

Assessing the Relative Contributions Transmission Line Rights-of-
Way have on Habitat Utilization by Moose
Case Study: Riding Mountain National Park

Submitted by:
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RIGHTS-OF-WAY HAVE ON HABITAT UTILIZATION BY MOOSE
CASE STUDY: RIDING MOUNTAIN NATIONAL PARK**

BY

LEANE HILL

**A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University
of Manitoba in partial fulfillment of the requirements of the degree
of
Master of Science**

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ABSTRACT

Moose (*Alces alces andersoni*) are one of many game animals managed for sustainable subsistence, sport hunting, and for non-consumptive users in Manitoba. Managing this species is essential if we are to ensure healthy populations for present and future generations. An important component of moose management is understanding how resource development affects moose-habitat relationships. Modifications to the landscape through resource development (ie. timber harvesting), often promote the growth of young vegetation that is favorable to moose. Growth of young vegetation can also be enhanced through the maintenance of an established transmission line right-of-way (ROW). However, few studies have examined the habitat relationship that exists between moose and transmission line rights-of-way. The focus of this study was to give insight into the relative habitat contributions these areas may provide for moose.

Set in Riding Mountain National Park, this study examined habitat use by moose along a transmission line ROW using methods that included a browse study, pellet group counts, track counts and aerial survey data. The results indicated that moose used ROWs for foraging, traveling to new food patches and for bedding. Beaked hazelnut in ROW areas experienced more intensive use by moose throughout the winter period when compared to adjacent forests. Bedding and pellet group occurrence were greater within the aspen ROW when compared to the adjacent forest. No differences were found in bedding or pellet group occurrence between the mixed-wood ROW and adjacent forest.

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Chapter 1

INTRODUCTION

1.1 Preamble

The value of moose (*Alces alces andersonii*) to Manitobans takes on a variety of forms. Moose are highly regarded as a food source by hunters, and as having great esthetic value by various groups. Whether moose are used for food or enjoyed by wildlife watchers and photographers, they are a part of North America's wildlife heritage and an integral part of a complex ecosystem (Timmermann and Buss 1997). Managing this species is therefore essential if we are to ensure healthy populations for present and future generations.

1.2 Moose Management and Industrial Development

It is only appropriate that managing moose populations incorporates knowledge and understanding of moose-habitat relationships. Not only is it important to understand the role of moose as important modifiers of the boreal ecosystem, but also how modifications to the landscape affect moose. Habitat alterations often result from industrial development, for example, timber-harvesting (Collins and Schwartz 1998). These practices create and maintain the growth of young early successional vegetation that is preferred by moose (Thompson and Stewart 1997). Following the removal of mature trees, the replanted or naturally regenerated growth provides moose with important forage high in protein content. Favorable timber-harvesting practices (for moose) include cutting narrow strips of forest, leaving adjacent dense closed-canopied areas intact to function as shelter during the winter months (Thompson and Stewart 1997). In areas where logging is infrequent, the halting of succession is often achieved naturally through natural disturbances, such as fire (LeResche *et al.* 1974b; Peek 1997).

Other developments that may affect moose habitat are the construction of seismic and transmission line rights-of way (ROW) (for Glossary of acronyms see Appendix 1). These areas generally enhance the growth of low growing shrubs, forbs and grasses through the removal of tall woody vegetation. Where development occurs through dense forests, ROWs containing young easily accessed vegetation may be attractive feeding areas for moose. This was apparent in a study on seismic lines and wildlife use in the Mackenzie Delta; moose were documented using the open line for feeding and traveling (Riewe 1980).

Few studies have actually focused on determining the contributions transmission line ROWs have on moose habitat utilization. One of the few studies that examined this relationship was conducted by Ricard and Doucet (1999) along transmission line ROWs in Quebec. They found that in some instances, moose browsed regions of the ROW more intensively than in the adjacent forest. However, moose density and use of forage results showed no difference in use between ROWs and adjacent forest areas. Since browse quality in both areas was considered low, they suggested extending the length of the vegetation control cycle to allow an increase in growth of available plant biomass. Ricard and Doucet (1999) felt that this, along with a greater sample size may have lead to more conclusive results pertaining to moose use of the ROW.

In areas of boreal forest, methods used to maintain ROW vegetation may promote the growth of young forbs and shrubs. This naturally depends upon the habitat type the ROW is crossing through, as not all regions would support shrub growth. However, in cases where shrubs do exist, line maintenance may enhance the overall forage quality of the region by promoting new growth in the ROW area. Through continued vegetative maintenance, shrubs and forbs within ROWs would never reach a "mature" state, making these areas favorable habitat for moose on a regular basis.

1.3 Issue Statement

Since moose is a valued both economically and socio-economically by hunters and “nature enthusiasts” throughout Manitoba, it is imperative that wildlife managers gain an understanding of not only the status of the populations, but more importantly how (changes in habitat composition) wildlife interacts with its environment. Of particular interest are the effects of landscape changes on moose habitat utilization. Human modifications to the landscape often result when industry develops resources, such as the case with timber harvesting, oil and hydro development. Through this development, habitat is often enhanced through the creation of new food sources for moose. Various studies have examined the effects of natural disturbances, such as fire (LeResche *et al.* 1974b; Peek 1997), and human disturbance such as timber-harvesting practices (Collins and Schwartz 1998) on moose habitat utilization, however few have investigated the effects of transmission line ROWs on moose habitat utilization.

To enhance our understanding of moose in areas where transmission line ROWS exist, it is necessary to first investigate the level of moose habitat use on and off transmission line ROWs occurring within an unhunted region. By removing the potential for behavioural modifications of moose in response to hunting pressures, conclusions regarding moose habitat use in these areas will be less influenced by hunting and instead be based on influences of the ROW. This study attempted to illustrate the relationship between moose habitat use and ROW habitats, with specific emphasis on browse utilization and pellet group counts. Based on these data, conclusions regarding the relative contributions of ROWs to moose habitat use are presented, and insights into the relationship revealed.

1.4 Research Objectives

The primary objective of this study is to assess the relative contributions a transmission line ROW has on moose habitat use in an area where direct human pressures are minimal (ie. hunting). RMNP was selected because of the prominence of moose and the prohibition to moose hunting within the park. Specific objectives are:

- to determine if moose utilize the ROW for browsing and bedding and if so, how this compares with browsing and bedding in adjacent forests;
- to determine if moose utilize the ROW to access food patches during snow covered months;
- compare the use of transmission line ROW and adjacent forests to alternate areas not affected by transmission line ROWs located in other areas of the park.

Chapter 2

ECOLOGY AND MANAGEMENT OF MOOSE

2.1 Introduction

The following is a brief overview of the history of moose in North America, with emphasis on Manitoba. This chapter describes some of the current moose management practices including hunter access issues, moose habitat selection and foraging behaviour.

2.2 Historical Moose

It is theorized that during the Wisconsin Glaciation, moose, the largest member of the deer family, Cervidae, crossed the Bering Land Bridge to North America from Siberia. Upon entering Alaska, an unglaciated refugia, they moved southward into 3 distinct refugia. According to one theory, it is believed that this is when subspeciation occurred. Four different subspecies of moose exist in North America, *gigas*, *andersoni*, *americana* and *shirasi* (Figure 1). Their distribution was determined by the dynamics of glacial epochs and associated boreal forests. Moose once ranged over the then-forested Great Plains and eastern United States but moved northward with the retreat of the glaciers and extension of boreal forests (Franzmann 2000).

The arrival of moose is believed to have coincided with the period of human expansion into North America. Primarily meat eaters, Aboriginal hunters preferred moose because of the high return per unit of time and energy invested (Franzmann 2000). For these boreal hunters, the use of moose defined subsistence. Practically everything a moose had to offer was used in some

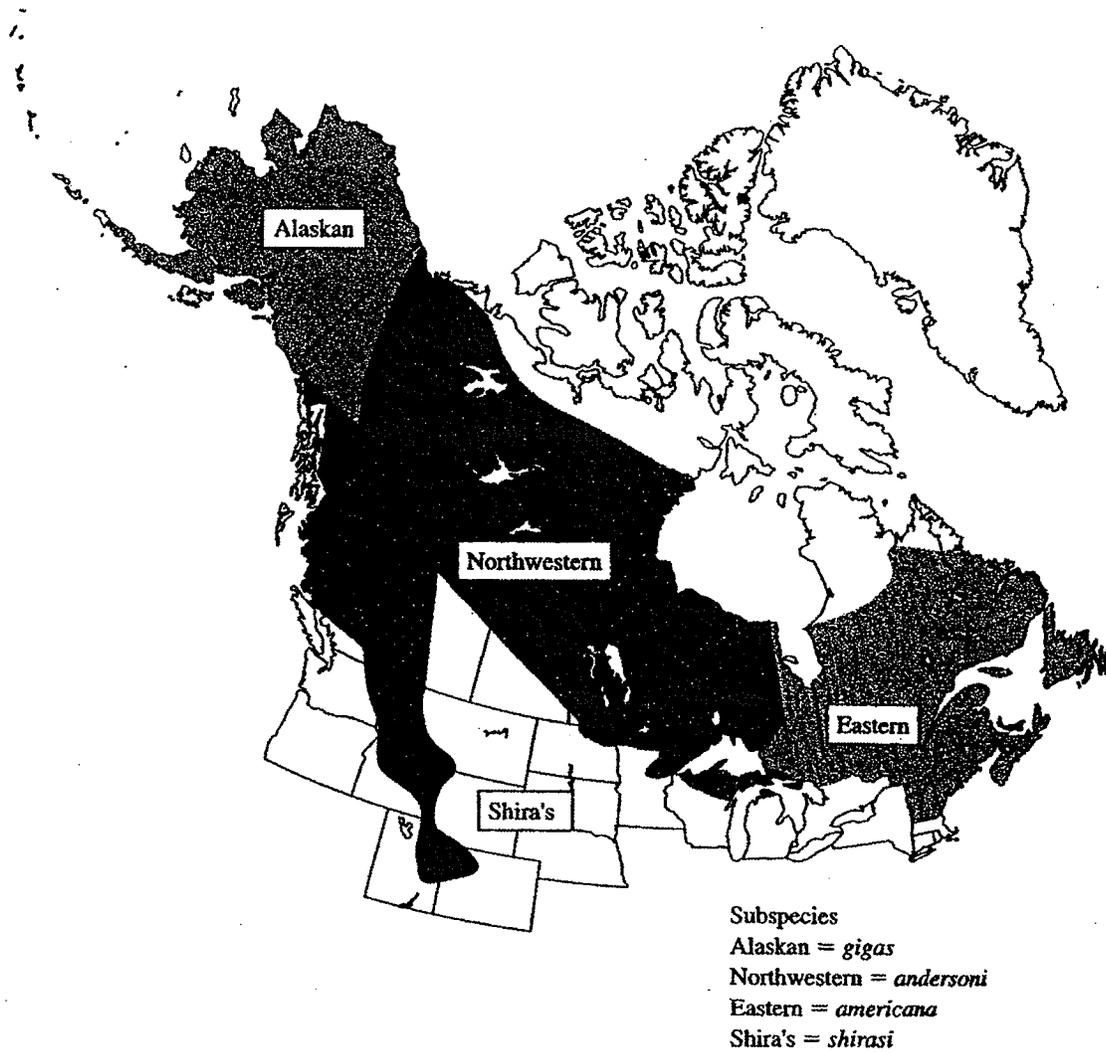


Figure 1. Distribution of moose (*Alces alces*) subspecies across North America (Franzmann 2000)

way. However, the value of moose extended beyond its physical importance. It was highly regarded culturally, and was involved in many traditions. When early European settlers arrived, Aboriginal people provided them with meat and fat. Eventually settlers too became dependent upon moose for their subsistence. They disregarded its cultural importance to Aboriginal People and valued moose mainly for its utilitarian value (Franzmann 2000). Thus, with the expansion of white settlers into western North America and the availability of firearms, the depletion of moose populations was inevitable.

2.3 Moose Management Today

Today, many hunters, both aboriginal and non-aboriginal, actively hunt moose. First Nation communities still hunt moose and other wild game, however access to modern conveniences may have resulted in less dependence on wild game. Despite this, moose still maintain their status as a valued species in northern First Nation, Aboriginal and non-aboriginal communities. More and more people are placing value on the aesthetics associated with the hunt, rather than the harvest (Franzmann 2000). Non-hunters are placing great value on programs such as "Watchable Wildlife". The value of moose is changing and cannot always be easily quantified. However, economically this resource generates a significant amount of revenue for Manitoba (Crichton pers. comm. 2002). The use of this resource, whether it be hunting, viewing or both, justifies the need for proper management if we are to sustain or increase current moose populations. Positive management actions can help to perpetuate healthy moose habitats and populations over the broadest possible area if moose are to prosper and humans are to benefit from their success (Coady 1982).

2.4 Moose Habitat Requirements

Moose possess a unique set of ecological and physiological adaptations that enable them to exploit forage resources in the harsh environmental conditions of circumpolar latitudes (Renecker and Schwartz 1997). They might be considered "selective generalists", as they are capable of adapting to various types of habitats (Peek 1997). Selected habitats include the boreal forests of Manitoba, where woody vegetation is abundant. Moose are primarily browsers of foliage and twigs but will, strip bark from aspen during extreme winters (Crichton pers. Comm. 2001). Although their diet is varied, moose prefer young stands of trembling aspen (*Populus tremuloides*), willow (*Salix sp.*), paper birch (*Betula papyrifera*) and red-osier dogwood (*Cornus stolonifera Michx*) (Coady 1982). Balsam fir (*Abies balsamea*), the only conifer browsed by moose, is taken when available. In RMNP, moose diet consists primarily of deciduous species (Trottier and Hutchison 1980). Winter foraging in the park is limited to shrubs and woody vegetation, important staples to wintering moose.

Appropriate food availability, along with access to shelter are two of the necessities required by moose during winter in the boreal forest. The following is a review of the habitat components moose require in order to meet their energetic needs.

2.4.1 Young Seral Vegetation

Optimal moose habitat is that which contains young, palatable forbs, shrubs and trees. Young seral vegetation is not only nutritious, but also readily digestible. This stage of succession is critical for moose since crude protein levels in twigs decrease with age (Oldemeyer 1974). For example, one study found that the crude protein in beaked hazel decreased from 8 % to 5.1 and 4.1 % from year 1 to year 3 respectively (Schwartz and Renecker 1997). Most nutrients are contained within the growing parts of the plant, namely the buds and the bark

(Oldemeyer 1974). As a result, young twigs have a high ratio of surface nutrients when compared to nutrient content in their core or pith. This ratio declines with age as the twig becomes more "woody" with hard to digest carbohydrates being deposited in the core (Schwartz and Renecker 1997). Moose would not only have to eat more of the older twigs to fulfill their energy requirements, but would be forced to spend more time ruminating and less time foraging (Vivas *et al.* 1991). Thus the availability of young seral vegetation is vital if moose are to meet their energetic requirements.

2.4.2 Fire and Logging

Ever since the Wisconsin Glaciation, fire has been the predominant factor responsible for shaping Manitoba's boreal forest. For moose, fire has been crucial in creating prime foraging habitat. Through fire, early seral (young, nutritious and palatable) shrub communities, such as willow, are generated (LeResche *et al.* 1974b). Moose are capable of rapidly inhabiting postfire habitats where high-quality early successional forage is created. However, colonizing these habitats is only possible if there is a local moose population present to expand into the new habitat (Peek 1997). Another determinant to whether postfire habitats are colonized, is vegetation and soil type. Density and frequency of willow and paper birch - staples in the moose diet - vary according to soil characteristics. Predation and hunting pressure may also limit moose from dispersing into postfire habitats (Peek 1997).

The quality of moose habitats are constantly changing because of forest succession. The highest moose densities are associated with subclimax vegetation, with populations decreasing as forests reach maturity (Krefting 1974). Population explosions usually occur when recolonizing shrubs reach a height that makes them available to moose during the winter (LeResche *et al.* 1974b). Some timber harvesting practices, like forest fires, alter succession by removing old

growth and encouraging the growth of young shrubs favored by moose. Usually a combination of clear-cutting and soil scarification on mesic sites partially mimics fire and windfall, important natural forces that drive regeneration of the boreal forest (Collins and Schwartz 1998).

2.4.3 Snow

Snow is, to a small extent, beneficial to moose. For instance, during bouts of warmer mid-winter weather, moose are often found bedded down in snow in an effort to thermoregulate their body temperatures. At approximately -5.1 °C, moose exhibit heat stress and begin panting at 2.2 °C in order to dissipate heat (Schwab and Pitt 1991). Since panting is energetically costly to moose, they seek thermoneutrality by bedding down under cooler coniferous forests, or in open snowy areas.

Snow may act as a coolant during warm weather but it also acts as an insulator during colder weather. Heat resonating from a resting moose is trapped in the air pockets that exist between snow particles. Although moose are well adapted to cold temperatures by storing body reserves and reducing metabolic rates (Gillingham and Klein 1992), they still utilize the beneficial properties of snow. In order to maximize its insulating properties, moose select light, deep, undisturbed snow when bedding down (Des Meules 1964).

Despite having some favorable properties, deep snow places constraints on foraging moose. Energetically, travel through deep snow levels is costly, especially in late winter when energy reserves may already be depleted (Histol and Hjeljord 1993). Therefore, as snow depths increase, moose move into sheltered closed canopied forests where snow depths are lower. Here forage quality is low, resulting in heavy use of coarse, less palatable forage (Histol and Hjeljord 1993) and increased periods of rumination (Gillingham and Klein 1992). As conditions improve, moose will move into more suitable habitat to browse.

2.4.4 Closed Canopied Forests

Closed canopied forests provide an important habitat requirement for moose during the late winter months. These forests are characterized by coniferous trees, but may include mature deciduous tree species. Habitats of this type provide cover from the harsh elements moose often face in late winter (Schwab and Pitt 1991). Moose will move into these areas as temperatures drop and snow levels increase to depths where travel is energetically costly. Normally these levels are around 60 plus centimeters (Des Meules 1964). Closed canopied forests offer lower snow depths than forests with more open canopies characteristic of immature forests or old age forests. Likewise, these habitats provide cooler ambient temperatures for moose during the summer months, making them especially important during periods of heat stress (Schwab and Pitt 1991).

2.5 Foraging Behaviour

Being the largest member of the deer family, Cervidae, moose have an advantage of being able to forage on taller shrubs in young seral communities. Their long legs allow them to access shrubs other herbivores such as white-tailed deer (*Odocoileus virginianus*) cannot. Moose consume a large biomass of foliage, stems and bark from relatively young trees (Renecker and Schwartz 1997; Miquelle and Van Ballenberghe 1989). The youngest branches are selected for, as they are the most palatable. Foraging on young nutritious plant material throughout the growing season enables moose to store energy as fat, which will sustain them during the winter.

Movements of moose may consist of local travel within seasonal ranges, migrations between seasonal ranges and dispersal to new ranges. Seasonal home ranges are normally 5-10 km² (Coady 1982), but have been documented as 0.4 km by 4.8 km during winter in northeastern

Minnesota (Krefting 1974). Home ranges are smaller in winter than in summer, and tend to become smaller with increasing snow depth. Movements within these ranges are related to food availability (Coady 1982). For example, in the early summer months, moose move into regions with aquatic habitats. Aquatic habitats provide moose with a refuge from flies, a source of highly nutritious aquatic vegetation and a means of cooling off when temperatures get too hot (Peek 1997). During the late summer months, moose may then move into closed canopied forests where shade offers relief from the hot sun. Open areas (characterized by a less dense canopy cover) are inhabited often in autumn, after the rut, and into early winter. Here, moose have access to the highest biomass of dormant shrubs. As temperatures of the late winter get severe, moose will migrate once again into closed canopied forests where vegetation serves primarily as cover. Such areas are composed of mature hardwood and/or softwood trees, with tall unproductive, poor quality shrub understories (Phillips *et al.* 1973). By late winter, moose are less mobile, conserving energy and essentially surviving off their summer fat reserves.

2.5.1 Diet Choice

Winter diets primarily consist of woody twigs from deciduous shrubs and some conifers. Moose tend to re-browse the same trees and shrubs every year, clipping off the past summer's stem growth. Only under severe conditions will moose re-browse stems where the current annual growth has already been previously browsed (Reneker and Schwartz 1997). Severe conditions are often encountered during winters of heavy snowfall, when moose mobility is restricted to small areas where quality forage is quickly depleted.

Moose clip twigs at different diameters when browsing, depending on the availability of the browse. Habitat containing poor quality forage forces moose to remove larger amounts of woody tissue per twig in order to fulfill their energy requirements. Since twig diameters increase

with distance from the distal tip, moose in poor quality habitats may take larger bites, thus producing larger clip diameters. As a rule, as clip diameter increases, digestibility decreases, for all species (Saether *et al.* 1989). Larger clips contain more woody, undigestible material and are therefore only taken when forage abundance is low (Telfer 1981).

The pattern of food resource use differs between low and high quality habitats. In areas where habitat quality and stem density is low, moose tend to use smaller areas for foraging and are less selective of stem size. As a result they consume more of the available twigs than in high quality areas (Reneker and Schwartz 1997; Saether and Andersen 1990). Movement through these areas is slow, due to the large handling time associated with foraging large twigs. Conversely, moose in high quality habitats containing high stem densities will move more rapidly through the shrubs and trees, nipping few select bites as they go (Vivas and Saether 1987). Less is consumed in these areas since digestibility, in terms of energetics, is high. This suggests that digestibility has a strong influence on daily activity, range use and the pattern of food exploitation (Saether and Andersen 1990).

Studies have shown that moose are selective browsers when a variety of foods are available. They exhibit preferences for red-osier dogwood, willow, aspen and paper birch. These foods are considered to be preferred because they are consumed in greater proportion to their presence in the habitat (Renecker and Schwartz 1997). Often these plant species are regarded as principal foods, when in the absence of choice, are consumed in large quantities. Beaked hazelnut (*Corylus cornuta*), is one such browse species that can either be considered as a preferred or principle food, depending on its availability and use. For instance, in Isle Royale National Park, Belovsky (1981) identified *Corylus cornuta* as a preferred food during winter and a non-preferred food item during the summer. Presence of alternate food sources allowed moose to maximize their net energy intake by selecting appropriate plant species. *Corylus cornuta* has

also been deemed an important food item in Quebec, alongside mountain maple (*Acer spicatum*), balsam fir and paper birch (Crête and Bedard 1975).

In RMNP, beaked hazel is considered a staple food for moose, especially during the winter when moose are dependant on woody twigs. Beaked hazel is one of the most common and widely ranging shrub found within the boundaries of RMNP.

2.5.2 Beaked Hazel

Beaked hazel is a shade-tolerant understory colonial shrub found in many forest habitats in RMNP. Although it exists in a broad range of habitats (Peek *et al.* 1971), it is less common in closed canopied coniferous forests or in open sunny areas of RMNP. The reason for this shrub's success in RMNP is partly due to its ability to withstand heavy browsing. Beaked hazel, along with paper birch and willow can withstand clipping of 50% of their current year's growth over a 6 year period (Peek *et al.* 1976). Continuous clipping shows no significant impact on beaked hazel production, where as site specific plants such as red-osier dogwood, cannot cope with continuous browsing (Aldous 1952; Peek *et al.* 1976).

Beaked hazel responds to browsing by producing multiple new leaders in the spring. This vigorous growth is triggered by the damage incurred during the dormant season. It is an adaptive response that may reduce the impact of further browsing through the modification of the herbivores foraging behaviour (Vivas *et al.* 1991). When beaked hazel produces multiple shoots, the degree of branching increases. As already mentioned, moose will select smaller diameters of twigs when utilizing high quality forage since small diameters are most palatable and easily digestible. Therefore, a shrub can modify foraging behaviour by increasing the number of branches it produces. Moose move quickly through high quality patches, clipping small diameters of twigs at fast clipping rates. This is an adaptive response to herbivory as smaller

clips result in less biomass lost by the plant. In areas where browsing intensities are low, beaked hazel's growth appears spindly. These shrubs are tall and thin, with minimal leader growth. Shrubs in mature forests decrease in quality as moose browse (Peek *et al.* 1976).

Some experimental and observed studies have shown that ungulate browsing on plants produces pronounced benefits to the plant. For instance, snow geese (*Chen caerulescens caerulescens*) grazing on *Carex subspathacea* and *Puccinellia phryganodes* showed an increase in net above ground primary production (Whitham *et al.* 1991). When elk (*Cervus canadensis*) and white-tailed deer were observed browsing on *Gilia* sp., there was an increase in the relative fitness due to an architectural change in the plants inflorescences. Browsed plants produced four inflorescences whereas uneaten controls produced only 1. This overcompensation of tissue growth whether it be stem, foliage or flower is still restricted by timing of herbivory, nutrient and moisture availability and light levels (Whitham *et al.* 1991).

Chapter 3

MATERIALS AND METHODS

3.1 Introduction

This chapter presents an overview of the study site background, and the methods used to identify the relative contributions that a transmission line ROW has on moose habitat use in the RMNP. Methods include a browse survey, track and pellet counts and aerial moose surveys.

3.2 Study Site Background

Sport and subsistence hunting of moose occurs extensively across regions of Manitoba where moose occur. In fact, there are few areas where hunting by both registered and subsistence hunters is prohibited. One such area is RMNP in southwestern Manitoba (Figure 2). It was designated as the study site based on many of its attributes.

1) The park contained a large population of moose.

In 2002, moose numbers were estimated as 3972 animals (with a 95 % confidence interval +/- 434 animals, Fry pers. comm. 2002) or 1.33 moose per km². These moose densities are in part attributed to the absence of hunting.

2) The absence of hunting is another attribute that makes RMNP an ideal study site.

The absence of hunting pressures is essential to researching the transmission line ROW contribution to moose habitat.

3) A transmission line with an established ROW

Large populations of moose, absence of hunting and an existing transmission line with an established ROW, deemed RMNP as an appropriate site for this study.

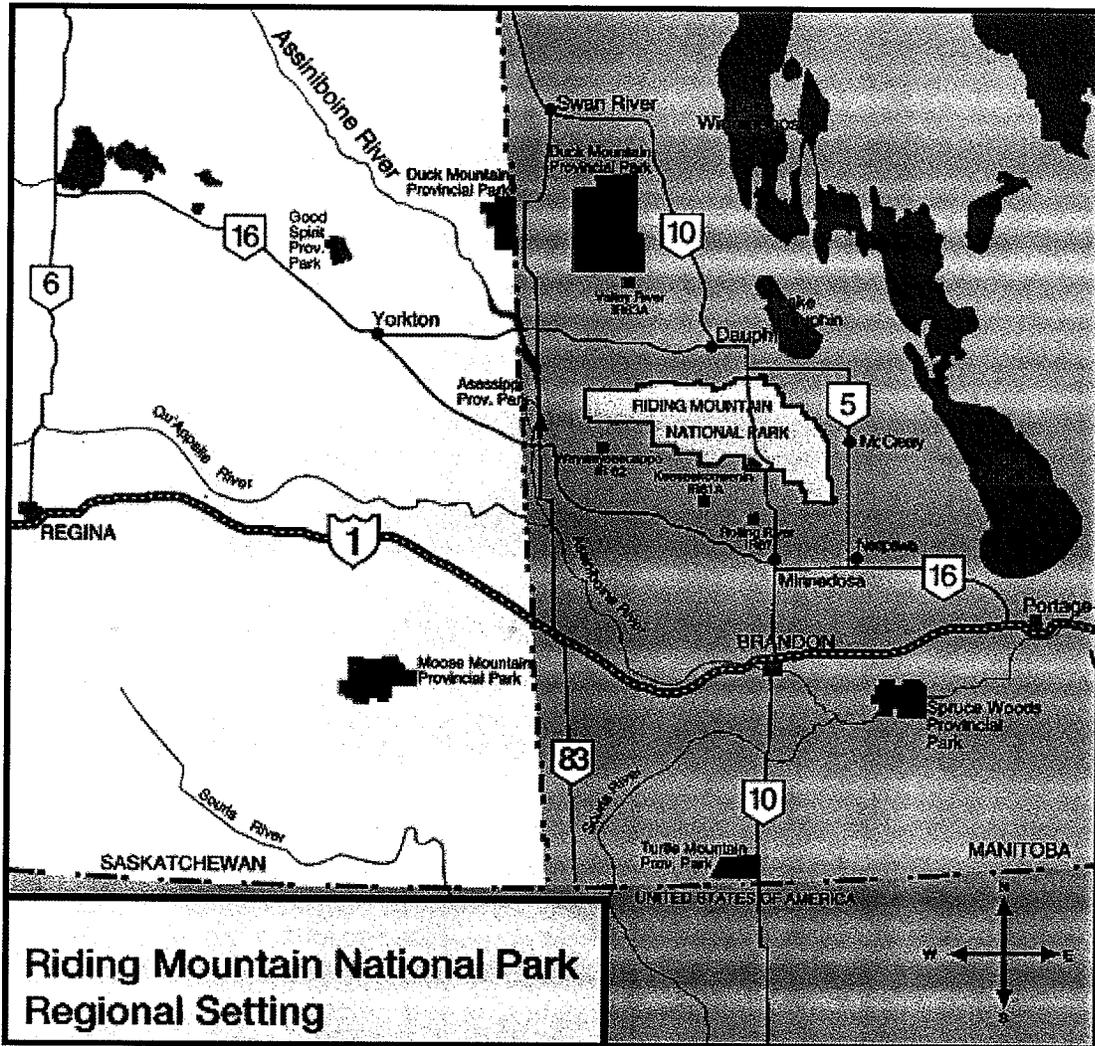


Figure 2. Riding Mountain National Park, Manitoba. (Parks Canada 2003)

3.2.1 Riding Mountain National Park

The creation of the Natural Resource Transfer Act in 1930 led to the establishment of RMNP (Figure 3), a 2978 km² island of wilderness encompassed by agricultural land in southwestern Manitoba (Bossenmaier 1978). At the time it was designated as a National Park, human influences in the form of logging, wildfires, hunting, homesteading and livestock grazing were constantly affecting and changing the existing natural communities. Today it is still being influenced by anthropogenic factors, namely by the suppression of fire, park visitors and increased isolation from other forested ecosystems (Richards 1997).

Since 1963, RMNP staff have been conducting aerial surveys on ungulates inhabiting the park. These data are not only used by managers to monitor population trends for moose, but also by Manitoba Conservation to determine yearly harvest limits for the population existing outside of the park boundaries where hunting is permitted (Richards 1997). These survey data will be useful in determining distribution of moose during the winter and density of moose within the park.

Parks Canada has adopted an ecosystem-based management approach to ensure the parks ecological integrity. As part of this "Ecosystem Conservation Plan" (revised in 1997), certain prescribed actions should be taken to protect, restore and monitor both natural and cultural resources in the park (Richards 1997). This includes the need to manage ungulate populations in concert with humans and the rest of the ecosystem. The goal is to address any threats that may compromise the ecological integrity of the park's ecosystems.

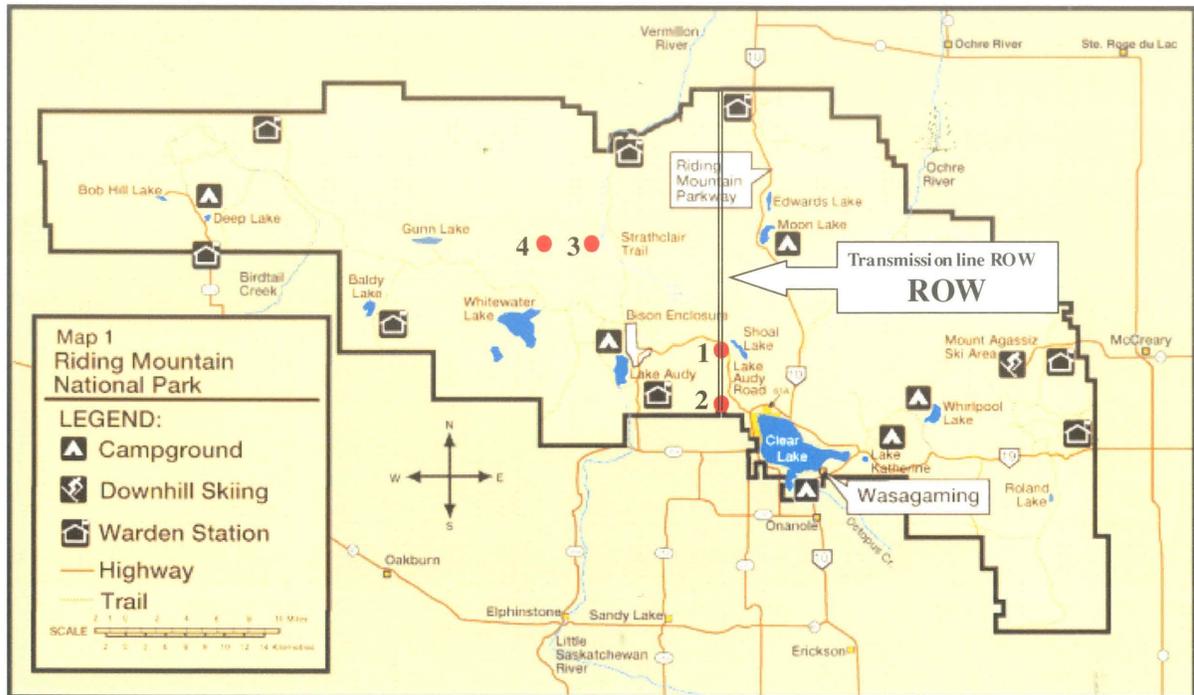


Figure 3. Study sites within Riding Mountain National Park, Manitoba (Parks Canada 2003)

3.2.2 Sampling Site Description

The remoteness of the transmission line ROW within the park has restricted this study to areas that were accessible by road. The Lake Audy road passes under the transmission line in the south end of the park (Figure 3) thereby providing direct access by vehicle. During the snow covered months, access along this road is restricted to snowmobiles operated by park wardens. Direct access to the chosen sites located on and off the ROW was restricted to foot or occasionally by snowmobile.

Two different habitats, mixed-wood forest and aspen forest, were selected for studying the relative contributions of ROWs on moose habitat. Both of these habitats are used by moose throughout the winter, contain woody browse and were bisected by a transmission line ROW. The location of the 2 sample sites were chosen based on access, distance from roads and size of habitat block or polygon. Orthophotos were used to determine size of areas for sampling. It was important that the areas be not only of one continuous habitat, but more importantly, large enough for random sampling.

Sample site 1 (Figure 4a and b), located along the ROW, is approximately 1.6 kilometers south off the Lake Audy road. It is comprised of the mixed-wood forest and adjacent transmission line ROW. This forest is subsequently referred to as the “mixed-wood transmission line forest” (MTLF), which technically is the forest lying immediately adjacent to the “MROW”. Within the mixed wood vegetation type described by Walker (1994), site 1 consists primarily of aspen (*Populus tremuloides*) and white spruce (*Picea glauca*). Black spruce (*Picea mariana*), paper birch, balsam poplar (*Populus balsamifera*) and jack pine (*Pinus banksiana*) are found occasionally. Under the aspen and paper birch, a dense growth of tall shrubs is present, dominated by beaked hazel and an herb-rich understory. Gentle slopes of moderately



Figure 4a. Sample site 1: MTLF and MROW



Figure 4b. Sample site 1: MTLF and MROW

drained glacial till are characteristic of this area.

Sample site 2 (Figure 5a and b) occurs in an eastern deciduous forest located 1.5 km north of the park's southern boundary. This deciduous forest is characterized by stands of mature, high-canopy trembling aspen and an herb-rich understory on nutrient-rich soil (Walker 2002). Subcanopy and sapling layers are poorly to moderately-well developed with tall shrubs such as beaked hazel being dominant. This is a mature site since aspen regeneration is poor and there is evidence of white spruce invasion. Again, the aspen transmission line forest (ATLF) refers to the forest lying adjacent to the "AROW" in the aspen habitat.

The neighboring natural areas (NNA's), sites 3 and 4 (Figure 6 and 7), are both found within an area composed of a mosaic of mixed wood, aspen forest, open meadow and shrubland. The aspen NNA will be referred to as the ANNA, while the mixed-wood NNA will be referred to as the MNNA. These habitats occur north of the bison compound (Figure 3) where the Lake Audy road terminates. Sites 3 and 4 are not affected by transmission lines but do contain similar forest characteristics as found in sites 1 and 2 and are being used for comparative purposes.

3.3 Right-of-way Ecology and Management

Within RMNP there exists a major 45-m wide hydro-electric transmission line ROW. Centered within this ROW are 2 transmission lines, both of which are operated and maintained by Manitoba Hydro (Creaser 2002). Line V38R, a 230 kV transmission line established in 1964, and Line 81, a 66 kV line established in 1965, run parallel to each other within this one ROW. These 2-poled ("H" frame and gulfput) structures run in a north-south direction for approximately 35 kilometers west of Highway 10 (see figure 3). Manitoba Hydro operates and maintains the transmission line and ROW on a regular basis. Inspections consist of quarterly air patrols and winter ground patrols by snowmobile. These investigations include the inspection



Figure 5a. Sample site 2: Winter ATLF and AROW



Figure 5b. Sample site 2: Fall ATLF and AROW



Figure 6. Sample site 3 and 4: ANNA



Figure 7. Sampling site 3 and 4: MNNA

of all poles, replacement of rotten or defective poles and arms, rating of deficiencies and vegetation control if and when required.

Shrub and tree growth is monitored annually during winter ground patrols, with clearing taking place every three years (Creaser 2002). Contractors use “brush bulls” to remove medium to tall growing woody vegetation. Brushing occurs during the winter, after frost has set into the ground as a mitigative measure to minimize soil compaction and other environmental disruption.

During the 1950s, broad-scale “blanket-spray” herbicide application was widely used in controlling vegetative growth along transmission line ROW’s in North America (Niering 1958). Broadcast application of vegetative non-discriminant herbicides is no longer employed for various reasons. It not only requires repeated use, but certain plants develop a resistance to the herbicides. Overall diversity of plants and animals are reduced in the ROW, turning them into unproductive and unesthetically pleasing areas (Niering 1958). Over the last few decades, mechanical clearing has become the more predominant method of vegetative control in Manitoba. However, selective applications of specific herbicides are occasionally used to stunt growth of selective vegetative species. In RMNP, the transmission ROW vegetation maintenance program is exclusively through mechanical means. Although Weedone C.B., a chemical used in stunting the growth of trees has been approved for use in RMNP, it has never been applied within park boundaries (Creaser 2002). Referred to as “stump treatment”, this method involves the application of specific herbicides using hand operated equipment.

The vegetation maintenance programs implemented by Manitoba Hydro are not the only source helping shape the various plant communities existing within the ROW. Vegetation within the transmission line ROW are also influenced by browsing ungulates. Moose help reduce the height of vegetation along the line by browsing woody twigs of young shrubs and trees.

Browsing pressure is believed to impede the encroachment of tree species into cleared areas such as the ROW (Niering and Goodwin 1974).

3.4 Browse Inventory

Two important moose habitats were selected for study in south-central Riding Mountain Park. Both mixed-wood deciduous forest and aspen forest provide optimal growing conditions for beaked hazel an understory shrub found throughout the park. Beaked hazel is one of many shrubs browsed by moose in RMNP. It was selected for the browse inventory based on its abundance in the forested habitats and on the transmission line ROW.

3.4.1 Browse Sampling Design

Quantifying browse use can be an important tool used by researchers when evaluating ungulate wintering areas. Studies of wintering areas may include browse surveys aimed at monitoring annual variations in forage production and/or comparison studies of the effects of disturbance (Telfer 1981). Sampling methods range from ocular estimates (Cole 1958), to clip and weigh techniques that involve current annual growth measurements, to comparing browsed and unbrowsed shrubs within plots (Crête and Bedard 1975). Another method, one employed for this research study, is a comparative study of before and after measurements of current annual growth (Wielgus 1980; Jensen and Scotter 1977). Known as the twig-length method, this technique of estimating browse use involves a double sampling, once in autumn and once in the following spring. Although time consuming, it produces better estimates of heavy utilization than twig counts (Jensen and Scotter 1977).

Depending on the inventory objectives, all of the above mentioned methods have their own set of strengths and weaknesses. Observer and statistical bias hinder such methods like the

ocular estimation and browsed and unbrowsed shrub comparison. Clip and weigh techniques are often expensive and tedious, however they can produce valuable predictive relationships. One should be cautioned however, as these relationships may be highly variable depending on local geographical and environmental factors (Pitt and Schwab 1990; Peek *et al.* 1971).

To implement the twig – length method of determining browse use, a series of line transects were randomly selected (using numbers from a random number table generated in Excel) both within the forest habitats and along the ROW. This was done within the mixed wood and aspen habitat. The forest transects commenced at the edge of the ROW and extended for approximately 80 m perpendicular to the ROW. A hip chain, a device used in recording distances (in meters), was tied to a flagged tree on the forest edge. From this start point, transects were walked in a linear path following a compass bearing approximately 90 degrees to the ROW.

Along these transects were a series of random sample points. Random numbers (produced in Excel) between 1 and 20 m were used in selecting sampling points along each forest transect and between 1 and 10 m for ROW transects. At each random point, four plants were selected using the point quarter technique (Cottam and Curtis 1956; Krebs 1999). The sample point is divided into four 90-degree quadrants and plants nearest to the sample point in each quadrant were chosen for measurement. Only one branch per shrub was tagged, using numbered aluminium tags, and the current year's growth on each twig off this branch was measured. Thus, each of the ten sample points per forest transect yielded measurements taken from four different beaked hazel plants, resulting in a total of 40 sampled plants. For the shorter ROW transects, an average of 6 sample points were used. As a result, 5 ROW transects and only 3 forest transects were required to collect the necessary 120 samples for comparison. The line

transects on the ROW began at the forest edge and extended across the open ROW for approximately 40 m.

Distances between points were spread out along the transect in such a way that no one plant had the same chance of being selected as the closest individual to 2 sample points (ie. no double sampling). If this situation arose, as often did when random numbers were less than 2 m apart, the random number was discarded and the next random number from the table was used. This avoided double sampling.

From each of the 120 samples collected per habitat, the current year's growth, identified by the smoother, lighter coloured bark (Figure 8), was measured and recorded for each twig off the selected branch. A ridged bud scar helps distinguish this current growth from the previous year's growth for up to about a year later (Telfer 1981). Only length of twigs located at a height above 50 cm, and with an annual growth of at least 5 cm were measured. In many areas of moose habitat, snow depths make twigs with heights less than 0.5 m unavailable to browsers. For this reason, they were excluded from the survey. As a general rule, twigs higher than 3 m are also considered unavailable, for they extend beyond the easy reach of moose. Twigs smaller than 5 cm are not usually selected by moose, and thus were not measured in this survey. Small shoots such as these are taken in the same mouthful as others that are selected (Telfer 1981).

One of 3 general degrees of "hedging" (zero to light, moderate and severe) was assigned to each habitat surveyed. These classes describe the appearance and length of the second year growth below the current year's leaders (Cole 1958). Shrubs are lightly hedged if the second year's growth is lengthened and only slightly clumped or unclumped, moderately hedged if it is lengthened and only moderately clumped (Figure 9), and severely clumped if it is relatively short and strongly clumped or "broom" shaped (Cole 1958). Figure 10 illustrates this difference.



Figure 8. Typical beaked hazel shrub in ROW containing current annual growth



Figure 9. Beaked hazel shrub with moderately clumped second year growth

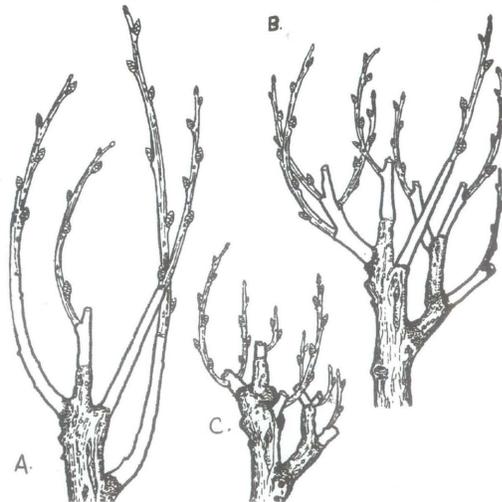


Figure 10. Three degrees of "hedging" A: Low B: Moderate C: Severe (Cole 1958)

As previously mentioned, there was a total of 3 transects containing 120 tagged and measured beaked hazel shrubs for each of the two forest habitats (aspen and mixed-wood) adjacent to the transmission line. This sampling method (point-quarter) was also conducted for the forest habitats located in areas not impacted by the transmission line ROW. These areas are composed of mixed-wood or aspen forests with the occurrence of natural openings of grassland or “meadow”. In this study, they are referred to as “neighbouring natural areas” or NNA’s, and contain randomly located browse transects within forested habitat.

3.5 Data Analysis Techniques for Browse Data

The following is a description of the types of analyses used to compare browse use between habitats. This includes analysing differences in mean amounts and proportions of growth removed from beaked hazel branches, comparing expected and observed values for browsed plants and lastly, determining differences in clip diameters.

3.5.1 Browse Production

Since plant biomass (weight of available standing browse) was not measured for this study, the sum of the lengths of new beaked hazel growth (cm) from 120 branches will serve as indicators of browse production. Total amounts measured (in m) will be used for comparative measures across the habitats surveyed.

3.5.2 % Browse Use

Browse or “utilization” data can only be used to reflect pressures exerted by ungulates on certain food species (Smith and Urness 1962). Browse use in this case, will therefore be described in part by the proportion of available twigs lengths removed from beaked hazel

branches, the mean length removed per branch, and also as the *total* or combined length of current annual growth removed from all surveyed shrubs. Required for these analyses are the measurements of available browse (current annual growth) in the fall, and a re-measurement of remaining lengths in the spring.

Habitat use, as indicated in part by the % of browse used, is defined as the proportion of browse removed relative to its availability. The percentage used is calculated as:

$$\frac{\text{Fall length of twigs} - \text{spring length of twigs}}{\text{Fall length of twigs}} \times 100$$

Some restrictions apply when using this method to determine browse use. For instance, proportion removed data does not incorporate estimates of plant biomass removed. It only describes the intensity of herbivory on an average beaked hazel branch.

Since this calculation produced proportional data, a transformation would be required to change its numerical scale to one suitable for parametric statistical tests. The browse use data contained extreme values nearer to 0 % and 100 % thereby necessitating the use of the arcsine transformation (Krebs 1999). Following this transformation, differences between mean proportions used were tested using Student's t-tests. Although 120 plants were measured for current annual growth, only those shrubs browsed by ungulates over the winter period were used from each habitat to calculate the p-values produced by the Student's t-tests. A total of 10 Student's t-tests were conducted on the % browse use data.

3.5.3 Browse Consumption

As mentioned in the previous section, included in the analyses of browse are comparisons of the mean amount of twig lengths removed per branch (includes only the current annual growth) between habitats. Amount of beaked hazel removed (cm) per branch by ungulates will

be tested for differences in means using Student's t-tests. Again only shrubs exhibiting tissue loss by ungulates will be considered for the analysis. P-values will also be compared to a Boniferroni corrected alpha value of 0.005 (Krebs 1999).

Total length (of annual growth) removed from all shrubs browsed within each habitat will also be calculated. This is important as total lengths removed can be used to identify habitats experiencing heavier use when compared to other habitats. Data regarding % use provides information on browsing intensity (the proportion of annual tissue being removed) per beaked beaked hazel branch but lacks information on how much forage is being consumed. Analyzing these two variables together is needed to produce a more concise description of browse use.

3.5.4 Number of Beaked Hazel Plants Used

To determine whether there is a significant difference between the number of plants used between the various habitats sampled, a Pearson's Chi-square test will be performed. Data will be transformed into use (1) as described by having at least one measured twig clipped by an ungulate, and non-use (0), having no twigs clipped. The number of 1's and 0's will be tested against the null hypothesis that there is no difference between the number of expected and observed browsed plants. P-values will be compared to a boniferroni corrected alpha ($\alpha/n = 0.05/10$) value of 0.005. This corrects for multiple comparisons to maintain a consistent overall error rate (Krebs 1999).

3.5.5 Clip Diameter at Point of Browse (dpb)

Ungulates clip twigs at different diameters when browsing shrubs and trees. These differences are more pronounced with seasonality, reflecting the decline in food quality with an increase in clip diameter towards late winter. Of particular interest in this study is whether or not

moose clip twigs at different diameters in response to habitat type (which may reflect quality and thus habitat choice). To determine this, diameters at point of browse (dpb), will be measured using an electronic caliper, to the nearest hundredth of a millimeter. For each plant, clip diameters will be averaged, producing no more than 120 diameter values per habitat. The means of these dpb values will be compared using Student's t-tests.

3.6 Beaked Hazel Density Estimation

The point-quarter method used in the browse sampling design was chosen not only for its ability to select shrubs randomly for browse measurements, but moreover for its reliability as a tree density estimation method (Beasom and Haucke 1975). This method, first used in plant ecology by Cottam *et al.* (1953), requires measured distances from a center point located randomly along a transect, to the nearest tree, or in this case, shrub occurring within each of the four quadrats (Krebs 1999). Thus, each point along the transect will generate 4 distance measures which will be used in calculating an unbiased estimate of population density for beaked hazel. It is important to note that only the nearest "browseable" beaked hazel shrub was included for measurement. This bias factors in food choice by moose. Prostrate beaked hazel shrubs (those which were flattened by previous years heavy snowfalls) were avoided for sampling because they appeared to be avoided by moose. Therefore, beaked hazel density will be considered "browseable beaked hazel density" and may not reflect the total beaked hazel density.

The formula for estimating population density is as follows (Krebs 1999):

$$\tilde{N}_p = \frac{4(4n-1)}{\pi \sum (r_{ij}^2)}$$

where \tilde{N}_p = Point-quarter estimate of population density of beaked hazel

n = Number of random points

π = 3.14159

r_{ij} = Distance from random point i to the nearest organism in quadrant

$$j (j = 1,2,3,4; i = 1,\dots,n)$$

$$\text{Lower 95\% Confidence Interval} = \frac{\text{sqrt}(16n-1) - z_{0.5+\alpha/2}}{\text{sqrt}(\pi \sum_{ij} r_{ij}^2)}$$

$$\text{Upper 95\% Confidence Interval} = \frac{\text{sqrt}(16n-1) + z_{0.5+\alpha/2}}{\text{sqrt}(\pi \sum_{ij} r_{ij}^2)}$$

Beaked hazel density is calculated for each of the 6 habitats as plants/ha. This method assumes that the points along transects are spread out sufficiently so that no quarters from consecutive transect points overlap, thus preventing the sampling of a plant in more than 1 quarter. In addition, the spatial distribution of plants should be random across the landscape. A dominate understory shrub in RMNP, beaked hazel appeared ubiquitous, yet not random throughout the entire study area. Density estimates using the point-quarter method are thus biased if the plant in question has a clumped distribution (Krebs 1999). It is important to note that since beaked hazel had a clumped distribution, the density estimations presented here are likely overestimated.

3.6.1 Basal Diameter

The basal diameter in this study is defined as being the diameter of the stem or the main stalk, before it branched off into multiple twigs with twiglets. In the case where the selected beaked hazel shrub does not branch and is composed of only 1 stem, the basal diameter will be taken at the point below the current year's growth. If the stem is completely composed of the current year's growth, the basal diameter will be measured at a height of 50 cm. Basal diameters will also be measured to the nearest mm using an electronic caliper.

3.7 Overview of Track and Pellet Counts

Counting moose tracks and pellet groups during mid- winter can be as accurate as counting the animals themselves when estimating populations (Lautenschlager and Jordan 1993). Usually these methods are conducted after an aerial survey and often reinforce the aerial census results. Pellet group counts however, generally follow spring thaw, when snow cover is absent and aerial surveys cannot be flown (Eberhardt and Van Etten 1956). Such counts enable researchers and managers to measure population fluctuations, verify big-game habitat selection and seasonal use patterns (Stordeur 1984; Peek *et al.* 1976; Franzmann and Arneson 1976; Neff 1968). Part of the investigation will reveal if moose utilize transmission lines as travel corridors in the boreal forest. The presence of tracks will be the most significant indicator of such use.

3.7.1 Pellet Group Count

Bennett *et al.* (1940) were the first to develop the method of counting fecal pellet groups to estimate deer populations in the late 1930's. Since then, pellet count surveys have been refined and are now commonly used as a tool in determining wildlife densities and habitat use (Forbes and Theberge 1993; Neff 1968). According to Heikkila and Harkonen (1998), browsing studies indicated that pellet group density correlated positively with browsing intensity. Not only was pellet group density used to indicate moose activity, but also to estimate habitat use by moose. This was also the case in British Columbia, where pellet group counts were widely used as a technique to identify those habitats of great importance to ungulate populations (Stordeur 1984). Pellet counts can be conducted during winter, when tracks and pellet groups are highly visible following a fresh snowfall (Lautenschlager and Jordan 1993) or as more commonly done, in spring, after snowmelt. The advantage of a winter pellet count is reduced sampling variability

as mid-winter defecation rates are expected to be more uniform than those extending through fall to spring (Lautenschlager and Jordan 1993). However, since winter counts require the removal of counted pellet groups, and thus large time and energy investments, they are most often done for research purposes rather than as management techniques.

Pellet group surveys conducted in the spring occur immediately after snowmelt and before leaf emergence. Only the pellets dropped after leaf-fall are counted. Pellets from that winter should be lying on the leaf litter dropped the previous fall (Figure 11). “Old” groups from previous seasons should not only be covered up by leaf litter and other dead vegetation but also differ in texture and colour. Spring and summer pellets lack distinct form and are more clumped together due to the high moisture content in the vegetation consumed at that time, whereas pellets from previous winters will show signs of decay, insect infestation and or be dark brown to black in colour.



Figure 11. Moose pellet group deposited after previous year's leaf drop.

3.7.1.1 Survey Design

The literature describes many ways to conduct pellet group counts for various species including deer, moose and snowshoe rabbit (Lautenschlager and Jordan 1993; Neff 1968; Van Etten and Bennett 1965; Smith 1964). The question being asked in this study is whether or not moose show preference for certain types of habitats, namely the ROW versus the adjacent transmission line forest habitat. Therefore, relative abundance of pellet groups will be compared across the different habitat types in RMNP to determine whether inferences can be made with regards to habitat choice.

Pellet counts were initiated as soon as the ground was free from snow in the spring of 2002. A series of belt transects 4 m x 45 m on the ROW and 4 m x 80 m in the forest were randomly chosen for this survey. Random numbers were generated in Excel. Transect boundaries were easily delineated and moose pellet groups were highly visible. If more than half of the pellet group fell outside of the belt transect, it was not counted. The entire rectangular belt transect was searched for moose pellet groups deposited on the previous fall's leaf litter. In areas where leaf litter was non-existent, such as found in areas on the ROW, only pellets lying on the grasses were counted. Pellets that appeared dried out and flaky or black in colour were considered "last years" and thus were not counted.

In order to determine sampling intensity, which varies inversely with pellet group density, it was necessary to conduct a preliminary survey of pellets on temporary belt transect plots located within the study area. These counts provided the necessary estimates of mean pellet-group density and variance as well as some idea of pellet group distribution (Neff 1968). Sample size was then calculated on these values using an effect size of 1 (difference of 1 pellet group) and power of 80%. From this it was determined that a minimum of 36 belt transects, were required in each habitat. Transects for all areas sampled were randomly chosen using

numbers (between 4 and 30) from a random number table generated in Excel. ROW pellet transects were paired with forest pellet transects in areas along the transmission line. This meant that where a belt transect occurred on the ROW, one continued for the same distance in the adjacent forest.

3.7.1.2 Pellet Group Count Analysis

In certain areas of North America, among certain ungulate populations, the occurrence of ungulate pellet groups follows a negative binomial distribution (Stormer *et al.* 1977; McConnell and Smith 1970; Bowden *et al.* 1969; Neff 1968). This clumped pattern of pellet groups is usually a result of winter “herding” behaviour by moose, caused by an increase in snow depths. Since this behaviour is relatively uncommon in RMNP (Crichton 2002 pers. comm.), pellet group frequencies were not expected to follow a negative binomial distribution. Based on the data that was collected, the resulting distribution of pellet groups followed a poisson distribution. Consequently, the well-refined, widely used negative binomial statistical analyses was not appropriate for this data but instead, an alternate type of analyses was required. One test that could be used to test differences in pellet group occurrences was the Monte Carlo simulation (Manly 1997).

A Monte Carlo simulation tests the significance of an observed test statistic by comparing it with a sample of test statistics. In the statistical package “R” a matrix of paired pellet group counts were created using data collected from the ROW and transmission line forest belt transects. Thus, separate matrices, one from the aspen habitat and the other from the mixed-wood habitat, were created. A chi-square test generated the expected values for the new randomly created matrices using the same marginal probabilities (based on the row and column sums) of each matrix. From these new matrices, a new statistic called “ ϵ ” was formed. The

significance of the original statistic was then tested by determining its p value from the null distribution. The null distribution was generated 999 times by the randomized matrices. A total of 999 “ ϵ ” statistic values were created and compared to the original statistic.

This analysis will determine whether or not the 2 triangles produced in the pellet count table or “matrix” are symmetrical. Symmetrical triangles would show no difference in the probability of a pellet group being in the ROW or the transmission line forest habitat.

3.7.2 Track Counts

This method is often used in conjunction with aerial surveys when determining moose densities in a given area. It is recommended for more precise population estimations. This method cannot only be used to determine wildlife densities, but also wildlife activity levels. In Quebec, a large-scale project on moose winter use of transmission line ROWs used helicopters to fly over a series of 120 km by 500 m long transects while observers recorded the number of moose tracks and trails (Ricard and Doucet 1999). This census helped determine differences in moose activity levels between ROW and adjacent forested areas.

3.7.2.1 Survey Design

For each of the 2 habitats along the transmission line (mixed deciduous and aspen forest), there was a 300 m transect both on the ROW and in the adjacent forest. The forest transects were 100 m east or west from the ROW and ran parallel with the ROW transect. The width of all transects was approximately 45 m, the width of the ROW. Every set of moose tracks crossing this wide transect was counted. The number of pellet groups and beds were also recorded. In the control sites, transects 100 m in length were used in the forested areas and 300 m in the open meadows.

3.8 Aerial Survey Technique

Aerial surveys have always been the most widely used method for estimating ungulate populations in North America (Timmermann 1993). The method involves using a fixed-wing aircraft (or helicopter) to fly over a designated survey area, while 2 observers record the number and distribution of moose that occur along a transect line (a predetermined line on a topographic map). Aerial surveying (strip-transect method) uses a repeatable, standardized survey design to produce population estimates with associated variance and confidence intervals (Miller *et al.* 1998).

Although aerial surveys are the best method to use when counting and estimating the density of scattered populations of large animals such as ungulates, they do have some restrictions. Weather is the greatest determinant of when surveys can be conducted. Not only is it important to have good flying conditions, but overcast days followed by snowfall are optimal. Contrast between animal and landscape is imperative for accuracy of counts. For this reason, during years of low or no snow cover, surveys are not conducted. Precision of counts can also be affected by observer experience and accuracy, by snow conditions and temperature, by habitat and terrain and by time of day. To avoid perception bias, it is necessary to have 2 independent, experienced observers in the plane.

Moose populations in RMNP have been determined via aerial surveys for many years during the last 3 decades provided there was sufficient snow cover. Surveys are usually flown at the end of January/early February when weather conditions are optimal. Co-ordinates for Flight-line Waypoints are downloaded into a Garmin Global Positioning System (GPS 111 XL) using North American Datum 1983 (NAD83). A Cessna 206 (CG-EXT) from Dauphin Air Service, flies at approximately 120 m above ground, while observers record ungulate sightings within a 1/8 mile (200 m) field of view marked out on the windows with masking tape (Parks Canada

unpublished data). Two observers, one on each side of the plane search for ungulates and record their positions using a Garmin Global Positioning System (GPS 111 XL). These data points, along with their location relative to the transect line are keyed into a laptop computer containing Fugawi software and saved to disk for future analysis (Parks Canada unpublished).

3.8.1 Aerial Survey Data Analysis

The moose aerial survey points for 2002 were transformed into a Geographic Information System (GIS) map layer to illustrate the distribution of moose across RMNP during late winter (January/February). To determine which habitats are preferred by moose at this time of year, the Forest Resource Inventory (FRI) (Appendix 5 and 6) data was incorporated as a GIS layer and overlaid with the ungulate survey points. These FRI data are considered to have the greatest vegetation resolution as it classifies vegetation at the stand level. From these data, numbers of moose sightings can be roughly grouped into habitat categories to identify habitat choice. Unfortunately, inferring habitat choice through the use of aerial data has many restrictions. For instance, the actual location of the ungulate is not recorded during flights since the aircraft does not depart from the line transect. GPS coordinates for each count are read off the aircraft thus reflecting the planes position rather than the animals. Another factor is visibility bias. Moose in open to semi-open habitats are detected much easier than those within closed canopied habitats, thus creating an over-representation of moose within these areas. Consequently, these results must be interpreted with the full understanding of the biases of aerial survey data.

Chapter 4 RESULTS

4.0 Overview

The following sections deal with the results generated from the data analyses pertaining to browse, pellet group counts, track counts and lastly aerial survey and FRI data. Ungulate aerial survey data are composed of moose GPS locations for the year 2002. They were used in conjunction with the FRI data for RMNP to gain information on habitat preference by moose during the survey period (January/February).

4.1 Browse Production

Browse production estimates are based on the measurement of multiple variables such as stem density, twig counts, twig weights and twig diameters (Goulet 1992; Telfer 1978). In this study, browse production will be reflected through the measured lengths of current year growth. Justification of this comes from the randomized sampling design applied consistently to all habitats surveyed. These samples should be representative of the overall production of browse within the habitat in question. For instance, the greatest amount of available browse (175 m) was seen in the MTLF (Table 1). The remaining habitats, AROW (105 m), MROW (103 m) ANNA (92 m) and the MNNA (93 m), all had similar amounts of available browse (Figure 12). The average length of current year growth per twig within the MROW and MTLF were 12.76 cm and 12.53 cm respectively. Larger differences were witnessed between the AROW, which had average lengths of 20.71 cm verses 15.4 cm in the adjacent forest. Interestingly, the mean length of current year growth in the AROW (20.71 cm) was similar to that found in the ANNA (19.48 cm). The MNNA had similar values as the other mixed-wood habitats, with an average of 13.03 cm of current annual growth per twig.

Table.1 Browse statistics for beaked hazel shrubs measured in each of the surveyed habitats

	Habitat					
	Mixed-wood			Aspen		
	MTLF	MROW	MNNA	ATLF	AROW	ANNA
Total length before (m)	175.16	103.14	93.29	102.65	105.03	92.65
Total length after (m)	105.16	37.34	47.41	74.97	57.68	48.78
Total length removed (m)	70	65.8	45.88	27.68	47.35	43.87
Average length / twig (cm)	12.53	12.76	13.03	15.4	20.71	19.48
Average # twigs / branch	12.33	7.2	6.4	6.2	4.95	5.1
Density of plants / ha	2208	429	458	3058	6066	21912
Upper/Lower Confidence Intervals	2637/1841	513/358	547/382	3654/2551	7247/5060	26176/18277
Basal diameter (mm)	7.72	5.92	5.87	6.21	5.7	6.3

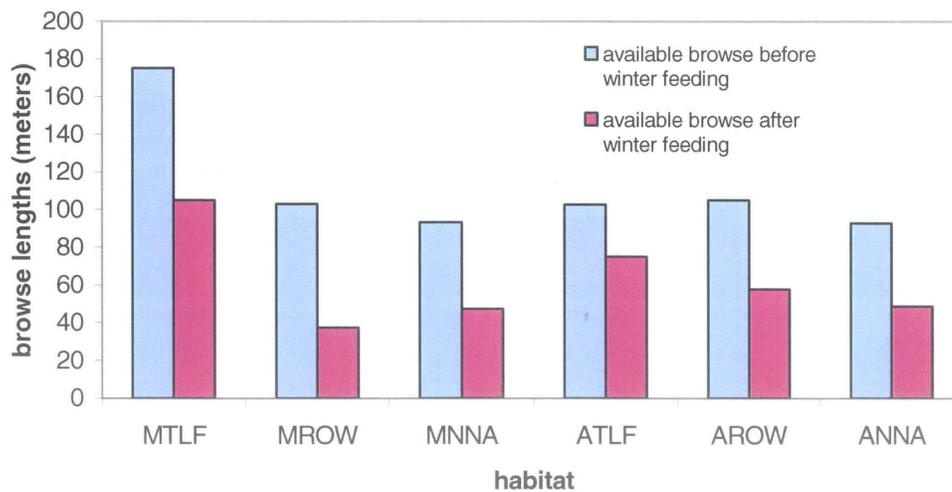


Figure 12. Available current annual browse lengths (m) before and after winter feeding by moose

Not only are lengths of current annual growth important when investigating browse availability, but also average number of twigs per branch. Together, these plant characteristics contribute to the overall availability of browse. Average length per twig in the MTLF was the

lowest (12.53 cm) from all habitats measured despite its total amount of available browse (175 m) (Table 1). The most important contributing factor to this measured amount of browse is the mean number of twigs per branch. The MTLF had the highest average number of twigs at 12.33 per branch. The data show that as leader length increases, mean number of twigs per branch decreases. This relationship between leader length and twig number is apparent in Figure 13. The AROW illustrates this relationship with the greatest average leader growth per twig at 20.71 cm, and the lowest average number of twigs per branch at 4.95. The remaining habitats fall somewhere in between these two extremes; the MROW had the second highest mean number of twigs per branch at 7.2, followed by MNNA (6.4), ATLF (6.2), and lastly ANNA (5.1). Average current annual length per twig increased for all habitats with decreasing mean number of twigs.

Shrub densities were calculated to assist in the understanding of browse use among the different habitats. The highest estimated “browseable” shrub densities were noted in the ANNA (21912 plants/ha) and AROW (6066 plants/ha), whereas the lowest occurred in the MNNA (458 plants/ha) and MROW (429 plants/ha). Moderate densities were estimated in both transmission line forests, approximately 2208 plants/ha in the MTLF and 3058 plants/ha in the ATLF. The 95 % confidence intervals for these density estimates are included in Table 1 and illustrated in Figure 14 (for estimate calculations see Appendix 2).

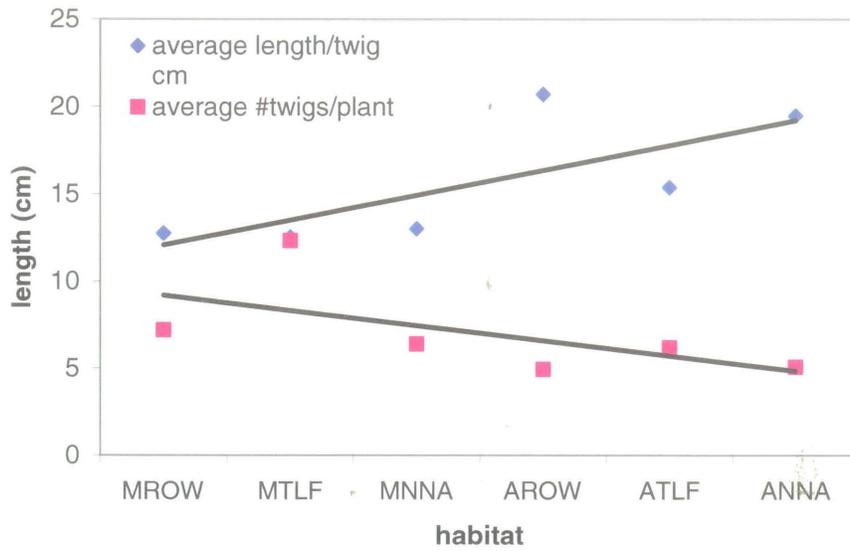


Figure 13. An illustration of the relationship between the average length of current annual growth (cm) per twig and the average number of twigs per measured beaked hazel branch

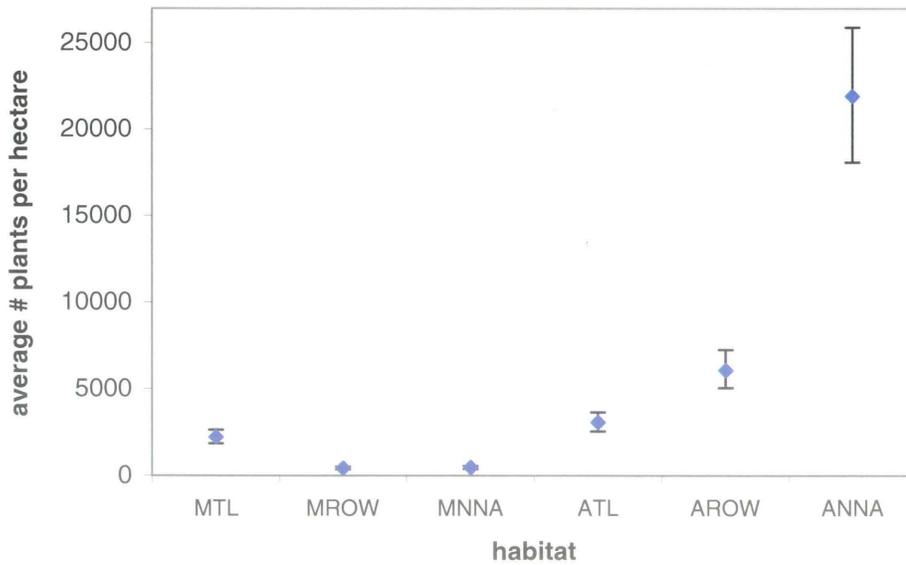


Figure 14. Mean number of beaked hazel plants/ha for each habitat surveyed

4.2 % Browse Use

Not only can browse use be described through amounts of current growth removed but it can also be expressed as the proportion of the current year's growth removed relative to its availability. For instance, the highest average proportions removed occurred in the MROW habitat, followed closely by the MNNA (Table 2). The most productive habitat in terms of browse production, the MTLF, experienced the lowest average proportion removed. These data were analyzed using Student's t-test in order to determine whether there were significant differences in the average proportions removed between habitats (Table 2). A comparison of mean % browse use (average use of beaked hazel branches that were browsed upon) between aspen and mixed-wood habitats yielded a significant difference ($p = 0.00035$). Further comparisons using this test indicate significant differences between the MTLF and its adjacent ROW ($p = 0.00004$) as well as the MTLF and the MNNA ($p = 0.003$). There were also significant differences between the MROW and the AROW ($p = 0.000026$) and finally between the ANNA and MNNA ($p = 0.003$). Within the aspen habitat, there were no statistical differences as p - values were greater than the Boniferroni corrected alpha value of 0.005.

The greatest *total* % use was witnessed in the MROW (59.16 %, Figure 15) followed by the MNNA (46.62 %). Total % use is calculated using all 120 surveyed shrubs, unlike the average % use per *browsed plant* data, which excluded plants that had not been browsed. The ANNA, MNNA and AROW all show similar levels of browse use. The AROW had 44.9 % use whereas the ANNA had 41.51 % use. Both transmission line forests had much lower levels, the MTLF with 31.7 % and the ATLF with 24.4 %. For 95% confidence interval estimates see Appendix 2 (Table 2).

Table 2. Student's t-test statistics on habitat comparisons of the proportion of current annual growth removed from each marked beaked hazel branch browsed by moose during winter of 2001-2002. Proportions were arcsine transformed.

a.)

	All Mix	All vs Aspen	MTL vs ROW	MTL vs MNNA	MROW vs MNNA
Mean	0.966	0.867	0.831	1.017	1.016
S.E.	0.02	0.0186	0.032	0.029	0.039
N	254	230	68	103	83
P	0.00035*		0.00004*		0.00052*

b.)

	MROW vs AROW	MTL vs ATL	ATL vs AROW	ATL vs ANNA
Mean	1.017	0.86	0.83	0.95
S.E.	0.029	0.22	0.032	0.040
N	103	95	68	46
P	0.000026*	0.019	0.029	0.088

c.)

	ANNA vs AROW	ANNA vs MNNA
Mean	0.8602	0.86
S.E.	0.0329	0.022
N	89	95
P	0.998	0.003*

* indicates significance $p < 0.005$

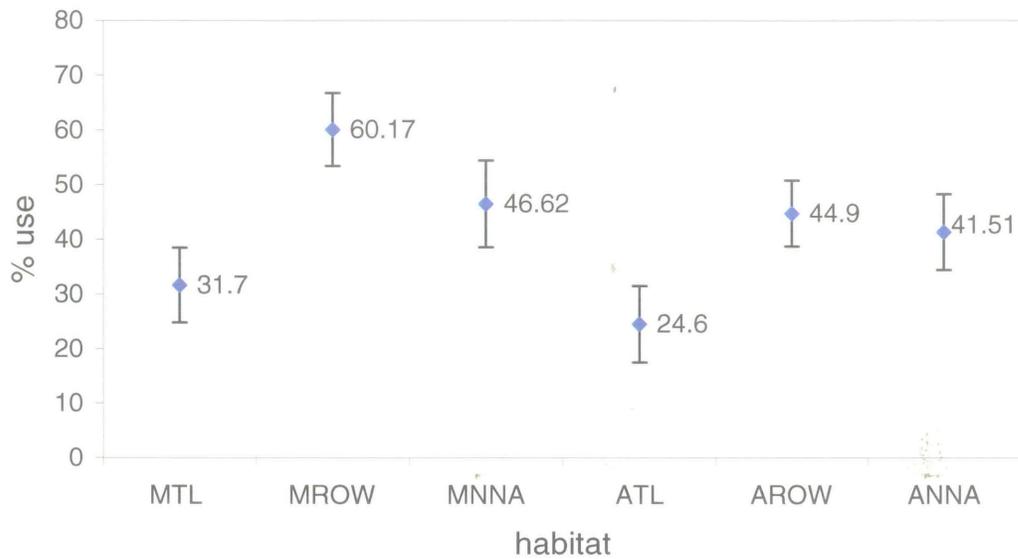


Figure 15. Mean total % use (per branch) of available beaked hazel browse within each surveyed habitat

4.3 Browse Consumption

Unlike % use, browse consumption deals with total amounts of current annual growth removed from beaked hazel by ungulates. This amount expressed in m, reflects biomass removed from a habitat. It is an absolute quantifiable measure of habitat use that in conjunction with % use gives an accurate idea of the overall degree of habitat utilization by ungulates. It should be noted that for statistical analyses, average amounts removed per plant were calculated using data only from shrubs that had been browsed.

There was an overall difference between the amounts removed per branch between the aspen and mixed-wood habitat types surveyed. Student's t-test revealed a significant difference between aspen and mixed-wood habitats ($p = 7.6 \times 10^{-6}$) (Table 3), with the mixed-wood habitat having the highest average length removed per branch (71.5 cm) (Table 3). Differences in average amounts removed per branch were also found between the MTLF and adjacent ROW (p

= 4.16×10^{-4}). MTLF and MNNA ($p = 0.00025$) showed differences, including the MROW and AROW ($p = 0.0028$) and MTLF and the ATLF ($p = 0.00079$). Student's t-test results indicate that there is no difference between the MROW and the MNNA ($p = 0.124$). Although total amount removed is significantly different between these habitats, average amount removed per beaked hazel branch is similar.

Table 3. Student's t-test statistics on habitat comparisons of the amount of current annual growth removed (cm) from browsed beaked hazel branches during the winter of 2001-2002

a.)

	All Mix	All vs Aspen	MTL vs MROW	MTL vs MNNA	MROW vs MNNA
Mean	71.527	51.359	102.93	63.88	102.93
S.E.	3.945	2.04	11.89	4.02	11.89
N	254	230	68	103	68
P	0.0000076*		0.000416*		0.0002543*

b.)

	MROW vs AROW	MTL vs ATL	ATL vs AROW	ATL vs ANNA
Mean	63.88	49.84	102.93	58.89
S.E.	4.02	2.31	11.89	4.3
N	103	95	68	46
P	0.00287*	0.000792*	0.068	0.127

c.)

	ANNA vs AROW	ANNA vs MNNA
Mean	49	49.842
S.E.	4.083	2.313
N	89	95
P	0.858	0.256

* indicates significance $p < 0.005$

The greatest total amount of browse removed (70 m) (Table 1, Figure 16) was seen in the MTLF with an average of 102.9 cm per beaked hazel branch (Table 3). The adjacent ROW had the next highest amount removed (66 m) with an average of 63.3 cm per branch. The least total amount removed occurred in the ATLF (28 m) (Table 1; Figure 12), which averaged 59 cm of

length removed per branch. Out of a possible 120 plants, only 47 experienced browsing by ungulates thereby producing such low values for total amounts removed. When the ATLF was compared to the AROW habitat, Student's t-test revealed no significant difference in average amounts removed per beaked hazel branch ($p = 0.068$) (Table 3). Apparent differences occur only when total amounts before and after are examined. For instance, within the AROW, over 47 m of plant biomass was removed from 105 available m compared to a removal of only 27 m from an available 102 m in the ATLF (Table 1). Similar amounts removed were witnessed in the AROW, ANNA and the MNNA (47 m, 44 m, 46 m respectively). Student's t-test results support this, as no significant differences between average amounts removed per branch were found between ANNA and AROW ($p = 0.858$), or between ANNA and MNNA ($p = 0.256$). For 95 % confidence intervals see Appendix 2 (Table 3).

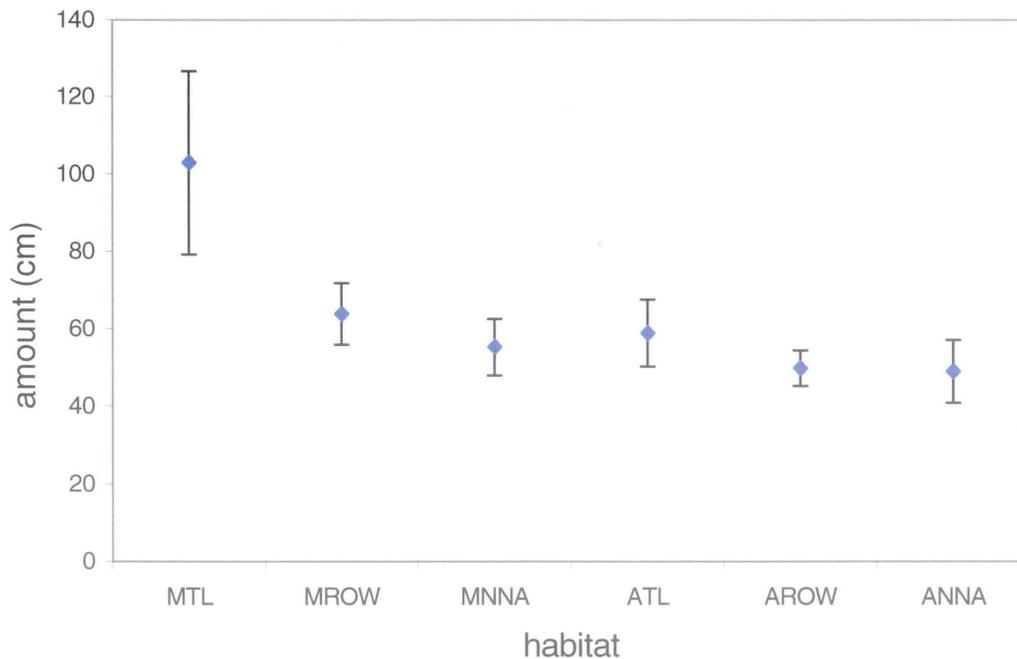


Figure 16. Average amount of current year growth removed (cm) per beaked hazel branch

4.3.1 Chi-Square Analyses of Use

Chi-square tests were used to determine if there were significant differences between observed and expected frequencies of browsed and unbrowsed beaked hazel branches across the surveyed habitats. If a beaked hazel branch was browsed by an ungulate, even to a small degree, it received a value of "1". Branches showing no evidence of browse received a value of "0".

When the chi-square test was applied to the mixed-wood habitats (MROW, MTLF, MNNA), there was a significant difference ($p = 4.3 \times 10^{-8}$) between observed and expected values (Table 4). This is also true for the aspen habitats ($p = 1 \times 10^{-11}$). Within both of these inter-habitat comparisons, the ROW habitats produced the highest number of observed browse values (1) and the TLF's, the lowest (Appendix 3, Table 1). When all habitats (mixed and aspen) were tested against the null hypothesis (that there is no difference between observed and expected number of browsed plants) the results were significant ($p = 4 \times 10^{-16}$). Observed values for use (1) within the ROW and NNA habitats were greater than expected. Only the TLF areas produced fewer use values (1), and more nonuse values (0) than expected (Appendix 1, Table 1). A significant difference between observed and expected values was found between the MTLF and the MROW ($p = 5 \times 10^{-7}$). More browsed values (1's) were observed than expected in the MROW habitat (103/85.9 respectively) whereas less were observed in the MTLF than expected (68/85.1 respectively). The MROW and MNNA also were significantly different ($p = 0.001$). No difference was found between the MTLF and MNNA ($p = 0.077$) (Table 6).

A significant difference did occur between the mixed-wood and aspen TLF ($p < 0.003$), with the MTLF having higher browse values (68) than the ATLF (46). AROW and the ATLF were significantly different ($p = 2 \times 10^{-10}$) as was the ATLF and ANNA ($p = 2.4 \times 10^{-8}$). For both of these comparisons, the ATLF had more non-use values (0) observed than expected. When the

AROW and ANNA were analyzed, there was no difference in browse use ($p=0.288$). A comparison of the MROW and AROW yielded the same results ($p=0.094$).

Table 4. Chi square test results for the comparison of browsed and non-browsed plant frequencies across all habitats surveyed.

	MIX vs ASPEN	All MIX	MTL vs MROW	MTL vs MNNA	MROW vs MNNA	MNNA vs ANNA
χ^2	80.53	25.06	25.22	3.127	11.44	0.5909
Df	5	2	1	1	1	1
P	$4 \times 10^{-16}*$	$4.3 \times 10^{-6}*$	$5 \times 10^{-7}*$	0.077	0.001*	0.476

	MTL vs ATL	All ASPEN	ATL vs AROW	ATL vs ANNA	AROW vs MROW	AROW vs ANNA
χ^2	8.951	50.97	40.54	31.11	2.807	0.706
Df	1	2	1	1	1	1
P	0.003*	$1 \times 10^{-11}*$	$2 \times 10^{-10}*$	$2.4 \times 10^{-8}*$	0.094	0.401

* indicates significance $p < 0.005$

4.3.2 Clip Diameter

Clip diameters at the point of browse were measured to the nearest millimeter for every twig bitten by moose. These diameters were averaged for each 120 plants surveyed before an average per habitat was calculated. Habitat averages are presented in Table 5 with 95 % confidence intervals illustrated in Figure 17 (for confidence interval estimate calculations see Appendix 2, Table 4). The highest average clip diameter is found in the AROW habitat, followed by the ANNA and ATLF. Mixed-wood habitats have lower averages, with the MNNA having the lowest mean clip diameter at 2.35 mm.

Table 5. Mean clip diameter at point of browsing for beaked hazel in all habitats surveyed.

	MTLF	MROW	MNNA	ATLF	AROW	ANNA
Mean diameter at point of browse (mm)	2.38	2.43	2.35	2.54	2.68	2.59

Although the average clip diameters appear very similar across all habitats, differing in only a few tenths of a millimeter, there is a significant difference between the 2 habitats aspen and mixed-wood when analyzed using Student's t-test ($p = 0.000003$) (Table 6). The only other significant difference was found between the two ROWs ($p = 0.00084$). P-values were compared to a Boniferroni corrected alpha value of $p < 0.005$.

Table 6. Student's t-test results for comparisons of the average clip diameter at point of browse for all habitats surveyed.

a.)

	All Mix	All vs Aspen	MTL vs MROW		MTL vs MNNA		MROW vs MNNA	
Mean	2.39	2.62	2.38	2.43	2.38	2.35	2.43	2.35
S.E.	0.031	0.037	0.054	0.051	0.054	0.057	0.051	0.057
N	254	230	68	103	68	83	103	83
P	0.000003*		0.545		0.691		0.312	

b.)

	MROW vs AROW		MTL vs ATL		ATL vs AROW		ATL vs ANNA	
Mean	2.43	2.675	2.38	2.55	2.55	2.67	2.55	2.59
S.E.	0.051	0.052	0.054	0.065	0.065	0.052	0.065	0.042
N	103	95	68	46	46	95	46	89
P	0.00084*		0.049		0.152		0.64	

c.)

	ANNA vs AROW	ANNA vs MNNA
Mean	2.59	2.35
S.E.	0.072	0.054
N	89	83
P	0.365	0.545

* indicates significance $p < 0.005$

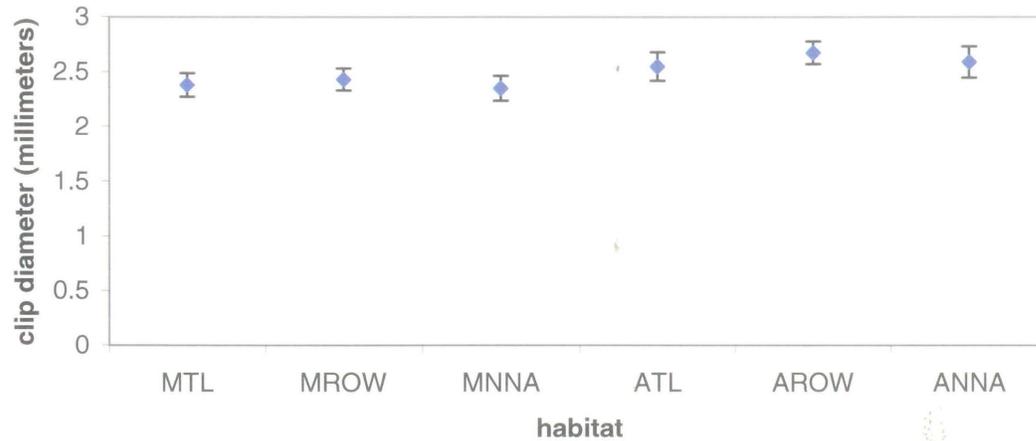


Figure 17. Mean point of browsing clip diameter (mm) for beaked hazel twigs within each habitat surveyed

4.4 Pellet Group Counts

Frequency data obtained for pellet groups surveyed in 36 paired transects (Appendix 4, Table 1) along the ROW and adjacent forest for the mixed-wood habitat are presented in Table 7, and for the aspen, in Table 8. Data collected are considered “paired” for they originate from equal sized transects in both the ROW and forest areas. Transects within the ROW (45 m x 4 m) continue as (45 m x 4 m) transects in the adjacent forest. Highlighted numbers located along the diagonals represent regions where pellet group frequency was equal across the habitats. The 2 triangles created on either side of the diagonal were tested for symmetry using the McNemar chi-square test in the Monte Carlo simulation. Creation of the matrices and analysis of symmetry were carried out using the “R” statistical package (Leisch 2003). The analysis of the mixed-wood matrix indicated no significant difference between the occurrence of pellet groups along the ROW and within the adjacent forest of the mixed-wood habitat ($p = 0.924$). There was however, a significant difference between pellet group occurrence in the ROW and adjacent forest within the aspen habitat ($p = 0.046$). The McNemar chi-square test results are supported by the Monte Carlo simulation results. The analyses produced a new test statistic “ $\hat{\epsilon}$ ”, which

returns the difference between the upper and lower matrix element sums. This statistic “ ϵ ” is accepted or rejected based on the newly created (using the marginal probabilities of the original matrix) null distribution. In the case of the mixed-wood habitat, “ ϵ ” (Table 9) fell within the null distribution, forcing the acceptance of the null hypothesis. Unlike the mixed-wood, the aspen “ ϵ ” value fell on the tail of the null distribution forcing the rejection of the null hypothesis.

Table. 7. Pellet count frequency data for 36- 180 m² transects in the MTLF and MROW habitat.

MIXED WOOD					
Row	No. of pellet groups	Forest			
		0	1	2	3
	0	9	2	1	3
	1	1	5	4	0
	2	1	3	5	0
	3	1	1	0	0

Table. 8. Pellet count frequency data for 36- 180 m² transects in the ATLF and AROW habitat.

ASPEN						
Row		Forest				
		0	1	2	3	4
	0	1	0	1	0	0
	1	5	4	2	0	1
	2	0	6	1	0	0
	3	4	4	1	2	0
	4	2	1	1	0	0

Table 9. Monte Carlo results for the analysis of the matrices (Table 7 & 8) of paired pellet group data in ROW and adjacent forested habitats

	McNemar's chi-squared test				
	X ²	df	p-value	ε	within Null distribution?
Mixed-wood TL forest vs ROW	0.4762	3	0.924	3	yes
Aspen TL forest vs ROW	.8	3	0.046*	-20	no

The ANNA had the largest frequency of pellet groups (2.36) per 180 m² transect (Table 10, Figure 18). This was similar to that found within the AROW (2.08) and MNNA (2). Areas containing the least included the MROW (0.94), MTLF (1.11) and the ATLF (1.027).

Table 10. Moose pellet group statistics per 36-180 m² transects

	Mixed-wood			Aspen		
	ROW	TLF	NNA	ROW	TLF	NNA
Mean number of pellet groups per transect	0.94	1.11	2	2.08	1.027	2.36
Variance	0.91	0.0958	1.31	1.33	0.99	1.6
Standard deviation	0.95	0.979	1.14	1.155	0.99	1.26

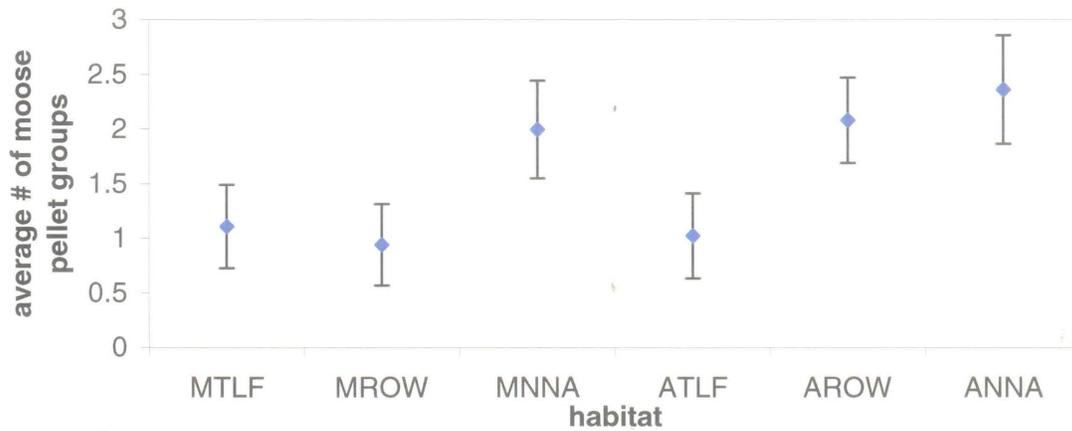


Figure 18. Mean number of moose pellet groups per 36-180 m² transect in each habitat type

Pellet group transects extended for 80 m in the forested habitats to determine if a relationship existed between distance from forest edge and pellet group occurrence. Figure 19 illustrates the distribution of pellet groups within the 36 – 4 m x 80 m (hence 320 m²) forest transects in all forest habitats. There is no obvious relationship between distance from edge of ROW and number of pellet groups.

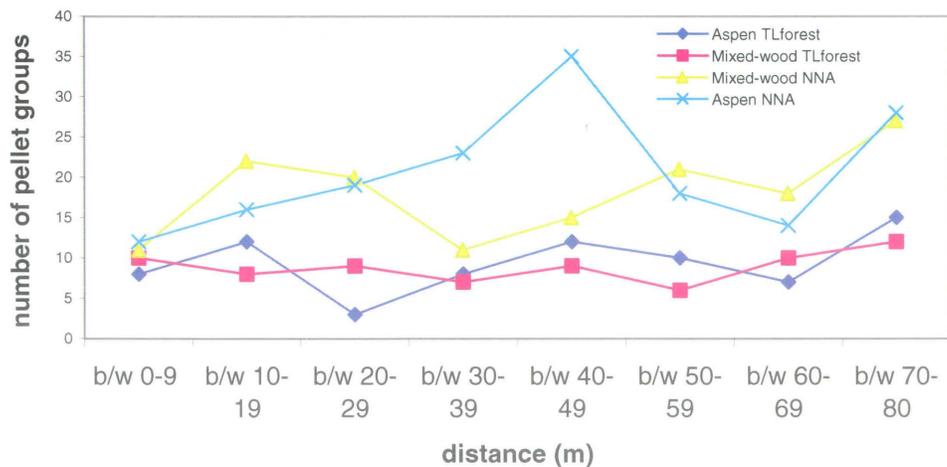


Figure 19. Distance of pellet groups from ROW/forest edge (0 m) into forest (80 m) for 36 – 320 m² transects / habitat type.

4.5 2002 Aerial Survey

By combining the FRI data and moose aerial survey points it is apparent that moose in RMNP are dispersed throughout the entire survey area (Figure 20) (Appendix 5 and 6). The dominant habitat type, aspen forest, covers nearly half of the park (41.1 %) and contained half of all moose sightings (49.9 %). An under-representation of counts occurred in the conifer-dominated habitats, where, although comprising 15.5 % of the park, these regions contained only 9.7 % of moose sightings. Remaining habitats, such as trembling aspen with spruce and balsam fir, beaver floods, moist prairie, and willow contained moose sightings proportionate to their size.

Although the distribution of moose sightings appears similar to habitat size (Table 11), they differed significantly from those proportions expected ($\chi^2 = 78.3$, d.f. = 7, $p = 3.056 \times 10^{-14}$). A closer look at habitat shows that areas with increased visibility (aspen) contained a higher proportion of sightings than expected. Likewise in areas of low visibility (conifer dominated), there were fewer moose sightings than expected. This is consistent with deviations caused by different visibility of moose in the habitats sampled.

Table 11. Percentage of moose survey points occurring in habitats found in RMNP

Habitat	% of aerial counts found within habitat type	% of park area
Trembling Aspen	49.9	41.1
Trembling Aspen with spruce and balsam fir	14.8	16.5
Beaver Floods	6.9	7.6
Moist Prairie	2.8	2
Willow	2.7	3.9
White Spruce (50 % or less) with balsam fir and jack pine	2.6	5.4
Water	2.2	4
Conifer dominated habitats	9.7	15.5

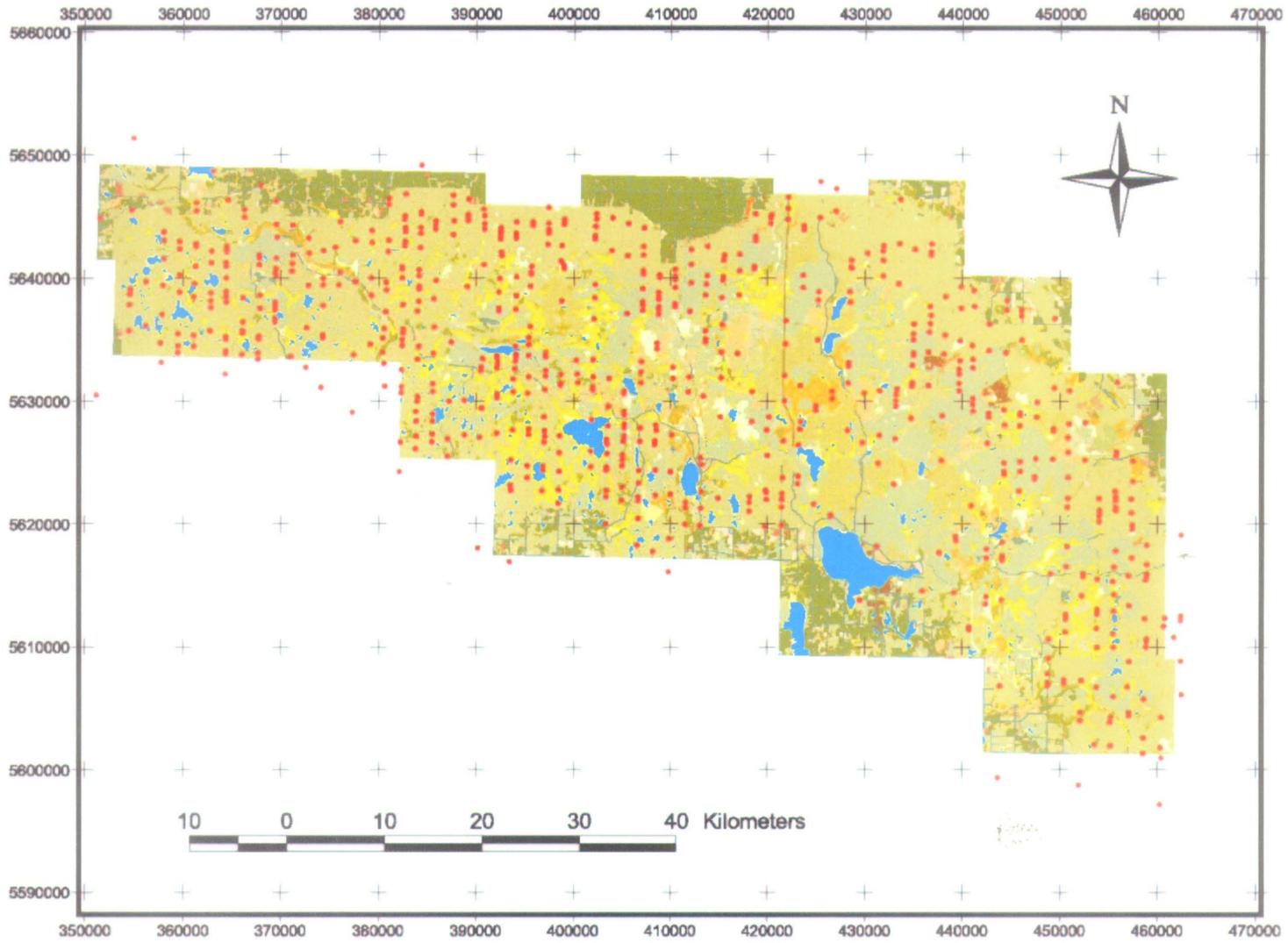


Figure 20. RMNP aerial survey data points for moose in 2002. FRI data in dark green represents aspen forest; areas of light khaki represent mixed-wood deciduous forest.

Chapter 5

DISCUSSION

5.0 Overview

This study was initiated to determine some of the relative contributions a transmission line ROW has on moose habitat use in RMNP. The objectives were to investigate ROW use by ungulates by comparing it to use in the adjacent forest habitat. ROW and adjacent TLFs were also compared to NNAs, areas not affected by anthropogenic factors. Use, as indicated by ungulate activity, is defined as browsing, bedding, traveling and pellet group deposition. Information gathered from these activities will be used to make qualitative and quantitative inferences on habitat use in areas where moose and a transmission line ROW exist.

References to ungulates include moose and elk, and to a lesser extent, white-tailed deer. Deer sign, although infrequent throughout the study area, are present in the park and therefore cannot be completely excluded from the discussion of range use.

5.1 Beaked Hazel and the Transmission Line ROW

Within RMNP there exists a variety of food sources for moose. The importance and use of these resources change seasonally, with the heaviest dependencies on woody vegetation during the winter (Danell *et al.* 1994). Within the park, intensive browsing occurs on favored species such as dogwood, aspen, willow and beaked hazel. Other browse species such as saskatoon (*Amelanchier alnifolia*), paper birch, cranberry (*Vaccinium* sp), and chokecherry (*Prunus virginiana*) are also browsed, but to a lesser extent. These shrubs, including dogwood, are less abundant within the park and are therefore taken in smaller proportions (Trottier and Hutchison 1980). The most abundant source of browse for moose during the winter is beaked

hazel. This shrub not only thrives in great densities as a major understory component in deciduous and mixed-wood forests, but it is considered a staple food item in ungulate winter diets (Trottier and Hutchison 1980).

Although generally a shade-tolerant shrub, beaked hazel does very well in the open ROW meadow-shrubland habitat. Manitoba Hydro created a linear opening (approximately 45 m in width) through dense forest habitat when they constructed the transmission line. This opening would have been quickly occupied by pioneer species and eventually beaked hazel. Since beaked hazel had already occupied the adjacent forest understory, it would have only needed time before it was able to send up new shoots. Lack of competition from other plants and access to full sun would have favored the growth and establishment of this species. Newly established plants would have been subject to browsing, as an open area would have been attractive to moose as an access route to new food patches and for bedding and foraging. Herbivory would in turn promote new growth, giving beaked hazel the ability to out compete other shrub species.

Vibrant shrub communities presently exist across various stretches of the ROW as it passes through a diversity of habitats. This is favorable to vegetation management along the line as shrub communities hamper the encroachment of tree species (Niering and Goodwin 1974). Competition for light and space impedes the establishment and survival of tree seedlings in naturally open or cleared areas occupied by shrubs. Shrub communities not only reduce the amount of available space and light, but they may cover up young seedlings during fall leaf drop. Moose as well as small animals feeding upon young vegetation within the shrub communities also threaten the survival of tree seedlings. For example, young aspen is palatable to moose and therefore selected when available. Heavy use of these trees has resulted in the destruction of aspen seedlings located within the ROW habitat. Despite the suckering response in browsed or damaged aspen, browsing pressure is heavy enough to limit reproductive regeneration in many

aspen. Therefore, an established shrub community is beneficial in keeping trees off the ROW and removed from transmission lines.

Shrub communities along the ROW are dominated by beaked hazel, intermixed with sedges in low areas and grasses and forbs on dry slopes. Shrub densities vary with topography, soils, and vegetation type with large densities existing in ROW areas associated with aspen forest, and lower densities in ROW regions surrounded by coniferous forests. Grasses and flowering plants dominate the mixed-wood ROW habitats, along with the occasional encroaching spruce seedling. Beaked hazel's growth pattern and ability to withstand repeated browsing has enabled it to survive regular line maintenance and wildlife use over many decades.

The interaction of multiple factors permits the sustainability of this unique habitat. The foremost influencing factor is the regular line maintenance conducted every 3-5 years by Manitoba Hydro (Creaser 2002). Mechanical clearing of the ROW removes older vegetation, allowing younger plants a chance to grow. The cutting may also initiate growth in already established beaked hazel shrubs. The second and perhaps as equally influential factor in the control or shaping of the ROW habitat is browsing by ungulates. From winter observations, moose travel on and browse the ROW. Frequent clipping of beaked hazel twigs by moose during winter encourages new leader growth in the spring. Vegetation on the ROW therefore is never allowed to reach "old age", or an unproductive state.

Based on its availability and use by ungulates, beaked hazel was selected for the browse survey. Other shrubs browsed by ungulates, including those previously mentioned, are encountered too infrequently to be included in the browse survey. Beaked hazel was the only shrub found consistently throughout the areas sampled with densities large enough to obtain a suitable sample size of about 100 plants (Cole 1958). According to Cole (1958), this sample size would permit the use of confidence intervals when analyzing data.

5.2 Browse Production

The production of beaked hazel within a habitat is inferred through the data obtained from random sampling along transects. For each plant sampled, lengths of current year growth were recorded for each twig on the sampled branch. The total of these lengths for all 120 plants sampled in each habitat allows for general comparisons regarding browse production amongst the various habitats. For example, within the MTLF habitat, a total of 175.16 m of current year growth was measured (Table 1). When compared to the ATLF, which produced 102.65 m of growth, the MTLF has a greater production of browse. In actuality, it produced the greatest amount of beaked hazel growth over all the sampled habitats. The remaining habitats, aspen ROW, ANNA, MROW and the MNNA all had similar amounts of available browse.

Multiple factors contribute to the apparent differences in the amounts of available browse across the habitats surveyed. Nutrient availability, soil moisture, light availability, age of the shrub and herbivory all influence new leader growth (Danell *et al.* 1994). Nutrient availability may be influence directly through the deposition of moose pellet groups. These feces may promote the growth of beaked hazel by returning nutrients to the soil. Areas associated with frequent moose feeding and bedding would likely experience a greater deposition or concentration of pellet groups. This additional biomass may enhance the growth of beaked hazel to varying degrees. A study on nutrient content of vegetation surrounding woodchuck burrows compared levels of crude protein in orchard grass (*Dactylis glomerata*). Results showed higher levels of crude protein in orchard grass less than 2 m from burrows compared to orchard grass 15 m away. Although this was not examined in this study, plausible differences in beaked hazel browse production across the habitats sampled may in part be due to deposited fecal biomass.

Aside from nutrient availability, differences in plant production may also be due to varying levels of sunlight penetration. Within the sampled mixed-wood forests, the overstory

canopy was semi-open, allowing adequate light penetration to the beaked hazel understory. A more dense, closed canopy was characteristic of the mature aspen forests sampled. Light levels are one contributing factor for the differences seen in the total production of browse.

Another factor affecting the growth response in beaked hazel is pressure exerted by browsing ungulates. Leader growth is initiated by the release of apical dominance through the removal of shoot tips (Bergstrom and Danell 1987). This in turn, leads to branching of side shoots and hence the “broom”-like shape of the shrub’s crown. New shoots are highly digestible and more favorable to ungulates than shoots that have never been browsed (Bergstrom and Danell 1987; Bowyer and Bowyer 1997). The repeated browsing of previously browsed twigs leads to the increased branching or “brooming” of the shrub. Long leaders and multiple shoots are some shrub responses to ungulate herbivory (Danell and Bergstrom 1989). Production of lengthy leaders is considered an adaptive measure to outreach browsers, whereas the production of multiple shoots may reduce the amount of biomass removed by herbivores (Vivas *et al.* 1991). Studies have shown that when presented with multiple twigs containing new growth, herbivores exhibit selectivity for the distal bud-containing twig tips. Smaller bites are therefore taken, resulting in less damage to the shrub (Vivas *et al.* 1991). These interactions between plant and ungulate promote both growth and sustainability of vigorous beaked hazel. However, repeated browsing, if intensive may lead to the ultimate demise of the shrub. Despite beaked hazel’s resilience to mammalian herbivores, like any plant, it can only withstand a certain degree of repeated tissue damage before the plant is killed.

A “broom-shaped” appearance of beaked hazel directly caused by the removal of growth by browsing ungulates is referred to as “hedging”. Cole (1958) gives a description of the three classes or degrees of hedging presented in Figure 5. The most severe degree of hedging was seen in some areas of the MNNA. Beaked hazel within both the aspen and MNNA’s had

moderate to severe degrees of hedging resulting from years of repeated browsing. Even though these areas showed some evidence of extreme over-browsing, as of 2001, beaked hazel shrubs were still producing new leaders with an average length of 13.03 cm of current year growth per twig in the MNNA and 19.48 cm in aspen NNA (Table 1). The mean leader lengths of the ANNA and MNNA are comparable to areas with low to moderate degrees of hedging as witnessed in the remaining habitats surveyed. This indicates that regardless of the apparent years of intensive browsing causing a “broom-shape” appearance of some shrubs, these habitats are still able to produce similar amounts of browse as other not so heavily browsed habitats. Whether or not moose would eventually kill all of the beaked hazel in these habitats would be a question of concern to wildlife managers within the park or in areas where great densities of ungulates occur. Typically, dead standing severely hedged or broom-shaped beaked hazel was found along forest and marsh edges and trails, where access to browsers would be the greatest.

Perhaps of more concern to wildlife managers is the over browsing of aspen seedlings within the park. The high densities of moose within the park have had detrimental effects on the regeneration of aspen in some regions of RMNP. Aspen is a highly palatable, nutritious food that is avidly selected for by moose when available. Being a preferred food, these aspen seedlings are vulnerable to repeated, intensive use resulting in death of the tree. Areas where aspen is attempting to expand into open meadow-like habitats are most vulnerable to over-browsing, as accessibility to these young trees growing along the forest edge is high. Figure 21 shows dead standing aspen seedlings killed by intensive browsing by ungulates along a MNNA forest edge.



Figure 21 a. Dead standing aspen seedlings in MNNA.



Figure 21 b. Dead standing aspen seedlings in MNNA.

In the aspen habitats, mean lengths of the current years growth per twig were greater than seen in the mixed-wood habitats. The highest averages were found within the AROW, which also had the lowest mean number of twigs per branch. Shrubs here are not only younger, but also smaller than those in the forest habitats, with fewer twigs produced. Less competition for light and greater vulnerability to browsers (hence, more browsing) initiates the growth response as indicated by the high averages of growth. In areas where competition for light is greater and shrubs are older, such as found within the ATLF, mean length of current year growth was lower. Average number of twigs per branch was greatest here compared to the adjacent ROW or the ANNA.

The relationship between the mean length of current year growth and mean number of twigs per branch is obvious when displayed in Figure 8. There is a trade-off between length of the leader and the number of leaders a plant can produce. This is so because plants have a finite amount of resources available for growth and reproduction. It appears that if this energy is put into growth of multiple leaders, the length of those leaders will be less than if the plant only grew a few leaders. In the aspen habitats, beaked hazel shrubs generally put more energy into growing longer leaders, but less of them. The opposite is true for the mixed-wood habitats where number of twigs is high and leader length is lower. As previously mentioned, it is theorized that as an anti-herbivore defense, some shrubs produce multiple shorter leaders. Ultimately, some leaders will escape damage from browsers, thereby reducing the loss of tissue that might otherwise have resulted (Vivas *et al.* 1991).

5.2.1 Stem Densities

Also included in determining browse production is density of plants/ha. This, along with other twig characteristics previously mentioned, provide a more detailed picture of food

production, or the potential for browse production within the habitats surveyed. Recall that these density estimates were of the “browsable” beaked hazel shrubs and thus excluded the prostrate or damaged beaked hazel. The habitat greatly influenced by this alteration was the ATLF where beaked hazel incurred the greatest damage. It’s true beaked hazel densities are not reflected in the density estimation of 3058 beaked hazel plants/ha (Table 1). Although the aspen ROW appeared to have lower beaked hazel densities, in actuality, it contained nearly twice the amount of “browsable” beaked hazel (6066 plants/ha) than the adjacent forest. A closer look at ROW shrub morphology, thinner stems (small basal diameters, averaging 5.7 mm as apposed to 6.2 mm in the ATLF) (Table 1), and less branching (an overall smaller % cover/shrub) allows for the observed densities per unit area.

Within the mixed-wood ROW, estimated beaked hazel densities (429 plants/ha) were not nearly as significant as found in the aspen ROW (6066 plants/ha). This area contained a greater mix of grasses and forbs. It did compare to the MNNA, which had approximately 458 beaked hazel plants/ha. Many sampling sites within this habitat contained a large number of shade producing conifers. As a result, the establishment of healthy shrub understories was restricted to open, sunny pockets. Conifer growth within the MTLF influenced shrub densities (2208 plants/ha) but not as severely as witnessed in the MNNA (458 plants/ha). Other factors such as soil conditions, age of beaked hazel and browsing history may also account for this difference in shrub density.

A more realistic representation of beaked hazel density within aspen forests is seen in the ANNA. Beaked hazel here did not experience the same levels of damage as in the ATLF. Their densities (21912 plants/ha) reflect this. Increased light penetration, decreased aspen regeneration and maturation of aspen trees within these areas together contribute to the thriving densities of beaked hazel found here. Although similar in forest characteristics to the ATLF, the ANNA

canopy had less continuity (more open pockets), which allowed for more light penetration and thus a denser understory.

Although important to consider when investigating browse production, shrub density estimates do not necessarily reflect the productivity of an area. For example, a forest containing high densities of beaked hazel may not produce greater amounts of available browse per stem than a forest containing low densities of beaked hazel. Browse studies require the consideration of multiple factors including twig leader length and number of twigs per branch, to produce accurate measures of browse production. Shrub density data may prove more useful when considered in % browse use interpretations.

5.3 Degree of % Browse Use

The remaining part of the browse study was implemented during the months of April and May, 2002, prior to leaf flush. Remaining growth from the selected branches of beaked hazel was re-measured and recorded. These data provided information directly relating to % use and amounts removed. Furthermore, it would provide an indication of whether or not certain habitats were being over-utilized by the local ungulate populations.

Habitat use in this study is reflected in part by browse utilization, has been defined by the amount of browse removed by ungulates, both in terms of total amounts removed and proportions removed from beaked hazel shrubs. Together, total amount removed and % use/branch data provide information on browsing intensity. When analyzed comparatively, total amounts removed indicate whether an area is experiencing heavy browsing intensity. To identify whether or not that area is being over browsed, % use per branch data is considered. For example, the MTLF lost 70 m of browse from an available 175 m. Compared to other habitats, this loss is considerable. However, on average, each beaked hazel branch in that habitat is

experiencing only 30 % use. In this study, this area would be considered moderately browsed. More heavily browsed would be the adjacent ROW, where 66 m of browse is removed from 120 beaked hazel branches. Beaked hazel branches in this area are, on average, experiencing 60 % use. Therefore, it is important that both analyses are considered together before reaching conclusive results regarding browse use.

This section will discuss the results from the analysis pertaining to the “ % use” data, that is the proportion of available browse removed relative to its availability. When mean % browse use *per beaked hazel branch* in the aspen habitats was compared to the mixed-wood habitats, there was a significant difference ($p = 0.00035$) (Table 2). Greater proportions of beaked hazel were being removed in the mixed-wood habitats. This is not surprising since some of the highest *total %* use values came from the mixed-wood habitats. In fact, the habitat that experienced the greatest % use (per beaked hazel branch) is the MROW (60.17 %) (Figure 15). Smith and Urness (1962), feel that use above 50 % may threaten the continued existence of many shrubs and that these areas may suffer from extended overuse. Even if this is factual, shrub communities along the ROW are short lived. Communities may exist for up to 5 years before Manitoba Hydro implements vegetative control measures and removes shrubs and trees along the ROW.

The ANNA, MNNA and AROW all show similar levels of browsing when the average proportions of browse used per branch are compared (Table 2). The same can be said for the ATLF and its adjacent ROW. In fact each sampled beaked hazel branch in all of the aspen habitats experienced the same proportion of tissue loss. But, in the mixed-wood habitats, there were significant differences in the degree of use as reflected by % use of current growth per branch. A comparison of the MROW and adjacent forest show that there is a significant

difference, with the ROW habitat having a higher mean proportion of growth removed relative to its availability per beaked hazel branch than the adjacent forest.

Possible explanations for this apparent difference may include repeated browsing of the same twig within the ROW or less selection of twigs within the ROW. The ROW area presents moose with easily accessed food patches, food patches that may experience heavier browsing intensities resulting from frequent visits by moose. Smaller densities of beaked hazel within the ROW (429 plants/ha) limit the availability of twigs containing new growth. Thus, moose may take greater proportions of the available growth within the ROW in order to meet their energetic requirements. It has been documented that moose will clip smaller bites of new growth in food patches that are of high quality. The abundance of forage within the MTLF forest may allow moose to meet their metabolic needs through clipping the most nutritious and highly digestible part of a dormant plant, the shoot tips. Thus, smaller proportions removed would not be surprising here.

Furthermore, it should be noted that proportions used might appear low if the amount of browse available to moose is high. For example, the MTLF produced the most browse for moose (175 m from 120 beaked hazel branches). If it is assumed that moose consume a finite amount of woody browse in any given day, some highly productive habitats may contain significant amounts of "left-over" available browse at the end of the winter period. Proportions removed may be low but that may be explained by the large quantity of browse available at the beginning of the season. Moose populating this area may not be dense enough to remove more browse than witnessed.

Between the MTLF and the MNNA, there was also a difference in the proportion of beaked hazel growth browsed per branch. Again, the mean transformed proportion was greater in the MNNA than in the MTLF. From the above comparisons, it can be concluded that the

degree of browsing in the mixed-wood ROW is therefore similar to that found within the MNNA. These habitats not only share similar beaked hazel morphology in terms of average twig length and average number of twigs per branch, but also similar beaked hazel densities. The mixed-wood ROW contained an average of 429 plants/ha whereas the MNNA supported on average 458 plants/ha. Results from the Student's t-test comparing % use per beaked hazel branch showed no difference between these 2 habitats. Moose are taking similar proportions of available browse per beaked hazel branch to fulfill their energetic requirements in each habitat.

These results only indicate the average proportion of beaked hazel removed from a branch when it has been browsed upon. What may be of equal or more importance is the *total* amount used relative to the total amount available. For instance, the MTLF lost only 70 m of browse from an available 175 m. To determine the overall % use this habitat was experiencing, the proportion used for each branch browsed was calculated, followed by an averaging of all plants tagged and measured. Due to the loss of plant tags by wildlife activity, some beaked hazel plants could not be relocated for re-measurement. Thus, some habitats had between 117 and 120 samples for averaging. The resulting average use per branch in the MTLF was 31 % (Figure 15). These data are presented as total % use values for each habitat. Again, it takes into account even the unbrowsed plants thereby providing a more accurate picture of total use of the area. For example, the AROW appeared to be more favorable for browsing since a greater proportion of biomass was lost relative to the ATLF. The 2 habitats have nearly equal amounts of available browse but the ROW habitat appears to be experiencing heavier browsing intensities.

Since browsing intensity is reflected in part by the number of plants browsed, a chi-square contingency test was conducted on all habitats to determine if there was a difference between the number of plants used and not used. Results showed a significant difference in the degree of use between the aspen and mixed-wood habitats, with a larger number of plants

browsed in the mixed-wood habitats. Difficulty accessing plants may account for the lower number of shrubs browsed in the aspen habitats. For example, damaged, prostrate beaked hazel in the ATLF may impede travel, leading to a decrease in browsing frequency. Due to heavy snowfalls from previous winters, much of the existing beaked hazel remained prostrate, making travel through the area difficult. Other factors influencing beaked hazel use in aspen regions may include presence of alternate food sources such as red-osier dogwood and the late-winter migration of moose from open canopy forests into closed-canopy forests.

The differences between the total % use values witnessed for ROW and adjacent forest habitats are in part due to the differences in the number of plants browsed upon. A chi-square test revealed a significant difference between the number of used versus non-used shrubs between the ATLF and ROW. It is likely that more shrubs were browsed in the AROW (See Appendix 1, Table 1) due to the accessibility of the beaked hazel along the ROW. In the area of aspen habitat, the ROW is composed of open shrub/grassland habitat that is easily traversable during most of the year. Unlike the AROW, the adjacent forested habitat is dense with not only aspen and black poplar, but also with older beaked hazel shrubs that have been bent over by previous winter's snowfall. As previously mentioned, this may affect travel throughout the forest habitat and thus browsing intensity. Movement amongst browse patches would be somewhat more restrictive here than within the mixed-wood forest or the ROW habitats. Results from the chi-square test support this as numbers of shrubs browsed upon was significantly lower in the aspen forest when compared to the mixed-wood forest. However, travel throughout the ATLF is not completely restricted. There was evidence of travel and browsing along game trails located throughout low-lying areas where beaked hazel density was low.

A chi-square test also revealed a significant difference between the ATLF and ANNA, with the ANNA shrubs experiencing greater use. In fact, there was an overall difference in used

versus non-used plants within the aspen habitat as a whole. All of these habitats share similar amounts of available browse, but differ in the number of plants used by moose. The number of non-use shrubs is partially, reflected by the overall % use values presented in Figure 15. For instance, out of all the aspen habitats sampled, the ATLF had the highest number of unused shrubs, giving it the lowest use value per tagged branch. High % use per branch values were calculated for the AROW which had the lowest number of unused shrubs. Again, these differences can be explained in part by shrub accessibility, encounter rate (shrubs along the ROW would be encountered more frequently than those in forested habitats since the corridor is used for other purposes such as bedding), and presence of alternate food sources.

Within the mixed-wood habitats, a chi-square test revealed a significant difference between the MTLF and MROW, and between the MROW and MNNA. In both cases, the ROW habitat contained a greater number of browsed shrubs than the forest habitats. Again this can be explained by reasons mentioned for the aspen ROW comparisons. Being a corridor used for bedding and travel to new food patches, this area is bound to experience a greater frequency of repeated visits by ungulates.

5.4 Browse Consumption

Analyzing the amount of current annual growth removed from beaked hazel provides an indication of the amount of biomass being removed from a habitat. Since the sampling protocol involved randomization of transects, sampling points and plant selection, the data obtained should be representative of the habitat sampled. Thus, amounts of available browse (m) will reflect habitat quality in terms of production of edible shoots. Although plant biomass data was not collected, amounts, in terms of lengths, should provide a basic measure of the quantity of browse available to ungulates in each of the habitats sampled.

The most accurate or reliable conclusions of habitat use by ungulates are based on total amounts of browse removed from a habitat, rather than solely on % use estimates (Smith and Urness 1962). It is important to note that total amounts of browse removed are limited by the number of moose within the sample area and also by the amount of browse a moose can consume in any given day. It is assumed that densities of moose are similar across the sampling areas. Restrictions on the % use data are that it merely expresses the proportion of the plant tissue under consideration that has been consumed. What is required are amounts removed and % use data, since they are both indicators of "use" that, with understanding of their limitations, will together be included in the assessment of habitat use by ungulates in RMNP.

Of the habitats surveyed in this study, none showed evidence of over-browsing of beaked hazel by ungulates, despite a number of beaked hazel plants experiencing 100 % removal of its current year growth. In the MTLF, beaked hazel appears low to moderately hedged, with moderate leader growth on most shrubs. Since this area contained the greatest amount of available browse (175 m), it is not surprising that it also experienced the highest loss of biomass. What is surprising is that only 31 % of the available browse was used (Figure 15). However, when the forest composition is considered, this is understandable. The MTLF contains a vast amount of beaked hazel dispersed throughout, often in areas of hundreds of square meters. From the amounts removed, ungulates are already taking a significant amount of biomass out of this habitat.

Immediately adjacent to the forest is the slightly less productive ROW habitat. Despite not producing the same levels of browse as the MTLF, the MROW experienced a similar loss of biomass. Ungulates traveling through this extremely productive mixed-wood forest are drawn to the open ROW habitat for one reason or another. In Richard and Doucet's (1999) study of moose use of transmission line ROWs, they accounted for the activity of moose on the ROW as a

result of low quality adjacent habitats. In RMNP, the mixed-wood forests adjacent to ROWs can be considered high quality. There is more than enough browse available for ungulates as indicated by the low % use value and the high amounts of available browse.

Although total amounts of current growth removed in both the mixed-wood ROW and adjacent forest is similar, they differed in the average amount removed per branch. For the MTLF to lose a greater amount of biomass per branch is not surprising considering it had a higher average number of twigs per branch than the adjacent ROW. Despite the large quantity of browse produced by the MTLF, total removal of browse was low. It was comparable to the total loss of biomass shared by the ROW habitat, perhaps due to a significantly lower number of browsed plants than the ROW.

Beaked hazel shrubs within the forest are older (with generally larger basal diameters, Table 1) and larger, giving them the capability to produce more annual growth than smaller (low mean basal diameters), younger shrubs on the ROW. Habitats that produce more are likely to lose more if herbivores are frequenting the area. The low number of plants browsed upon in the transmission line forest can be explained by the extensive availability of numerous beaked hazel shrubs throughout the habitat. Here, moose are likely to follow game trails and low lying wet areas when browsing. This behaviour would leave many shrubs untouched.

There must be potential benefits for moose to move from high quality forage areas (MTLF) into the adjacent ROW habitats. Beaked hazel and seedling growth is limited through regular line maintenance, providing an open mix of grasses, sedges, forbs and shrubs. Travel down or across the corridor in search of new food patches or shelter would present ungulates with the opportunity to browse beaked hazel. Increased use of the ROW as a travel corridor by multiple ungulates would result in an increase in browsing pressure on beaked hazel. Unlike the 100's of m² of beaked hazel found in the adjacent forests, beaked hazel within the ROW corridor

occurs at lower densities within a smaller, defined area. Fewer shrubs in a small area frequently visited by ungulates would experience heavier use. The results support this, as the number of plants browsed upon was far greater in the ROW than the adjacent mixed-wood forest.

When the AROW was compared to the adjacent aspen forest, it was apparent that these 2 habitats differed significantly in absolute total amounts of plant biomass removed, but not so in average amounts removed per plant. Recall that the AROW and adjacent forest share similar amounts of available browse (approximately 100 m). More biomass is being removed along the AROW because more plants are being browsed upon compared to the adjacent forest. Reasons for this are similar to those mentioned for the MROW and adjacent forest comparison. The low number of plants browsed upon in the ATLF may however, be due to travel constraints. As commented on in section 5.2, damaged, prostrate beaked hazel within this forest made travel difficult. Browsed shrubs in the ATLF generally occurred along trails and in semi-open low-lying areas.

The forested habitats, in both circumstances, have on average, a greater amount removed per plant than their adjacent ROWs. Shrubs in the aspen and mixed-wood forests are significantly larger, with a higher mean number of twigs per branch than that found in their adjacent ROW habitats. A significant difference was found when the mean amount of current annual growth removed per beaked hazel branch was compared between the ATLF and MTLF. On average, the MTLF experienced nearly twice as much loss of browse per branch than the ATLF. It also had on average, twice the number of twigs per branch than the ATLF. Perhaps these differences are simply explained by the greater productivity of the MTLF.

In the NNAs, both the mixed-wood and aspen habitats have similar amounts of total plant biomass removed as the aspen ROW. There was no significant difference in the average amount of biomass removed per branch between the NNAs, nor were there any difference between the

ANNA and the AROW. In fact, there was no apparent difference between any of the aspen habitats. Each plant browsed upon in each of these areas experienced a similar loss of tissue. However, the MNNA, is significantly different from the MTLF. There was a greater loss of browse per branch in the MTLF than in the MNNA, perhaps due to a higher number of twigs per branch of beaked hazel than the MNNA. Furthermore, each of these twigs in the MTLF contained a considerable amount of leader growth, resulting in large averages of available browse per branch. The end result were larger amounts removed per branch browsed upon in the MTLF and smaller amounts removed per branch in the MNNA. In this case, the habitat that produced more, lost more. In the MNNA, moose may have to search longer, feeding upon more beaked hazel plants to meet their energy requirements than in the MTLF.

Student's t-test results for mean amounts removed per branch indicate that there is no difference between the mixed-wood ROW and the MNNA. The two areas have similar mean lengths of current year growth per twig, similar mean number of twigs per branch and similar densities of beaked hazel plants/ha. Where they do differ is in total amounts of biomass removed by ungulates. More plants were browsed upon in the MROW, resulting in a larger loss of plant biomass when compared to the MNNA. Again this is understandable considering the likelihood of a higher frequency of browsers visiting the smaller ROW area. Overall, despite the MROW having a greater amount of biomass removed than the MNNA, each plant in both of these habitats is experiencing similar browsing intensities by ungulates.

5.4.1 Clip Diameter

Investigating clip diameter allows researchers to identify whether or not a certain habitat is being over-browsed. Over-browsing involves the removal of previous years growth, a more woody, harder to digest part of the twig that contains low quantities of protein. The removal of

previous years growth not only indicates that a habitat is being heavily used, but also that the ungulates using this area are stressed. Ingesting low quantities of protein mean more forage is required to meet energetic needs and more time is needed for rumination to digest that woody material. Ungulates experience a weakened condition that may lead to starvation, predation or disease.

Thus, an averaging of clip diameter, the point at which an ungulate bites off a twig, reflects browsing intensity and perhaps carrying capacity of a particular habitat. Generally, the larger the clip diameter, the higher the ratio of lignin and other woody tissues to protein content. The most palatable and protein rich tissues lie in the buds and shoot tips of the current year's growth, making them particularly favorable to foraging moose during the winter. Therefore, a large clip diameter is an indication of heavy browsing of poor quality forage. The results show that all habitats shared a relatively low clip diameter ranging from 2.35-2.68 mm (Figure 17). This reflects that the habitats surveyed were not experiencing over use and that most tissue removed was that of the current years growth. There was a significant difference in mean clip diameter between the mixed-wood and aspen habitats and more specifically, between the MROW and AROW. Aspen habitats had a slightly larger clip diameter on average than the mixed-wood. This difference, although statistically significant, is not large enough to draw any conclusions that one habitat is composed of poorer quality forage than the other. In fact, these values for beaked hazel clip diameter are similar to those documented in the literature. Recall that there are fewer twigs produced on average in the aspen regions as apposed to the mixed-wood areas. Fewer twigs often mean larger bites. Perhaps intensive sampling of clip diameters along with nutrient analysis of beaked hazel tissue within aspen forests would provide enough information to draw conclusions directed towards browsing intensity and forage quality.

5.5 Pellet Group Counts

The MTLF and MROW pellet group analyses indicates that these 2 habitats are experiencing similar levels of activity as reflected by the occurrence of pellet groups. Despite these areas having many structural differences as far as vegetation composition and age class is concerned, they both shared similar averages of pellet groups per area of land. The best explanation for this may come from the existence of suitable bedding areas. Mixed-wood habitats are a mosaic of microhabitats. Within each there exists patches of dense beaked hazel, aspen and black poplar interspersed with areas of closed-canopied conifers. Amongst the deciduous trees, where light penetrates to the understory, beaked hazel is plentiful and productive. In areas of conifer, the understory is nearly absent as light does not readily penetrate to the forest floor. This in turn leads to a network of game trails and suitable bedding sites. Trails not only occur under tall spruces, but also follow edges of conifers, beaked hazel patches, creeks and wetlands.

Although not quantified, moose pellet groups within the forested habitats appeared to be located more often in or near beds and along game trails, than in the surrounding habitat. This is not surprising since game trails experience considerable use. On the easily traversed ROW, pellet groups appeared to be deposited at random when not associated with beds. This is easily explained by the open, free-ranging habitat associated with the ROW. Lack of structural hindrance permits the unrestricted movement of moose throughout the entire ROW.

It is apparent that the aspen ROW contained a greater number of pellet groups from looking at the lower triangle in Table 8. An analyses show that there is indeed a difference between the use of the two habitats when it comes to defecation. To explain this difference, it is necessary to understand the structure of the aspen forest in the southern end of the park. This forest is particularly dense with deciduous trees and beaked hazel shrubs, with lower densities of

various other shrubs including dogwood and cranberry. High densities of woody vegetation restrict bedding by moose to open, low-lying areas such as creek beds and wetlands. Areas along the ROW would provide nearly unrestricted bedding opportunities.

These ROW areas present ungulates with ideal bedding conditions- open grassy areas with greater snow depths than adjacent forests during the winter months. The terrain is semi-flat to rolling, providing ample bedding opportunity on steep slopes. Increased occurrence of pellet groups on the ROW may result directly from the increased frequency of beds. Moose beds could only be distinguished from elk beds by the presence of pellets-which in most cases were present. The association of beds and pellet groups is not unexpected since ungulates defecate not only while browsing or travelling, but also following periods of rumination. Bouts of chewing the "cud" increase in time as food intake becomes more fibrous, as is the case with a winter diet of twigs (Schwartz and Renecker 1997). Defecation following this extended resting and ruminating period may explain why the ROW would have more pellet groups than the adjacent forest.

It is important to note that although the aspen ROW habitat is experiencing a significantly different occurrence of pellet groups than the adjacent forest, this difference, in numerical terms is only about 1 pellet group per 180 m². It is difficult to conclude that these areas are experiencing different levels of use based on an average difference of only 1 pellet group per area.

Of particular interest was the distribution of moose pellet groups relative to the distance from the edge of the ROW. Despite the productivity of the beaked hazel growing along edges of the ROW area, there did not appear to be a concentration of pellet groups that would be associated with periods of extended browsing. The distribution of pellet groups is spread out throughout the areas surveyed. Small peaks in the distribution of pellet groups are largely due to

low-lying wet areas such as streambeds and ponds. There may have been an overall increase in pellet group deposition with increased distance from the ROW corridor, however, an 80 m transect was not long enough to discern this.

5.6 Track Counts

The number of moose tracks present during periods of snow cover has in the past been used in conjunction with aerial survey data to calculate animal density estimations. The inclusion of track data in these calculations has not been well received by researchers and managers due to the constraints of weather and snow conditions (Timmerman 1974). In fact, it is not recommended for estimating missed ungulates (during the actual direct survey count), but instead should be used to establish relative density levels for stratification of the survey range. Alternate uses include gauging and comparing activity levels of moose between different habitats (Richard and Doucet 1999). In a study of moose winter use of power lines in Quebec, Richard and Doucet (1999) flew 120 km long transects for moose trails and tracks. They compared means to determine if there were differences in trails and tracks between rights-of-way and forest areas. Using track information for any purpose, including those mentioned has multiple limitations and therefore will only be considered qualitatively in this study.

Moose tracks are evidence of activity occurring during a defined period of time governed by snowfall frequency. Measuring the level of moose activity during these “snowfall-free” periods can prove difficult, on various levels. For instance, track formation and persistence is highly dependant on snow conditions and its characteristics, ambient air temperatures and also on the activity of other animals. Altogether these variables, along with snow contrast and vegetation cover, affect the ability to detect and identify moose tracks with accuracy. One condition encountered during the winter track counts in RMNP was crystallized snow pellets.

Snowflakes had melted into crystals, making the grainy snow light and loose; sub-optimal for forming tracks left by moose. Size and gait were characteristics used to roughly identify moose tracks under these conditions. Animals using trails, like the one that occurred along the center of the ROW, trampled over pre-existing tracks making identification of tracks difficult.

Ideally track counts should be conducted a few days following a fresh snowfall of at least 12 cm. This amount should cover up old tracks and prevent recounting those from previous surveys. These conditions were encountered during the early part of the winter when snow depths averaged between 10 and 12 cm. "Old" tracks were not being completely covered up by successive snowfalls, and therefore had to be excluded based on other characteristics such as less pronounced edges with centres slightly filled in with small accumulations of snow. Weather was the most important factor in conducting track counts with any level of accuracy. Quite often, visits to the survey sites followed too soon after a snowfall, before moose had time to move throughout the area.

Even with optimal track formation and counting conditions, collecting these data for parametric and nonparametric analyses is challenging. For example, during this study, it was found that distance and angle data from the line transect to tracks were needed in order to calculate a detection function associated with track density estimations (Cottam and Curtis 1956). A detection function accounts for the bias that arises when tracks occurring farther from the line transect are missed due to limited observation. The detectability of tracks decreases with increased distance from the line transect as a rule. Krebs (1999) gives a description of the 4 assumptions that are needed in order to estimate population density from the detection function. For each of the habitats surveyed, these measures, distance and angle, were needed to calculate a separate detection function. This was required since detectability of tracks within open areas would differ from track detectability in closed forested habitats due to vegetation cover.

This method, although robust to statistical analysis when designed and implemented accurately, is extremely costly in terms of time and energy (Anderson *et al.* 1979). For the purposes of this study it was decided that the use of track data would be considered qualitatively. Moose activity can be described by making comparisons of track densities across various habitats. By assigning low, moderate or high, track density classifications, researchers can get a general picture of the amount of travel use a particular area is experiencing. The objective of this study was to investigate and determine the degree of use of the transmission line ROW and its adjacent forest by moose. From the data collected, there is little overall difference between travel use of the ROW and the adjacent forests. During the early part of the winter, the ROW appeared to experience a great amount of use as indicated by the presence of well-packed game trails and random feeding tracks. Moose were not only traveling down the center of the ROW, but also meandering throughout the beaked hazel patches present on the ROW. It was common to see tracks of moose walking parallel to but off the main, central packed trail. This implies that moose were spending time on the ROW for feeding purposes, not just crossing it (as was often apparent) to access adjacent cover.

Towards mid-winter, travel along the ROW appeared slightly reduced. Snow depths increased to an average of 25 cm in the forest and 35 cm in open areas. Although moose are long-legged creatures, this depth along with other factors, appeared significant enough to affect the movement of moose within the ROW area. Actual numbers of tracks along the ROW and in the adjacent forest were similar at this time. By late winter, snow depths had increased, making moose tracks nearly absent in open areas and only occasional in forested habitats.

Possibly the greatest difference in track numbers occurred between the aspen ROW and its adjacent forest during early and mid-winter months. Tracks and trails were more numerous,

(nearly 2:1) along the open ROW compared to the adjacent aspen forest. This is not unusual considering the density of vegetation within the surveyed aspen forest.

Overall, the ROW did experience use by traveling, bedding and foraging ungulates. The area serves as a corridor for many types of wildlife, including ungulates and their predators, such as the wolf. Numerous sets of wolf tracks were visible during the early part of the winter (December- February) but decreased in occurrence with snow depth. Many of these tracks lead off of Lake Audy road (which is closed to the public during the winter) onto the ROW. Travel down the ROW by wolves (evident by tracks and scat) was noted for 2 km south of Lake Audy road. Wolf scat was found in the south end of the park, in areas of sample site 2 (aspen forest) however, no wolf tracks were located during winter data collection. Travel by wildlife along the ROW is evident throughout the entire winter period, with fewest occurrences during periods of greater snow accumulation. Foraging and travel are more favourable in the more closed, forested habitats at this time.

5.7 2002 Aerial Survey

FRI data were used in this study to determine if habitats influence the occurrence of moose at the time of the aerial survey (early February 2002). Results indicate that moose are dispersed throughout RMNP. This is apparent when % counts are compared to % habitat composition. Habitat appeared used by moose in proportion to it's occurrence. For example, aspen forest, the dominant habitat type in RMNP, contained the greatest amount of moose sightings. All remaining habitats had counts in relatively equal proportions to habitat size. However, when analyzed using a chi-square test, results indicated that there was a difference between observed number of sightings and expected number of sightings. Areas where moose

were more visible, such as in the aspen forests, had more counts than expected. Similarly, areas with dense cover (conifer-dominated habitats) had fewer counts than expected.

Since conifer dominated habitats are considered optimal habitat for moose when winter conditions become severe, under-representation of moose within these areas may be a result of two main factors. Likely explanations include visibility issues, as closed-canopied habitats would decrease the probability of sighting moose during aerial surveys. Milder weather may also contribute to the lower observed sightings. Severe weather and deep snow depths are conditions that normally force moose into dense cover, cover that is often associated with low forage quality. Milder weather conditions would encourage moose to remain in the higher quality habitats, which include the aspen dominated regions of RMNP.

CHAPTER 6

CONCLUSIONS

This study investigated the use of transmission line ROWs and their adjacent areas by moose in RMNP. The primary objectives were to determine whether or not moose utilized ROWs for browsing, bedding and travel during the snow covered months, and if so, how this compared to adjacent forest habitats. Moose use of areas influenced by transmission line ROWs would then be compared to the use of areas not subjected to such anthropogenic factors.

The first of these objectives examined ROW use by moose for various purposes during the winter period. Field observations revealed that moose use ROW for travel, bedding and for browsing.

6.1 Moose Activity: ROW vs Adjacent Forest

From observations of the track activities the following was concluded:

- There is little overall difference between travel use of the ROW and adjacent forests.

This conclusion is based on the level of activity (tracks, trails, beds) noted throughout the entire winter period (December- April).

- Within the aspen habitat, there appeared to be a greater occurrence of tracks and trails along the ROW when compared to the adjacent forest.

During the early part of the winter, the ROW appeared to experience a great amount of use as indicated by the presence of well-packed game trails and random feeding tracks. Moose were not only traveling down the center of the ROW, but also meandering throughout the beaked hazel patches present on the ROW. It was common to see tracks of moose walking parallel to but off the main, central packed trail. This implies that moose were spending time on the ROW for feeding purposes, not just crossing it to access adjacent cover.

- Towards mid-winter, travel along the ROW appeared slightly reduced.
- When snow depths increased in open areas, track counts indicated that moose used ROW habitats less and adjacent forests more.
- By late winter, tracks were nearly absent in open areas and only occasional in forested habitats. Snow depths were at their greatest, averaging 40 cm in forested areas and 60 cm in the more open wind blown areas.
- Ungulates not only utilize the open ROW for travel but also for bedding. Many sets of tracks were associated with beds within the ROW.
- It is suggested that the most important use of the ROW as a travel corridor by ungulates comes during the snow-free months of the year.

Well-worn game trails are evident along the ROW throughout the year, disappearing into a scattering of tracks by late winter. It might be that despite fluctuating degrees of use, moose use the ROW and its adjacent forest for travel to similar extents over the winter period. These findings are similar to those found by Richard and Doucet (1999). When the mean number of tracks and trails present in the right-of-way were compared to the forest, results were not significant. The presence of the transmission line ROW was not influencing moose use of the area.

6.2 Moose Pellet Group Deposition

Pellet group data also indicated that moose were actively using the transmission line ROW. The following are conclusions based on observation and analyses of pellet count data:

- There was no significant difference between the probability of being in the ROW versus the adjacent forest in the mixed-wood habitat. These areas were experiencing similar levels of use as indicated by pellet occurrence.

- Pellet group analyses did show a significant difference between pellet occurrence in the aspen ROW and adjacent forest habitat.

This difference may be a result of the damaged shrub understory present within the ATLF.

Travel, bedding and foraging would be more challenging in this area, making the open ROW more energetically efficient for moose activities.

Although the aspen ROW appeared to have more pellet groups per unit area than the adjacent forest, this alone cannot support conclusions that moose prefer the ROW habitat to the adjacent forest habitat. Activity levels may be greater in the ROW area because it is smaller, with well-defined boundaries that act to channel, and therefore concentrate the activities of foraging ungulates. The expansive continuous forests lying adjacent to the ROW lack directional boundaries to concentrate ungulate activity making them appear “less” used.

- Few opportunities to bed within the aspen forest may explain why moose use the open, meadow-like habitat of the ROW.
- Although not quantified, moose pellet groups within the forested habitats appeared to be located more often in or near beds and along game trails, than in the surrounding habitat
- Despite the productivity of the beaked hazel growing along edges of the ROW area, there did not appear to be a concentration of pellet groups that would be associated with periods of extended browsing.

6.3 Browse Production and Use

Stronger evidence for heavier use of ROW areas was gained from the browse results.

The following conclusions are based on the browse analyses:

- Young beaked hazel branches in the ROW produced amounts of browse comparable to older, taller beaked hazel communities occurring in the other surveyed habitats (ATLF).
- In terms of browsing, the MROW habitat appears more favorable to moose than the MTLF.

The slightly less productive beaked hazel in the MROW lost nearly the same amount of available growth to ungulates as the highly productive MTLF beaked hazel. The % use data showed a greater use on average per beaked hazel branch in the mixed-wood ROW than the adjacent forest and the total amount removed data are almost the same. A corridor for travel, bedding and browsing makes this area indeed useful to moose when encountered. Although pellet count data showed no difference between the MROW and MTLF, and track count data suggested similar use patterns between the two areas, browse results indicate heavier use of the beaked hazel in the ROW. Chi-square results support this, as more shrubs were browsed in the MROW than expected and more went unbrowsed in the adjacent forest than expected.

- In terms of browsing the AROW habitat appears more favorable to moose than the ATLF.

Differences in use per browsed branch were less pronounced between the AROW and ATLF. Mean amounts removed per branch including the proportions removed per branch were comparable between the two habitats. They also shared similar levels of browse production despite the shrubs along the ROW being younger and therefore smaller (in terms of shrub height and number of twigs produced). Where they did differ was in average % use per branch, referred to as total % use. The average beaked hazel branch within the aspen ROW experienced nearly twice the amount used per branch than the adjacent forest. This difference reflects how more shrubs are being encountered and therefore browsed upon in the aspen ROW. The total amount

removed from the measured beaked hazel branches was also greater in the ROW compared to the adjacent forest. Both pellet count and track count data support this finding, namely that greater use of the ROW area occurred.

It should be mentioned that although results indicate that certain habitats appear more heavily used by moose than other areas in terms of browse use, movement, and bedding, it is impossible to determine whether or not this “use” is by a few or many animals. The methods involved in this study do not include the ability to determine whether a few moose are using these areas for extended periods, or if many individuals are frequenting the areas for short periods of time.

The second objective of this study was to identify whether there was a difference in use between the transmission line areas and areas uninfluenced by anthropogenic factors. The ANNA and MNNA were sampled for these comparisons. The following are some of the conclusions that were drawn based on the browse results:

- Both the MNNA and ANNA experienced use similar to ROW habitats rather than the transmission line forest areas.
- It appears that shrubs within ROW habitats have a higher probability of being browsed than those within forest regions.
- However, the number of shrubs browsed in the ANNA was similar to the aspen ROW, not the ATLF

The damaged beaked hazel understory in the ATLF is likely the cause for the differences seen between these two forests.

- The mixed-wood areas lost the most plant biomass to browsers.

Overall, moose show selectivity for the mixed-wood habitat over aspen based on the browse results. The mixed-wood habitats had the highest proportions of twig removed on

average and the highest total % use. Average amounts removed per branch were also greater as were the number of plants used overall.

- It is suggested that the least expensive habitat to move through would be the ROW area during periods of little or no snow cover.

Moose are frequenting habitats for activities such as traveling and foraging because they are inexpensive in terms of energetic costs. More costly would be the dense forests containing damaged prostrate beaked hazel shrubs, as was the case in aspen habitats. These areas were less frequented and thus experienced lower levels of use. Furthermore, the seasonal shift of ungulates from open to closed canopied areas would mean less use of aspen areas and more of the mixed-wood forests.

6.4 Recommendations

Further studies on time spent by moose within each habitat are needed to provide more understanding of habitat use by moose within the areas studied.

- Although it appears that moose are browsing ROW to a greater degree than witnessed in the adjacent forest habitats, they may only be spending a small portion of their time in ROW areas.

It is difficult to determine if browsing intensity within the ROW is reflective of frequent visits by foraging ungulates, or rather, a result of longer periods spent browsing available beaked hazel. A radio-telemetry study of moose would answer such questions and provide more in-depth data pertaining to habitat use.

Future browse studies should also include an estimate of the standing biomass available to ungulates as well as the total biomass removed. This would involve removing large samples of twigs to produce weight measures that could be converted into biomass values. Such data

could be used to estimate habitat use, but also to estimate ungulate carrying capacity of various habitats. A pre-browse survey, one that is conducted prior to sampling, is also required to determine the intensity of browsing within each habitat. This would enable the allocation of sufficient sample sizes specific to each habitat. Appropriate sample sizes would enable the use of specific, predetermined confidence intervals.

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APPENDICES
(1-6)

APPENDIX 1

Glossary of Acronyms

<u>Term</u>	<u>Definition</u>
RMNP	Riding Mountain National Park
MTLF	Mixed-wood transmission line forest
MROW	Mixed-wood right-of-way
MNNA	Mixed-wood nearest neighboring area
ATLF	Aspen transmission line forest
AROW	Aspen right-of-way
ANNA	Aspen nearest neighboring area
FRI	Forest Resource Inventory

APPENDIX 2

95% Confidence interval data

Table 1. Pellet group 95 % confidence interval estimate calculations for each habitat surveyed

	MTLF	MROW	MNNA	ATLF	AROW	ANNA
mean	1.111	0.944	2	1.027	2.083	2.361
var	0.958	0.9111	1.314	0.999	0.999	1.608
sd	0.979	0.9545	1.146	0.999	0.999	1.268
S.E.	0.163	0.159	0.191	0.166	0.166	0.211
t0.975,n-1	2.34	2.341	2.341	2.341	2.341	2.341
t0.975,n-1*SE	0.382	0.372	0.447	0.390	0.390	0.495

Table 2. The 95% confidence interval estimate calculations for total % use data

	MTL	MROW	MNNA	ATL	AROW	ANNA
mean	31.7	60.17	46.63	24.4	44.92	41.8
sd	32.494	31.303	38.198	33.754	29.072	33.199
n	68	103	83	46	95	89
se	3.94	3.084	4.192	4.976	2.982	3.519
t0.975,n-1* SE	1.996	1.983	1.989	2.014	1.985	1.987
	7.865	6.118	8.34	10.023	5.922	6.993

Table 3. The 95 % confidence interval estimate calculations for mean amounts removed/branch data.

	MTL	MROW	MNNA	ATL	AROW	ANNA
mean	102.93	63.88	55.28	58.89	49.84	49
sd	98.048	40.801	33.398	28.487	22.552	38.52
n	68	103	83	46	95	89
se	11.89	4.02	3.66	4.3	2.31	4.08
t0.975,n-1	1.996	1.983	1.989	2.014	1.985	1.987
t0.0975,n-1*SE	23.732	7.973	7.28	8.66	4.586	8.108

Table 4. The 95 % confidence interval estimate calculations for mean clip diameters (mm)

	MTL	MROW	MNNA	ATL	AROW	ANNA
mean	2.38	2.43	2.35	2.55	2.675	2.59
sd	0.461	0.518	0.525	0.433	0.518	0.694
n	68	103	83	46	95	89
se	0.054	0.051	0.057	0.065	0.052	0.072
t _{0.975,n-1}	1.996	1.983	1.989	2.014	1.985	1.987
t _{0.0975,n-1} *SE	0.107	0.101	0.113	0.13	0.103	0.143

APPENDIX 3

Table 1. Chi square test results for the comparisons of browsed plants (1) versus non-browsed plants (0) (out of a possible 120 plants) between habitats

	X ²	df	p	Browse		MTL	MROW	MNNA	ATL	AROW	ANNA
MTL vs MROW	25.22	1	5x10 ⁻⁷	0	obs	49	15	-	-	-	-
					exp	31.9	32.1	-	-	-	-
				1	obs	68	103	-	-	-	-
					exp	85.1	85.9	-	-	-	-
MTL vs MNNA	3.127	1	0.077	0	obs	49	-	37	-	-	-
					exp	42.5	-	43.5	-	-	-
				1	obs	68	-	83	-	-	-
					exp	74.5	-	76.5	-	-	-
MROW vs MNNA	11.44	1	0.001	0	obs	-	15	37	-	-	-
					exp	-	25.8	26.2	-	-	-
				1	obs	-	103	83	-	-	-
					exp	-	92.2	93.8	-	-	-
MTL vs ATL	8.95	1	0.003	0	obs	49	-	-	73	-	-
					exp	60.5	-	-	61.5	-	-
				1	obs	68	-	-	46	-	-
					exp	56.5	-	-	57.5	-	-
ATL vs AROW	40.54	1	2x10 ⁻¹⁰	0	obs	-	-	-	73	25	-
					exp	-	-	-	48.8	49.2	-
				1	obs	-	-	-	46	95	-
					exp	-	-	-	70.2	70.8	-
ATL vs ANNA	31.11	1	2.4x10 ⁻⁸	0	obs	-	-	-	73	-	30
					exp	-	-	-	51.7	-	51.3
				1	obs	-	-	-	46	-	88
					exp	-	-	-	67.3	-	66.7
AROW vs MROW	2.807	1	0.094	0	obs	-	15	-	-	25	-
					exp	-	19.8	-	-	20.2	-
				1	obs	-	103	-	-	95	-
					exp	-	98.2	-	-	99.8	-
AROW vs ANNA	0.706	1	0.401	0	obs	-	-	-	-	25	30
					exp	-	-	-	-	27.7	27.3
				1	obs	-	-	-	-	95	88
					exp	-	-	-	-	92.3	90.7
MNNA vs ANNA	0.509	1	0.476	0	obs	-	-	37	32	-	-
					exp	-	-	34.5	34.5	-	-
				1	obs	-	-	83	88	-	-
					exp	-	-	85.5	85.5	-	-
All MIX	25.06	2	4.3x10 ⁻⁶	0	obs	49	15	37	-	-	-
					exp	33.3	33.6	34.1	-	-	-
				1	obs	68	103	83	-	-	-
					exp	83.7	84.4	85.9	-	-	-
All ASPEN	50.97	2	1x10 ⁻¹¹	0	obs	-	-	-	73	25	30
					exp	-	-	-	42.7	43.0	42.3
				1	obs	-	-	-	46	95	88
					exp	-	-	-	76.3	77.0	75.7
MIX vs ASPEN	80.53	5	4x10 ⁻¹⁶	0	obs	49	15	37	73	25	30
					exp	37.7	38.0	38.6	38.3	38.6	38.
				1	obs	68	103	83	46	95	88
					exp	79.3	80.0	81.4	80.7	81.4	80

APPENDIX 4

Table 1. Pellet group raw data for 36 transects in each habitat sampled

Transect	Mixed-wood			Aspen		
	MTLF (within 45m)	ROW	NNA	ATLF (within 45 m)	ROW	NNA
1	2	2	3	2	4	2
2	0	1	1	3	3	4
3	0	3	3	2	1	1
4	0	0	2	0	4	4
5	1	1	1	0	1	2
6	0	0	1	0	0	4
7	2	2	2	1	1	3
8	1	1	1	0	3	2
9	2	2	3	3	3	3
10	1	2	1	1	4	1
11	2	1	3	1	3	1
12	0	0	2	1	2	3
13	0	2	0	0	3	4
14	1	1	4	1	3	3
15	0	0	2	0	1	0
16	2	1	4	1	1	3
17	0	0	1	2	0	0
18	1	3	2	4	1	2
19	3	0	1	1	2	3
20	0	0	1	2	1	3
21	1	2	3	2	2	5
22	3	0	3	2	3	2
23	1	0	1	0	1	2
24	0	0	2	1	2	2
25	1	0	4	0	1	1
26	2	1	0	0	3	5
27	1	1	3	1	2	1
28	3	0	3	0	4	2
29	2	2	1	1	2	2
30	2	0	2	1	3	1
31	1	1	0	1	1	2
32	0	0	3	0	3	4
33	0	0	1	1	3	2
34	2	1	3	1	1	2
35	2	2	3	0	1	3
36	1	2	2	1	2	1

APPENDIX 5

RMNP FRI Legend

GRIDCODE LEGEND

6 Jack Pine 40-70% -spr	163 Pastureland
10 White Spruce 71-100%	165 Land Clearing
11 White Spruce 40-70%-bf,jp,bs	166 Abandoned Land
13 Black Spruce 71-100%	171 Dry Upland Ridge Prairie
14 Black Spruce 40-70%-jp	172 Moist Praire
15 Black Spruce 40-70%-bf,ws	173 Wet Meadow
16 Black Spruce 40-70%-tl	181 Muskeg
20 Balsam Fir 71-100%	185 Marsh
21 Balsam Fir 40-70%-spr	188 Mud/Salt Flats
30 Tamarack 71-100%	189 Sand Beaches
31 Tamarack 40-70%-spr	191 Townsites/Residential Sites
44 Jack Pine 51%+	192 Airstrips
46 Jack Pine 50% or less-spr	193 Roads/Railroads
50 White Spruce 51%	194 Transmission Lines
51 White Spruce 50% or less-bf,jp	195 Gravel Pits /Mine Sites
53 Black Spruce 51%+	196 Fence Lines(Community Pasture)
55 Black Spruce 50% of less-bf	197 Drainage Ditches
56 Black Spruce 50% or less-tl	198 Beaver Floods
58 Black Spruce 50% or less-ws	199 Dugouts/Water Holes
60 Balsam Fir 51%+	201 Oil Fields
61 Balsam Fir 50% or less-spr	210 Water
70 Tamarack 51%+	211 River
81 Trembling Aspen-jp	
82 Trembling Aspen-spr,bf,tl	
87 Birch-spr & bf	
88 Balsam Poplar-spr,bf,tl	
90 Trembling Aspen	
91 Trembling Aspen < 50%,wb(20%+)	
92 Birch	
94 Ash	
95 Elm	
96 Oak	
97 Manitoba Maple	
98 Balsam Poplar	
101 Black Spruce Treed Muskeg	
102 Tamarack Larch Treed Muskeg	
112 Black Spruce Treed Rock	
121 Willow	
122 Alder	
123 Dwarf Birch	
124 Shrub	
125 Shrub/Prairie	
131 Recreational Sites	
132 Small Islands	
133 Precipitous Slopes/Fragile	
134 Shelter Belts	
161 Hayland	
162 Cropland	

APPENDIX 6

Number of aerial moose counts in FRI vegetation types

Veg Code	Frequency
0	Count 28
10	Count 3
11	Count 5
13	Count 5
15	Count 3
16	Count 4
21	Count 1
30	Count 2
50	Count 16
51	Count 19
53	Count 4
55	Count 6
61	Count 4
82	Count 109
90	Count 368
91	Count 2
96	Count 3
97	Count 1
101	Count 3
102	Count 2
121	Count 20
123	Count 1
124	Count 3
133	Count 3
163	Count 1
172	Count 21
173	Count 10
181	Count 3
185	Count 3
193	Count 12
198	Count 51
210	Count 16