habitat based on existing habitat suitability models, and to ensure connectivity between habitat patches.

The daily movement rate analysis demonstrated that some caribou might respond to increased heli-skiing by moving more often. Thus, it could be beneficial to caribou if pilots and guides change skiing terrain as much as possible. In addition, it is always advisable to keep some areas as refuges from disturbance. Also, it is essential for ski guides and pilots to know that the degree of movement varies highly among individuals. Therefore, no conclusions should be drawn when seeing responses of one animal or group of animals, as others might respond quite differently. A distance of 500 metres towards caribou should be kept at all times, as required by the Memorandum of Understanding regarding management of helicopter and snow-cat skiing in Mountain Caribou habitats (Ministries of Agriculture and Lands, Environment, Tourism, Sports and the Arts, and BCHSSOA 2005).

Enhanced communication between heli-skiing operations and ministry agencies responsible for the introduction of best management practices is also suggested. Over the course of this research project both stakeholders were consulted separately and together for regular committee meetings. A positive observation I made during these consultations was that communication and the sharing of information has improved substantially.

It is important that heli-skiing companies provide environmental agencies with consistent data on caribou observations and flight activities, and also vital for government representatives to share data on caribou censuses and provide heli-skiing companies with information on how their data is being interpreted. Caribou census updates and feedback on management practices employed by different heli-skiing companies and their effectiveness can be discussed during annual wildlife training sessions held for ski guides and pilots to improve understanding of fundamental issues.

If people continue to work together on this issue, it appears that heli-skiing and mountain caribou can coexist in the future. And if we continue to study these animals in the future, they are sure to tell us more about what they need to survive in this changing world.

REFERENCES

Apps, C., McLellan, B., Kinley, T., and J. Flaa. 2001. Scale-dependent habitat selection by mountain caribou, columbia mountains, British Columbia. Journal of Wildlife Management **65**: 65-77.

Baskin, Y. 1998. Winners and Losers in a changing world. BioScience. **48:** 788-792.

Clavel, J., Julliard, R., and V. Devictor. 2010. Worldwide decline of specialist species: toward a global functional homogenization. The Ecological Society of America.

Kinley, T. 1999. Mountain Caribou.Victoria : Wildlife Branch, Ministry of Environment, Lands and Parks .

Ministries of Agriculture and Lands, Environment, Tourism, Sports and the Arts and the British Columbia Helicopter and Snowcat Skiiing Operators Association (BCHSSOA). 2005. Memorandum of Understanding regarding Management of Helicopter and Snow cat skiing in Mountain Caribou Habitat.

Seip, D. 1990. Ecology of Woodland Caribou in Wells Gray Provincial Park. Ministry of Environment.

Terry, E., McLellan, B., and G. Watts. 2000. Winter Habitat Ecology of Mountain Caribou in Relation to Forest Management. Journal of Applied Ecology. **37:** 589-602.

APPENDIX A. COLLARING INFORMATION. Summary of collaring info on mountain caribou fitted with GPS collars during winter months between 1996 and 2007 near Blue River, BC

Animal	Caribou ID	Collaring Time Frame	Sex	Age (at time of collaring, N/A= info not available)	General Location (within ski terrain, outside, or both)
a	91	1996/1997	F	N/A	inside
b	92	1997/1998	F	N/A	inside
c	146	2002/2003	F	adult	inside
d	155	2003-2005	F	Adult	both
e	87	1996/1997	F	N/A	outside
f	95	1997/1998	F	N/A	outside
g	96	1997/1998	F	N/A	outside
h	189	2007	F	adult	outside
i	158	2003-2005	F	adult	outside
j	90	1997/1998	F	N/A	both
k	140	2002	F	N/A	outside
l	127	1999/2000	F	N/A	both
m	190	2007	F	adult	inside
n	160	2003/2004	F	adult	both
o	118	1998/1999	F	N/A	both
p	164	2003	F	adult	inside
q	144	2002/2003	F	adult	both
r	117	1998/1999	F	N/A	both
s	137	2002/2003	F	adult	both
t	143	2002/2003	F	adult	both
u	80	2003-2006	F	adult	both
v	157	2003	F	adult	both
w	177	2005/2006	F	adult	outside

APPENDIX B. HELICOPTER TRACKING. Example of heli tracking sheet for March 11th, 2004. Tracki sheets were used prior to flight activity being stored in Blue Sky computer program after 2006. Pilots called their locations in at least hourly, to be recorded by a radio dispatcher.

MIKE WIEGELE HELICOPTER SKIING

Helicopter Activity Log - Page __ of __

Date: MAR 11/04 Lead Guides: MIKE ERIN NORBERT. HELI #: 6

Guides: ______ Pilot: ANDREW

ZONE	HOUR	TIME	LOCATION REPORT	INIT
		0850	Airport - Lodge ↑ → EASTBOUND	[illegible]
M-8	9hr	0856	Yukon Jack.	[illegible]
		0936	SOFT COTTON	[illegible]
	10hr	1004	SOFT COTTON	[illegible]
		1017	EARLY BASKET	[illegible]
	11hr	1100	3 gps GRIZZ → AP. Fuel + 1 QUEST	[illegible]
		1106	↓ AIRPORT FUEL	[illegible]
		1116	↑ AIRPORT → GRIZZLY hut.	[illegible]
	12hr	1207	GRIZZLY HUT.	[illegible]
	13hr	12:42	groups to Mud 1	[illegible]
	14hr	1401	MUD 1	[illegible]
M-8	1409	~~1409~~	3gps MUD 1 → REDSANDS Fuel	[illegible]
		1425	↑ REDSANDS → MUD 1	[illegible]
	15hr	1454	gps → SOFT COTTON	[illegible]
		1542	→ ↓ to Ldg. with Mike + John	[illegible]
		1548	↑ → to Redsands for	[illegible]
		〃	fuel	[illegible]
	16hr.	1556	↑ Redsands → Soft Cotton	[illegible]
		1626	↑ SOFT COTTON → LODGE	[illegible]
		1647	↓ Lodge	[illegible]
		1706	↑ TOUR FOR VIP	[illegible]
		1726	↑ Lodge → A.P.	