University of Alberta

The Impacts of Horse Grazing on Conifer Regeneration in West-Central Alberta

by

Barry David Irving ©

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and research for acceptance, a thesis entitled The Impacts of Horse Grazing on Conifer Regeneration in West-Central Alberta submitted by Barry David Irving in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Plant Science.

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Dr. Roger Cohen

This dissertation is dedicated to the women that have shaped my life:

Audrey, Jennifer, Judy, Michelle, and Lindsay Irving

ABSTRACT

Historical studies of the interaction of livestock and conifer seedling regeneration on timber cutblocks have concentrated on establishing safe livestock stocking rates on areas of uniform vegetation and topography. Forestry cutblocks typically encompass a variety of forest sites that produce a variety of forages for domestic livestock and elicit a complex grazing pattern determined by grazing behaviour. Traditional grazing management using set stocking rate theories often results in variable grazing effects on regenerating conifer seedlings. The purpose of this study was to determine horse grazing behaviour on forestry cutblocks with heterogeneous vegetation and topography under different confinement strategies. Grazing behaviour and conifer seedling damage were studied under free-ranging, semi-confined, and confined strategies for managing horses in Upper Boreal Cordilleran forests south of Hinton, Alberta (400 km west of Edmonton).

Horses exhibited selective grazing behaviour. Preferred habitats for winter grazing free-ranging horses were hygric meadows, a non-commercial forest type that is common in west-central Alberta. Diagnostic species for preferred foraging sites were straight horsetail (*Equisetum variagatum*) and dwarf birch (*Betula glandulosa*). Winter free-ranging horses avoided grazing recent forestry cutblocks, suggesting hygric meadows provide an alternative

preferred habitat that reduces the probability of horse-caused conifer seedling damage.

Horses grazing in the summer selected disturbed sites (spur roads, landings, and power lines), hygric meadows and dry pine sites but avoided moist pine and pine/black spruce transition sites. The existence of disturbed sites and hygric meadows attracted horses away from cutblock sites with regenerating conifer seedlings. Disturbed sites and hygric meadows are important alternative preferred habitats for summer grazing horses.

Conifer seedling damage and mortality was elevated by horses confined to cutblocks in the summer. Horses damaged conifer seedlings by trampling (vertical displacement and/or basal scarring); there was no evidence of browsing damage in this study. Although conifer seedlings were damaged at rates as high as 37 percent, seedling mortality increased only 2 percent during 2 years of horse grazing. Conifer seedlings were more susceptible to horse damage when they were less than 50 cm tall, were growing on moist sites, or were exposed to early summer horse grazing.

The preferred alternative habitat concept can be used to minimize damage to regenerating conifer seedlings coincidental with horse grazing. Horses are a minor damage threat to forestry cutblocks if they are selectively grazing areas that have no conifer seedlings.

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1. INTRODUCTION

Livestock have been grazing in the forest since explorers introduced cattle to eastern North America in 1619 (Rouse 1973). They thrived in the New World environment and within a few decades of their introduction the herd had increased enough to allow a modest export trade to begin. Horses were re-introduced to North America by the Spaniards in 1519 and quickly spread throughout the Great Plains (Roe 1955). They were used by Aboriginal people as far north as Saskatchewan by 1740. The process of European colonization of North America has resulted in the widespread introduction and use of livestock. The continuing search for virgin land for livestock grazing is expanding, and the boreal and cordilleran forests of Canada are one of the few remaining frontiers.

Livestock grazing in the forest can create conflicts with other forest users, mainly forest companies, wildlife, and recreationists. Grazing and the human desire to increase forage production also have impacts on watershed values which affect a wider society that relies on water downstream from grazing areas (Holechek et al. 1989). There is a developing conflict between horse grazing and a forest company in the foothills of the Rocky Mountains in western Alberta. The conflict centers around the seedling stage of regenerating conifer timber stands after harvest. The forest company contends horse grazing is a major cause of seedling mortality resulting in poor stand establishment and a significant economic loss. The horse grazing interest group counters that horses do not eat or damage conifer seedlings and that poor seedling establishment is a result of mismanagement by the forest company. Both interest groups have a long history of anecdotal observations to support their stand and an equally long history of antagonism towards the other group. The lack of quantified study of the relationship of horse grazing to forest regeneration and especially the lack of information on the effects of horse grazing in a forested environment has been a major deterrent to resolution of this long standing conflict. The conflict exists because of an environment of mistrust coupled with a lack of solid scientific information upon which land management decisions can be based. This study will provide the scientific base on which management decisions regarding horse grazing and coniferous forest regeneration can be made.

PURPOSE

The overall goal of this study is to determine the effect of horse grazing on conifer seedling survival and growth in a sub-alpine coniferous forest near Hinton, Alberta. This will be accomplished by conducting three sub-studies that encompass three levels of horse confinement: free ranging horses, horses that are confined to a large area that contains cutblocks, and horses that are confined to small areas within cutblocks. Horse grazing behaviour will be examined in all three studies while the interaction between horse grazing behaviour and conifer seedling damage will be examined in the two studies where horses can be confined to known areas. The combination of these three studies address 2 fundamental questions:

1. What vegetation types do horses prefer and does the degree of confinement affect this preference? The degree of confinement will determine what vegetation types are available to be grazed while horse grazing behaviour will determine which vegetation types are selected or avoided.

2. What is the expected level of damage to conifer seedlings if horses graze on cutblocks?

These questions can also be paraphrased to ask: given an array of vegetation types to choose from do horses select or avoid areas that have conifer seedlings and if they select these areas, what level of seedling damage can be expected?

Additional study objectives will be to determine if seedling size has an effect on expected horse damage and if the degree of damage affects subsequent survival and growth of damaged seedlings. This research will provide an information base from which informed management decisions can be made regarding the integration of horse grazing and coniferous forest regeneration attempts.

Study Philosophy

This study was conducted under a philosophy of multiple land use where the preferred outcome is a coordinated sharing of land by competing land uses. Although western Canadians have enjoyed an abundance of natural resources and they have experienced a minimal amount of competition for the use of those resources, an ever increasing global and Canadian population will result in increasing competition between natural resource users. Increasing competition and tension between resource user groups can be resolved using two philosophical approaches:

1. Dominant uses within land use zones. This approach would stratify an area into zones and each zone would have one dominant land use with the exclusion or minimizing of competing land uses. The dominant use would change depending on the zone and there would be continual conflict between the resource users about zone priorities and boundaries. The information required for resource management decisions is relatively simple as each zone will only be used for one land use, the needs of competing land uses will be met in other zones.

This management philosophy promotes competition and conflict between land use groups.

2. Multiple use over the entire area. This approach would coordinate levels of use between competing land use groups so as to minimize conflicts. No land use group would have priority but all land use groups would have to coordinate their levels of use with the other land use groups. The information required for land use decisions is relatively complex. The needs of each land use group are weighed against and coordinated with the needs of all other land use groups and the interactions between land uses is an important consideration. This management philosophy promotes interaction and dialogue between competing land use groups.

This study has been developed under the second philosophy. Historical studies have focused on the negative interactions between forestry and grazing interests. This study will attempt to determine the common ground on which forestry and horse grazing interests can be coordinated on the same land base.

History of the Horse

Horses; arguably no other animal species has had more of an impact on the human race. Horses have been revered or feared, loved or hated, used or misused, and controversial or benign. Horses have found use in war, peace, exploration, exploitation, as a mode of travel, for recreation, for business, or even for their intrinsic value of simply being a horse. Horses have contributed to cultural development, and to cultural destruction, on all continents with the exception of Antarctica.

Equids evolved in North America and dispersed throughout Eurasia and Africa about 2.5 million years ago (Macfadden 1992). Horses, along with numerous species of large bodied herbivores and predators were extirpated from North America in what has been called the Pleistocene mega-faunal extinction about 8,000 years ago (Martin and Wright 1967). The causes of the Pleistocene extinction are still debated, but centers around hypothesis of over-hunting or climate change. The rapidity of the extinction seems to support the over-hunting hypothesis, but climate change was probably a factor as well (Martin and Wright 1967).

Horses are primarily grazers (Grubb 1981). Although horses selectively graze monocotyledon grasses, they do exhibit some diet plasticity, and can shift to specific species of shrubs and forbs (Duncan

1992). Horses in the Carmargue region of southern France consume principally grasses during all seasons except winter, when halophytes constitute a significant portion of their diet. It was postulated that the horses of the Carmargue selectively grazed plant material that was green, and halophytes were the only species of plants that were green in the winter.

Horses evolved on relatively open grasslands or steppes. After the Pleistocene, horse evolution occurred in four major areas: true horses in Europe and northern Asia, half asses in the Middle East, asses in northern Africa, and zebras in southern Africa (Zeuner 1963). Two races of true wild horses survived into the nineteenth and twentieth century: the Przewalski's horse of Mongolia and the tarpan of northern Europe and Russia. It is generally agreed that a significant percentage of modern horse breeds originated from the tarpan (Zeuner 1963, Davis and Dent 1966, Clutton-Brock 1981) but not all authors agree on the contribution of the Przewalski's horse. Some authors feel the heavier, draft horse breeds originated from the Przewalski's horse while the finer featured breeds came from tarpan stock (Davis and Dent 1966). Other authors indicate the Przewalski's horse contributed minimally to the modern horse, that draft and fine horse breeds both originated from the tarpan (Zeuner 1963) and that all the variations in domestic horse breeds today are a result of artificial selection (Clutton-

Brock 1981). It is unlikely the origin of the domestic horse will ever be clearly known; the tarpan is extinct today and the Przewalski's horse exists only in zoos and wildlife parks. Recent developments in genetic testing may lead to further insights, but with no source of pure tarpan genetic material the discussion is likely to continue.

Horses were the last of the large, agricultural animals to be domesticated, the first evidence of domestication occurring 2000-3000 years ago (Zeuner 1963, Davis and Dent 1966). Although it is likely horses were domesticated as food animals before this time, the use of iron in chariots provides the first evidence of horse domestication. The use of chariots catapulted the horse beyond a simple food or cartage animal and changed it into an animal of war, a position of importance it would hold until the twentieth century (Ambrose 1975). Cultures who possessed the horse and chariot quickly conquered less fortunate cultures and by 500 B.C. every community in Europe was ruled by aristocracies of charioteers (Davis and Dent 1966). Armies of chariots could overcome infantry with the speed, power, and brute force provided by the horse. Chariots ruled until about 300 B.C. when armies of well trained infantry combined with mounted swordsman began to defeat armies of chariots. The principle innovation involved a movement of the warrior from behind the horse, where he could not engage the enemy until the horse was exposed to damage, to a warrior that sat on the horse, where he could use spear or sword to vanquish the enemy before the enemy could damage his mount. By 100 B.C. the last of the chariot societies, the Gauls of central Europe and the Celts of the British isles had been defeated by mounted armies (Davis and Dent 1966). The only innovation that remained to take the horse to modern times was the advent of the stirrup. Prior to development of the stirrup riders were limited in the types of weapons they could use because of their precarious position on the back of a moving animal. Evidence of the use of stirrups appears first in the Mongols about 200 A.D. (Davis and Dent 1966) and Chinese about 500 A.D. (Clutton-Brock 1981); stirrups were not found in western Europe until 800 A.D. (Clutton-Brock 1981). Stirrups were an additional innovation for war that allowed mounted warriors more stability during battle making the horse an even more effective weapon. The stirrup was the final innovation that modified the use of the horse in war.

Christopher Columbus is credited with re-introducing the horse to the western hemisphere, although all the horses brought on his expeditions remained on the islands of the Caribbean (Wyman 1945). In 1519 Hernando Cortez introduced the first horses to mainland North America when he brought sixteen Spanish horses to Vera Cruz, Mexico. The Spanish used the horse as a weapon in the wars fought with the native Indians, which were precipitated by the search for gold. The Spanish introduced the first horses to South America in 1531 when Alvarez Pizzaro invaded Puru with a mounted army and in 1540 to the Great Plains of North America when Francisco Vasquez de Coronado headed an expedition seeking the Seven Cities of Gold (Lacey 1978). Perhaps the best example of the effectiveness of the horse in battle is shown by the conquering of the Inca Empire by Alvarez Pizzaro in 1532. Pizzaro, with an army of 106 infantry and 62 cavalry conquered the Inca Empire, estimated to be 16 million, a military achievement that has not since been duplicated. He used treachery and the speed of his cavalry to capture the Inca king and in doing so toppled the entire Inca Empire. Hernando Cortez had used horses when he defeated the Aztec Empire in central Mexico in 1521. When Coronado explored the southern Great Plains in 1540, he used the horse to overrun any Indian resistance his expedition encountered (Lacey 1978). He did not find the gold he sought, but he may have changed the course of North American history. Coronado's expedition moved 1000 horses, 500 cows, and 5000 sheep to the prairies of the southern United States (Costello 1969). He is credited with introducing the plains Indians to the horse, an event which eventually lead to the spread of the horse throughout North America and to the transformation of the plains Indians into a military force.

The horse became part of the plains Indians being. Horses were not only used in battle, but were a measure of wealth and prominence in Indian culture (Roe 1955). The horse enabled the plains Indians to be more effective in battle, and it was also a primary reason for raiding and warfare between adjacent tribes. Young warriors could honor themselves in at least three ways: counting coup on the battlefield, as hunters and providers, and capturing horses from enemy tribes (Dempsey 1980). In addition to the obvious advantages of horses in warfare, the horse was an intimate part of Indian culture, social society, and economy. The plains Indians were one of three great equestrian cultures, along with the Mongols and Egyptians, whose existence was dependent on the horse.

The acquisition of the horse by the plains Indian tribes is a significant event in North American history. Starting in 1540 the horse spread from southern Texas, New Mexico, and Nevada northward until the northern plains tribes were using the horse in the early 1700's (Wyman 1945, Roe 1955, Byfield 1991). The horse transformed the plains Indians, making them more mobile, which increased their effectiveness in gathering food and engaging in war. At least one author has postulated that had the plains

Indians not acquired the horse most of western North America would have been conquered by the Spanish (Roe 1955). A mounted Indian warrior could ride 100 metres and shoot 10 arrows in the same time it took a European invader to reload his musket. With the horse the plains Indians were a sufficient military force to stem the exploration of the central Great Plains, thus stopping the Spanish from invading from the south and the Americans from the east (Roe 1955). The plains Indian tribes maintained their dominance of the Great Plains until the advent of the repeating rifle. With the close of the Civil War in 1865, the discovery of gold on Indian Treaty land, and increasing demand for land by settlers, a directed effort to control and confine the plains Indians was initiated by the United States Government (Ambrose 1975). In the final battles for control of the Great Plains the horse maintained its importance as a weapon of war, but the repeating rifle and artillery gave a decided advantage to the United States Army (Wellman 1987). The northern Indian tribes had been conquered by 1880 (Wellman 1987) and the last organized resistance in the southwestern United States had been eliminated by 1886 (Wellman 1963). After the Indian tribes had been beaten in battle they were stripped of their main military weapon, their horses.

Following the Indian wars the horse became more important in transportation and economy in the development of Western North America and less important in warfare. The ranching industry blossomed in the late 1800's, filling a void created by the demise of the plains bison and the confinement of the plains Indian to reservations. In Western Canada a local demand for beef was created when Treaty 7 was signed in 1877 and the Canadian Government promised to feed the newest Canadian citizens, the Canadian plains Indians (Dempsey 1980). The growing ranching industry had a need for horses for ranch work and the growing western society had a need for horses for transportation. Cattle ranches were established in Western Canada beginning in about 1880, and horse ranches to supply working and transportation horses appeared a short time later (Jameson 1987). An era of large ranches existed in Alberta until 1907, when a severe winter decimated western cattle herds. Previous to 1907, a change in federal government from Conservative to Liberal had also changed the land use pressures on western Canada. While the Conservatives favoured large scale ranches, the Liberal government, elected in 1896, favoured smaller farming operations. An influx of settlers resulting from new political policies changed western society, from a large scale commercial ranching-based economy to a smaller scale family farming society (Symons 1973). The need for the horse was again evolving. Farmers needed horses to pull the plows that broke the prairie sod. The move from ranching to farming actually increased the demand for horses, especially draft horses. This trend would last until the 1920's when the draft horse would ultimately be replaced by machinery for farming purposes (Symons 1973).

The horse found limited military use in the twentieth century. The Boer War began in South Africa in 1899 and pitted Dutch and German settlers against the British army (Byfield 1992). The British had more troops, were better armed, and had advanced military training. The Boers had fewer troops and a small population to draw replacements from, inferior weaponry, and had no military training, but they were mounted and fought with a strike and run style that stymied the British at every move. Eventually the British enlisted mounted recruits from western Canada and Australia and began beating the Boers using their own style of warfare. The horse was once again a decisive factor in war. The horse was used sparingly during the First World War, being replaced by machinery and being of limited use in the trench warfare employed by that time (Byfield 1994). The horse was used for some fighting, but was mostly relegated to an animal for cartage and delivery.

Thus, the evolution of the horse as an animal of war was complete, from cartage to chariot at the dawn of domestication and from cavalry to cartage during the First World War. The importance of the horse in the development of western society cannot be ignored. The use of the horse as an animal of war may have lead to widespread bans on eating horseflesh (Zeuner 1963). Not all cultures abstained from eating horses, the Mongols in particular used horses for milk, blood, and meat whenever they needed (Zeuner 1963). Western culture has rarely embraced eating horseflesh, perhaps because of the historical use of the horse and the partnerships that developed between horse, rider, and society. Today the horse is used for work on farms, ranches, and as a pack and transportation animal, for pleasure, and for sport but not war. The psychological attachment between people and horses is still apparent and the modern horse ranks high on the list of western societies favorite animals.

The horse in western Canada remains a prized companion as well as a useful animal for work and pleasure. In Alberta today horses are used extensively on farms and ranches for handling livestock, as a means of transportation in and out of Alberta's remote wilderness, and as an important contributor in a vibrant hunting and guiding industry. Community history books of western Alberta towns are filled with references to horses (Hart

1980). Although horses have been replaced by modern transportation, there are still areas of Alberta where access is limited to horseback, either because of legislation or practicality. Even where transportation alternatives to horseback exist, there is a significant portion of the population who would choose to ride a horse. Ranching and guiding are industries where the relationship between the horse and rider is still primarily economic. Whether the association between horse and rider is economic or emotional, the horse remains an important part of western Alberta economy and culture.

Forestry History in Alberta

The need for timber products paralleled the development of an industrial society in early Alberta. In southern Alberta there were small lumber mills by the early 1880's, mostly servicing local markets (Buziak 1992). When the Canadian Pacific Railroad arrived in Calgary in 1883 (Byfield 1991) it provided an immediate market for timbers for track building and also provided a means of exporting lumber to distant markets. Peter McClaren operated a mill in the Crowsnest Pass in 1881 and Colonel James Walker, a former manager of the Cochrane Ranche started a mill in Kananaskis in 1882. Both profited from contracts to supply timbers to the C.P.R. (Buziak 1992). The largest timber operator of the time was the Eau Claire and Bow River Lumber Company, which operated out of Calgary, starting in 1886 (Buziak 1992). The Eau Claire and Bow River Lumber Company held log berths in the foothills west of Calgary and floated logs down the Bow River, starting in 1887, until the mill burned in 1920 and was not rebuilt. The fire sealed the fate of the Eau Claire and Bow River Lumber Company, as competition, settlement ingress onto its timber berths, uncontrolled fires, and a slackening lumber market had already weakened the company (Buziak 1992).

In central Alberta lumbering had an early start, and in some cases preceded the development of the southern forestry industry. A mill was initiated on the Sturgeon River near St. Albert in 1878, funded by the Catholic Church and local investors. It was operated under water power; a 30 metre dam was constructed to channel the necessary water and provide a continuous flow (Buziak 1992). Roderick, Benjamin, and David McKenzie founded a successful mill on the south side of the Red Deer River, west of present day Red Deer (Munns 1995). The mill mainly supplied local demand which was strong enough to require a 24 hour shift. In the decade of 1900-1910, Alberta's population quintupled to 374,000 (Byfield 1992). The population boom and the demand for lumber led to the development of the largest lumber operation to date, the Great West Lumber Company (Buziak 1992). The Great West Lumber Company held timber berths in the headwaters of the Red Deer and James Rivers and operated a mill near Red Deer. The Great West Lumber Company operated until 1916 when a world wide recession, labour shortages caused by the First World War (Buziak 1992), and an untimely accident that killed their chief sawyer (Munns 1995) resulted in it's demise. Edmonton's first mill was established by John Walter in 1894 in what was then Strathcona. Walter's mill operated until 1915 when a flood by the North Saskatchewan River washed every business in the river valley away. At its highest point the Walter mill was the largest supplier of sawn lumber west of Winnipeg (Buziak 1992).

Economic growth was resulting in increased demand for natural resources in Alberta, a fact not lost on the provincial and federal governments. The governments of Alberta and Canada were aware of the increased interests in forestry, grazing, recreation, and industry, particularly for the eastern slopes of the Rocky Mountains. Discussions initiated in 1937, and interrupted by the Second World War, culminated in 1947 with the establishment of the Eastern Rockies Forest Conservation Board (Hanson 1973). The Board was established in response to concerns about unregulated resource use on the eastern slopes and the effect of resource use on watershed values. The Board was established by joint agreement and acts passed in the Alberta Legislature and the Parliament of Canada. Its principal mandate was to develop policies and practices that would protect watershed values on the eastern slopes while allowing resource extraction and use to continue. The Board's initial responsibility was to establish the necessary infrastructure to facilitate resource management and conservation. Transportation, communication, and personnel networks were installed, initially for forest fire control. Eventually the infrastructure would be used to manage all activities on the eastern slopes: timber extraction, recreation, grazing, petroleum, and mining. The Eastern Rockies Forest Conservation Board continued to operate until 1973, when it was generally thought the Alberta Forest Service had gained the necessary personnel, equipment, and financing to become the sole manager of the eastern slopes. Before it was disbanded the Eastern Rockies Forest Conservation Board had established a firm policy of integrated resource management with all uses being managed so as to not detrimentally affect watershed values (Hanson 1973).

In north-western Alberta lumber production was limited to small mills supplying local demand until the 1950's, when a scheme was formulated by Frank Ruben to use plentiful stocks of coal and natural gas to fuel Alberta's first pulp and paper mill (Hart 1980). Ruben's initial forays into coal production were failing because of the high cost of freight to markets in eastern Canada. He reasoned that if an industry could be created that would use a lot of coal and power he could market his coal reserves by producing another commodity, pulp and paper. Two companies were involved in the venture; North Canadian Oils Limited would supply the fuel to the prospective mill and St. Regis would manage the pulp making and sell the final product (Hart 1980). The two companies pooled the necessary capital to construct the mill and develop the pulpwood delivery system. The valley district of Hinton, Alberta was selected as the site for the mill. In 1954 the first Forest Management Agreement (FMA) in Alberta was awarded. The initial FMA area covered 3,000 square miles of timber. The FMA required the company adopt mandatory reforestation of cutover areas as part of its operational planning with fines and/or loss of the FMA imposed for failing to reforest. The Hinton mill and associated FMA have changed hands several times and are now owned and operated by Weldwood of Canada Ltd.

Conifer Seedling Growth and Wound Healing

Tree seedling growth is usually classified into two types (Zimmerman and Brown 1980). While height growth and extension of the lateral branches is called primary growth, an increase in diameter through annual increments is referred to as secondary growth. Primary growth occurs first in the spring, beginning at the apex of the tree, the apical bud, and quickly spreads downward until the whole tree is actively growing. Secondary growth occurs in a region known as the cambium. The cambium is a thin layer of cells that extends from immediately beneath the terminal bud to immediately above the root apex. Cambial growth also starts in the spring and begins below the terminal bud and proceeds downward. The order of initiation of cambial growth is twigs, stem, and roots. Both the apical bud and the cambium have common and distinct zones of growth: (1) a zone of active cell division (2) a zone of cell enlargement and (3) a zone of cell differentiation and maturation. The apical bud and the cambium are different; the apical bud has only one of each of these zones while the cambium has two, an inner and an outer meristem. The centre of the cambium is comprised of an undifferentiated zone of cell division; the inside of the cambium consists of differentiating xylem cells and the outside of differentiating phloem cells. The outermost layer of a tree stem is known as the periderm; it is a layer of protective tissue that results from radial growth and replaces the epidermis in juvenile stems and roots (Biggs 1992). The periderm contains the cork cambium and an inner and outer layer of differentiating cells. Unlike the vascular cambium, the cork cambium produces more external derivatives than internal (Zimmerman and Brown 1980). The periderm is not synonymous with the term bark. Bark includes all layers outward from the secondary ring of xylem. Thus, diameter growth occurs in two meristematic regions, the vascular cambium and the periderm which contains the cork cambium. Growth in these two meristems increases stem strength, by continually adding suberized xylem cells to the stem, and resistance to wounding, by continual thickening of the bark as a tree seedling grows and matures.

Basal scarring is the major type of damage to conifer seedlings caused by livestock grazing (Newman and Wikeem 1990). Bark slipping is a well documented phenomena that can be found in numerous tree species (Zimmerman and Brown 1971); although the term basal scarring is commonly used to describe damage by livestock, bark slipping is the accepted technical name. Bark slipping is most prevalent when diameter growth is occurring and is correlated with cell division activity in the vascular cambium. During the growth period bark can be easily peeled, leaving the underlying tissues exposed to desiccation and opening a potential site for pathogen invasion. When the bark is peeled during the growing season, the fissure most often occurs in the mother xylem zone with the vascular cambium usually attached to the bark and severed from the tree (Zimmerman and Brown 1971).

Following injury most tree species exhibit a predictable sequence of wound closure (Biggs 1992). The principal steps in the recovery process are:

1. Formation of a primary lignin-suberized boundary layer.
2. Rapid cell division and the formation of wound periderm.
3. Production of callus tissue that covers the wound.
4. Formation of a new vascular cambium.
5. Closure of the wound.

Suberin is a plant compound that is common in the cell walls of xylem vessels and is relatively impermeable to water (Salisbury and Ross 1978). Suberin production is stimulated by wounding, possibly by an increase in abscisic acid at the wound site (Biggs 1992). The ultimate control of suberin production is poorly understood, but suberin is deposited on wounds of trees and acts as a barrier to moisture loss and pathogen entry. The occurrence and sequence of the final four steps listed above appear to be modified somewhat by the degree of wounding and the environmental conditions at the time of wounding. If the exposed xylem cells of a bark wound are quickly covered with an impermeable layer, such as suberin, a uniform wound callus (undifferentiated cells) will form across the surface of the wound (Zimmerman and Brown 1971). Over time a new cambium will begin to form along the undamaged cambium at the edge of the wound. The new cambium will continue to develop from the edges of the wound and proceed inwards from all sides until cambial continuity is restored throughout the callus layer. This process occurs relatively quickly because the wound callus simply changes from undifferentiated cells to differentiated cambium through hormonal control. However, if the wound is not quickly covered by an impermeable layer the exposed xylem cells die from desiccation and the layer of callus does not form. In this instance the wound can only heal by the formation of wound cambium and it's associated outer periderm and annual growth from the edges of the wound. Wound periderm is the same as natural periderm in both origin and growth (Esau 1965). Thus, wound periderm will grow across a wound, and cambial growth will follow in the same manner as natural cambium will grow outward. The wound will take several years to heal, and will possibly never completely heal. If a callus layer forms, wounds will heal relatively quickly through cell differentiation. If a callus layer does not form completely across a wound the wound can only heal through annual cambium growth from the edges of the wound.

Interaction Between Forestry and Grazing

Coniferous tree seedlings must survive and grow in a competitive environment. In a model of a micro-ecosystem, an individual conifer seedling must compete for light, water, space, and nutrients (Carter, et al.

1984, Elliot and White 1987). In most natural systems there are three possible outcomes to competition: the conifer seedling will out compete surrounding vegetation and survive with unlimited growth, the conifer seedling will compete successfully with surrounding vegetation and survive with limited growth, and the conifer seedling will not compete successfully with surrounding vegetation and will not survive. In most natural systems the outcome of competition is not guaranteed, subtle changes in the competitive environment or even the timing of those changes can result in different outcomes of individual survival and growth.

Grasses are efficient competitors with conifer seedlings because they initiate root growth at cooler soil temperatures, have more rapid root growth after disturbance, and have an overall larger root system (McDonald 1986). Conifer seedlings planted immediately after logging can avoid competition by rapidly developing their root systems and overtopping competing vegetation before it becomes established (Eis 1980). New cutblocks are invaded first by pioneer species, then by biennial and perennial herbaceous species, with shrubs being the last vegetative component to establish and grow. Although this sequence is predictable, the colonization rate after the forest canopy is removed is modified by site and the condition of the pre-harvest forest canopy. Conifer seedlings are exposed to more competition on moist sites than dry sites because competing vegetation establishes and develops faster when there is improved moisture. Open forest canopies usually have an established herb and shrub layer that is released by cutting while poor light penetration to the forest floor inhibits the herb and shrub layer in closed forest canopies. Conifer seedlings will have more competition on sites where the pre-harvest canopy is open because herbaceous plants and shrubs are already established and will be released by removal of the canopy.

Competing vegetation can physically modify sites to be more or less favourable for conifer seedling growth. Grasses, although an initial hindrance to conifer seedling growth, may be beneficial in the longer term by inhibiting shrub invasion (McDonald, 1986). Grasses may also stabilize sites and reduce erosion. Grasses and grass litter will modify the soil thermal regime; this modification could be either favourable or detrimental depending on the site. Plant litter has an insulating effect on the soil (Facelli 1991). On hot, dry sites this insulating effect might be beneficial by keeping the soil cool and reducing direct loss of water through evaporation. On cool, moist sites the insulating effect will be detrimental because the soil will warm slower in the spring, resulting in a reduced growing season (Hogg and Lieffers 1990) and thus a reduced growth rate for conifer seedlings. Grasses can also act as an attractant to animals and insects (McDonald 1986). Small mammals that find shelter in grass litter can girdle conifer seedlings. Large mammals may also be attracted to grasses and damage conifer seedlings directly through browsing or indirectly by trampling. Whether the large mammals are natural wildlife or managed livestock, the attractant is the same: grass production attracts herbivores.

Grazing by livestock on cutblocks could have a beneficial affect on conifer seedling growth by reducing grass competition (Karl and Doescher 1993, Doescher and Tesch 1989). However, livestock grazing also has a potential detrimental effect on conifer seedlings by trampling and browsing. For western Canada it seems trampling by livestock is more prevalent than browsing (Kingery and Graham 1990, Mclean and Clark 1980, Nordstrom 1984). In set stocking rate studies, conifer seedling damage increases with stocking rate (Newman and Wikeem 1990, King, Bailey, and Walston 1978). Field scale studies indicate that conifer seedling damage remains at acceptable levels when livestock are properly managed (Kingery and Graham 1990, Kosco and Bartolome 1983, Mclean and Clark 1980, Adams 1975).

Conifer seedlings damaged by livestock will either recover, recover with reduced growth, or die. Girdling (basal scarring), trampling, or defoliation are the three sources of damage to conifer seedlings. Controlled studies of these three damage types indicate that unless damage is severe, pine seedlings have a high recovery rate (Newman and Wikeem 1990, Lewis 1980a, Lewis 1980b, Lewis 1980c). Mortality of pine seedlings is negligible until girdling approaches 100 percent (Newman and Wikeem 1990, Lewis 1980a). Basal girdling of 75 percent results in a reduction in growth but not mortality. Seedlings are more susceptible to damage when they are less than six months old (Lewis 1980a) and after bud set (Newman and Wikeem 1990). Seedlings damaged after bud set have a reduced time to recover before the onset of winter. Different species of conifers may react differently to damage. Douglas fir seedlings are more susceptible to damage than pine seedlings (Eissenstat, Mitchell, and Pope 1982); damage by livestock was most prevalent the year following planting.

Most historical studies examining livestock damage on conifer plantations have used fixed stocking rates or fixed utilization levels as correlates for resulting damage. Studies of this nature yield recommendations that apply to cutblocks or forest/pasture plantations that have uniform vegetation, but may give misleading results on cutblocks that have heterogeneous vegetation. Herbivores are selective (Bailey et al. 1996, Coughenour 1991, Senft et al. 1987). Herbivores select plant species from within feeding stations, feeding stations from within plant communities, plant communities from within landscapes, and landscapes from within regions (Senft et al. 1987). This sequence is defined as an ecological hierarchy; the theory is a contrast to the traditional view of herbivores interacting with their environment in terms of set stocking rates and definable areas. The application of hierarchical theory to management situations can solve ambiguities presented by the application of set stocking rate theory. In simplistic terms, even though a landscape system may have a set stocking rate of herbivores, each plant community within the landscape system will have a different stocking rate because of selection or avoidance by herbivores. By extension, each feeding station within each plant community will endure a different level of defoliation because of selection or avoidance by herbivores.

Hierarchical foraging theory can be used to explain ambiguities in the literature on the effect of livestock grazing on conifer regeneration. Several authors have noted that livestock grazing has minimal impact on conifer regeneration as long as the livestock are properly managed (McLean and Clark 1980, Kosco and Bartolome 1983, Kingery and Graham 1990, Adams 1975). The authors imply that proper management entails minimizing concentrated grazing by minimizing selective grazing. Stocking levels should be set by obtaining moderate grazing pressure on preferred sites, not by obtaining moderate grazing pressure over an entire landscape.

Grazing capacity has been defined as the maximum number of animals that can graze an area for a specific period of time without inducing a downward trend in forage production, forage quality, or soil productivity (Stoddard, Smith, and Box 1975). Historically, grazing capacity has been considered only from a forage (herbaceous) productivity standpoint. In multiple use situations other site parameters have to be considered. On tree plantations, grazing levels that are sustainable in terms of forage production might result in unacceptable levels of damage to tree seedlings. If seedling damage is an issue, grazing capacity should be set based on acceptable levels of damage to tree seedlings. In this case grazing capacity will likely be less than if based on forage productivity. If seedling damage is not an issue, then grazing capacity can be set based exclusively on forage production and rangeland conservation criteria (the traditional method).

Horse grazing within areas managed for timber resources is an established land use and may increase in the future. Many tourist activities that rely on horses are expected to increase in western Alberta. Local research is required to coordinate horse grazing with regeneration efforts. Historical studies have focused on the negative interactions between forestry and grazing interests. This study will attempt to determine the common ground on which forestry and grazing interests can be coordinated.

STUDY AREA

The study area was located south of Hinton, Alberta, located in the foothills of the Rocky Mountains. The area has a continental climate, with cold winters and warm summers (Dzikowski and Heywood undated). The Rocky Mountains block the movement of Pacific air masses and channel Arctic air masses on to the Great Plains region of central North America. The proximity of Hinton to the Rocky Mountains results in a variable, but predictable climate. Rapid changes in elevation result in variation in local climate over relatively short distances. Hinton townsite receives about 500 mm of precipitation annually with 70 percent falling as rain and 30 percent as snow (Dumanski et al. 1972, Anonymous 1982). Hinton is located in a river valley, so precipitation levels outside the river valley are likely higher, perhaps 600 mm of annual precipitation (Dzikowski and Heywood undated). July is the warmest month with a mean temperature of 15° C, while January is the coldest month with a mean temperature of -12° C (Dumanski et al. 1972).

Bedrock geology in the study area belongs to the Paskapoo Formation of Paleocene age. The Paskapoo Formation consists of beds of sandstone and siltstone with frequent shale, coal, and chert (Roed 1968). The study area was covered with ice sheets in the Pleistocene. Although the study is on the boundary of the continental and Cordilleran ice sheets, most of the surficial deposits are Cordilleran in origin (Dumanski et al. 1972). Surficial material can be classified into three broad categories: till, alluvial, and organic deposits. Glacial till was deposited in the study area in two glaciations; Obed till is the most recent deposit while Marlboro till is the older deposit (Roed 1968). Obed till is restricted to the immediate slopes of the Athabasca River valley while Marlboro till underlies most of the benchlands outside of the river valley (Dumanski et al. 1972). Marlboro and Obed tills are similar, both are Cordilleran in origin and lime-based, and different, Obed deposits are coarser in texture and higher in lime content (Roed 1968). Alluvial material is deposited by streams. It is comprised of gravel and sand and is isolated along stream courses throughout the study area. Organic surficial material can be found throughout the study area in association with depressions and areas of localized poor soil drainage. Organic deposits are a result of continual addition of dead vegetation in areas with continuous saturated conditions and slow decomposition.

Soils in the study area are strongly influenced by parent material and topographic position. The dominant upland soil is an Orthic Gray Luvisol developed on Marlboro till (Dumanski et al. 1972). This is the most common soil throughout the study area. Two types of imperfectly drained soils have been mapped in the study area. The Erith Complex is a collection of soils that are mineral in origin and are classified in the Gleysolic Order. These soils are usually found in side slope positions between well-drained Luvisolic soils above and poorly drained soils of organic origin below (Dumanski et al. 1972). The Erith Complex is most often associated with seeps and springs, commonly located in the toe slope position. The Fickle Complex of soils is organic in origin. Soils of the Fickle Complex are always found in concave or level topographic positions (Dumanski et al. 1972). Soils of the Fickle Complex are characterized by a layer of undecomposed organic matter at least 60 cm thick.

Vegetation of the study area is classified as Upper Boreal Cordilleran (Corns and Annas 1986). Vegetation types occur in a predictable pattern that repeats along rolling topographic gradients. Most of the study area is either forested or is recently harvested cutblocks. Natural herbaceous sites are limited to depressions dominated by sedges (*Carex spp.),* poorly drained areas found on gentle slopes dominated by sparse black spruce (*Picea mariana*), or seep areas dominated by a guild of high moisture and salt tolerant species. There are three well defined types of forest in the study area. Lodgepole pine (*Pinus contorta var. latifolia*) and black spruce (*Picea mariana*) are the dominant tree species. Well-drained sites are typically dominated by lodgepole pine, drier south-facing slopes have a herbaceous understory dominated by hairy wild rye (*Elymus innovatus*) while moist north-facing slopes have a shrub understory dominated by green alder (*Alnus crispa*) (Table 1-1). Black spruce forests are common on gentle slopes that are poorly drained. Black spruce forests are usually associated with Labrador tea (*Ledum groenlandicum*) and woodland horsetail (*Equisetum sylvaticum*). On intermediate slope positions between the pine sites and the black spruce forest is a transition forest type. Transition forests contain elements of a typical pine and typical black spruce forest site. The relative size and distribution of the transition site are dependent on slope; it is narrow on steeper slopes and wider on gentle slopes. Muskegs are common throughout the study area. Muskegs are associated with depressions and consequently have saturated soil conditions year round. Muskegs are dominated by sedges and other moisture tolerant herbaceous species. Tree growth on muskegs is limited by high soil moisture. Hygric meadows are herbaceous sites dominated by species that are tolerant of water saturation and salt accumulations. Hygric meadows usually occur on poorly drained gentle slopes or seep areas, often in close association with black spruce forests. Hygric meadows have a sparse cover of black spruce, a shrub layer of dwarf birch (*Betula glandulosa*) or shrubby cinquefoil (*Potentilla fruticosa*), and herb layer of dwarf and straight horsetail (*Equisetum scirpoides* and *E. variagatum*), Rushes (*Juncus spp.*), and wheatgrasses (*Agropyron spp.*). Disturbed areas are independent of the site they occur on. Disturbed areas such as cutlines, spur roads, and landings are dominated by introduced herbaceous species. Creeping red fescue (*Festuca rubra*), orchard grass (*Dactylis glomerata*), timothy (*Phleum pratense*), and clover (*Trifolium repens* and *T. hybridum*) are common introduced species on disturbed areas. Disturbed areas occur on all site types and are generally differentiated because of the dominance of introduced species.

Much of the study area has been modified by forest harvesting activities. Forest harvesting does not alter the site type but it does alter the overstory vegetation. Dry and moist pine forests and a portion of the transition foresests typically have sufficient timber volume to support commercial forest operations. Black spruce forest, muskegs, hygric meadows, and a portion of the transition forest do not have sufficient timber volume to support commercial forest harvest. The current landscape of the study area is a predictable catena of vegetation that has forest harvesting superimposed on it. Consequently, the pine sites and the merchantable part of the transition site can be further classified into undisturbed forest and cutblocks. The degree of forest harvest complete at the time of study was variable and depended on specific location within the study area and the size and juxtaposition of the forest types at that location.

Table 1-1. Vegetation types and selected characteristics of the study area. Adapted from Corns and Annas, 1986.

Nomenclature			Topographic		Moisture
Corns and Annas 1986	Common Name	Dominant Species	Position	Drainage	Status
Lodgepole Pine/Elymus	Dry Pine	Pinus contortus var. latifolia Engelm Elymus innovatus Beal	South Facing Slopes	Good	Dry
Lodgepole Pine/Alnus	Moist Pine	Pinus contortus var. latifolia Engelm Alnus crispa (Ait.) Pursh	North Facing Slopes	Good	Moist
Lodgepole Pine/Black Spruce /Ledum/Pleourozium	Transition	Pinus contortus var. latifolia Engelm Picea mariana (Mill.) BSP Ledum groenlandicum Oeder Pleurozium schreberi (Brid.) Mitt	Mid Slope	Fair	Moist
Black Spruce/Ledum/Equisetum	Black Spruce Forest	Picea mariana (Mill.) BSP Ledum groenlandicum Oeder Equisetum sylvaticum L.	Lower Slope	Poor	Wet
Muskeg[1]	Muskeg	Carex spp. L.	Depressions	Poor	Saturated
Hygric Meadows[1]	Hygric Meadow	Equisetum variagatum Schleich. Equisetum scirpoides Michx. Juncus spp. L. Agropyron spp. Gaertm. Betula glandulosa Michx.	Gentle Slopes	Fair	Seasonally Wet or Moist
Disturbed Sites[1] Cutlines Spur Roads Landings	Disturbed Sites	Festuca rubra L. Dactylis glomerata L. Trifolium repens L. Trifolium hybridum L.	All Slope Positions	Variable	Variable

[1] Not described in Corns and Annas 1986

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2. HABITAT SELECTION OF WINTER GRAZING HORSES IN AN UPPER BOREAL CORDILLERAN ENVIRONMENT

INTRODUCTION

Conflict between the forest industry and owners of free-ranging horses originated as early as 1960 west of Hinton, Alberta (Ranger 1972). Free ranging horses, both tame and feral, were implicated in the damage and eventual death of conifer seedlings over large areas of replanted cutblocks. The tame horses consisted of mostly outfitters stock turned out on public land to graze during the winter when they were not needed. Recreational riders also enjoyed free winter grazing for their horses, although the numbers were generally thought to be less than those owned by outfitters. Feral horse populations in the area originated from tame stock that had escaped capture and control by their owners.

The issue of free-ranging horse use on cutblocks west of Hinton was brought to a head by persistent complaints from the forest industry. In the mid 1970's a round up and dispersal of free ranging horses was initiated. Some of the free-ranging horses were removed to grazing leases or head tax permit areas held by individuals and grazing associations. It would seem that other free-ranging horses were temporarily removed but apparently their owners simply moved them to less accessible and less popular areas of public land. Thus, the locally accepted practice of allowing domestic horses to free-range on public land continued, but was less obvious because it occurred in areas farther from town and more remote in nature.

Free-ranging horse grazing went almost unnoticed until the late 1980's and early 1990's. When timber harvesting expanded into some of the less accessible areas used by free-ranging horses the real or perceived conflict between horses and conifer seedlings appeared once again. The same issues outlined earlier (Ranger 1972) again came to the forefront; free ranging horses were causing unacceptable levels of conifer seedling mortality, were a threat to public safety both in road collisions and by their aggressive nature, were a threat to reclamation efforts along roads and right of ways, and were an unnecessary competitor to indigenous wildlife.

Intuitively, there is an apparent potential for horses to cause damage to conifer seedlings. Horses are primarily grazers (Ralston 1984) and will preferentially seek habitats that produce large amounts of herbaceous forage (Salter and Hudson 1978). Harvesting timber removes the canopy and releases understory vegetation; harvested cutblocks typically have more herbaceous growth than mature forest (Eis 1980). It is reasonable to assume that free-ranging horses should be attracted to cutblocks because of the increased herbage biomass relative to adjacent forests. The tendency of horses to graze in groups (Salter and Hudson 1982) rather than singly would further increase the likelihood of conifer seedling damage.

Herbivores are selective (Bailey et al. 1996, Coughenour 1991, Senft et al. 1987). They select plant species from within feeding stations, feeding stations from within plant communities, plant communities from within landscapes, and landscapes from within regions (Senft et al. 1987). This sequence is defined as an ecological hierarchy, which contrasts the traditional view of herbivores interacting with their environment in terms of set stocking rates and definable areas. The application of hierarchical theory can solve ambiguities presented by set stocking rate theory. In simplistic terms, even though a landscape system may have a set stocking rate of herbivores, each plant community within the landscape will have a different stocking rate because of selection or avoidance by herbivores. By extension, each feeding station within each plant community will endure a different level of defoliation because of selection or avoidance by herbivores.

Hierarchical foraging theory can be used to explain ambiguities in the literature on the effect of livestock grazing on conifer regeneration. Several authors have noted that livestock grazing has minimal impact on conifer regeneration provided livestock are properly managed (McLean and Clark 1980, Kosco and Bartolome 1983, Kingery and Graham 1990, Adams 1975).

The authors are implying that proper management entails reducing concentrated grazing by minimizing selective grazing. Previous study of horse grazing behaviour indicates that hierarchical foraging theory will apply (Berger 1986), but lack of empirical observation of horses grazing in Upper Boreal Cordilleran vegetation limits the conclusions that can be drawn.

The purpose of this study was to document winter grazing behaviour of free-ranging horses in an Upper Boreal Cordilleran vegetation zone that contained recent timber cutblocks. A major goal of this study was to determine preferred winter grazing habitats of free-ranging horses. Specifically, this study will answer the question of whether free-ranging horses preferentially use timber cutblocks for winter foraging activities.

STUDY AREA

Habitat preference of free ranging horses was studied in the Macpherson Creek area, south of Hinton, Alberta, 450 km west of Edmonton, Alberta. Soils in the study area are strongly influenced by parent material and topographic position. The dominant upland soil is an Orthic Gray Luvisol developed on Marlboro glacial till (Dumanski et al. 1972). Two types of imperfectly drained soils have been mapped in the study area. A collection of Gleysolic soils that are mineral in origin are usually found in side slope positions between well drained Luvisolic soils above and poorly drained soils of organic origin below. Gleysolic soils are often associated with seeps and springs and are commonly located in the toe slope position. Organic soils are always found in concave or level topographic positions and are associated with poor drainage.

Vegetation of the study area (Table 2-1) is classified as Upper Boreal Cordilleran (Corns and Annas 1986). Vegetation types occur in a predictable pattern that repeats along rolling topographic gradients. In general, lodgepole pine (*Pinus contorta*) (Moss 1983) is the dominant tree species on upland sites while black spruce (*Picea mariana*) dominates on poorly drained sites. A transition site that is co-dominated by both species occurs on moderately drained sites.

Much of the study area has been modified by forest harvesting activities. Forest harvesting does not alter the site type, but it does alter the overstory vegetation. Although dry and moist pine sites and a portion of the transition sites typically have sufficient timber volume to support commercial forest operations, black spruce forest, muskegs, hygric meadows, and a portion of the transition sites are non-merchantable. The current landscape of the study area is a predictable catena of vegetation that has forest harvesting superimposed on it. Consequently, the pine sites and the merchantable part of the transition site can be further classified into undisturbed forest and cutblocks. The degree of forest harvest complete at the time of study was variable and depended on specific location and the size and juxtaposition of the forest types at that location.

METHODS

Habitat preference was assessed primarily for the winter period. Habitat use evaluation during the winter periods involved tracking individual horses or groups of horses and recording and mapping habitat use and activities. The main times of sampling were early winter (December), late winter (February), and early spring (April). As many individuals or groups as possible were located, tracked, and monitored for as long as possible. The purpose of winter tracking was to locate zones of active horse habitat use; these zones were intensively sampled the following spring. In May, 1995 and 1996, overall winter habitat use evaluations were done using a fecal group survey. A fecal group was defined as a single incidence of fecal material. Used and unused habitats were surveyed using a non-mapping technique (Marcum and Loftsgaarden 1980). Linear transects were run through areas of confirmed free-ranging horse activity. Sample plots were established at 100 m intervals. At each sample plot, site and vegetation was characterized and a 0.01 ha plot was assessed for horse use. If the plot contained a horse fecal group it was classified as used. If the plot did not contain a fecal group but had evidence of horse use (heavy grazing, tracks, or trails) it was also classified as used. Site characterization included physiognomy (forest or cutblock), site type (Table 2-1), aspect, slope, forest canopy closure, dominant herbaceous species (up to 3), and dominant shrub species (up to 3). Horse use was also characterized in each plot as present or absent. A total of 472 plots were established over 2 years of study. Site types were complex and included dry pine, moist pine, transition, residual black spruce forest, muskeg, hygric meadows, and disturbed sites. Sampling in areas of concentration such as salt licks was avoided.

ANALYSES

Selection ratios were computed from cross tabulations of raw count data. Nomenclature, symbols, and methodology followed standard convention (Table 2-2, Manly, McDonald, and Thomas 1993). Selection ratios were computed by dividing the proportion of used plots by the proportion of available plots. Selection ratios greater than one indicate selection while those less than one indicate avoidance. Significant selection or avoidance was determined using Bonferonni confidence limits. If the Bonferonni confidence limit contains one there is no evidence of selection or avoidance, if the upper confidence limit is less than one there has been significant avoidance, while if the lower confidence limit is greater than one there has been significant selection.

RESULTS

Free ranging horses selected from a wide variety of habitats. Of 472 horse use plots established in the spring of 1995 and 1996, the most common vegetation physiognomy encountered was forest or cutblocks (Table 2-3). Hygric meadows, disturbed areas, and muskeg were less common. Although hygric meadows comprised only 8 percent of the total area sampled they received 26 percent of the horse use, indicating significant selection. Cutblocks were significantly avoided by winter grazing horses; they comprised 32 percent of the total area but received only 14 percent of the horse use. Forest was neither selected nor avoided by horses. Use or occurrence of muskegs and disturbed areas was too small to draw conclusions.

Horses showed selective grazing behaviour for forest sites (Table 2-4). Winter grazing free ranging horses showed significant selection for hygric meadows and significant avoidance for dry pine sites. All other sites were neither selected nor avoided. Although black spruce forest and disturbed areas had selection ratios that would be indicative of selection, the response was not significant.

Horses grazing in winter revealed selective grazing behaviour for dominant herbaceous and shrub species. Winter grazing horses showed significant selection for sites dominated by straight horsetail (Table 2-5) and bog birch (Table 2-6) and significant avoidance for sites dominated by hairy wild rye (Table 2-5). Although several other herbaceous and shrub species revealed trends of selection or avoidance, the response was not significant.

Horses grazing in winter appeared to be unaffected by steepness of slope (Table 2-7) but showed significant avoidance for northeast and southeast aspects (Table 2-8). Small numbers of either occurrence or use limit interpretation for some slopes and aspects.

DISCUSSION

In the winter, horses show a selective response for a specific non-commercial forest habitat, hygric meadows. There was also evidence of selection of black spruce forests with an understory that contains dwarf horsetail, but the selection response was not significant. Both are soil water discharge areas and have saturated conditions for part of the year and both likely have accumulations of salts. Hygric meadows differ from black spruce forests in that they have a sparse forest canopy, occur at the toe of the slope in seep areas, and are dominated by shrub, grass, and forb species that are indicative of soil salt accumulations (shrubby cinquefoil, dwarf birch, wheatgrasses, baltic rush, and straight horsetail). In winter cutblocks are used sparingly by horses and are not a preferred site. Residual commercial forest types are lightly used by horses during the winter, mostly for travel between preferred foraging sites. The preferential use of habitats by winter grazing horses that are dominated by horestail has not been reported in previous literature, although it appears to be common local knowledge in west-central Alberta (Gosney and Groat 1994).

Clearly, free-ranging horses grazing in winter had an alternative preferred habitat to cutblocks. These horses were a minor damage threat to conifer seedlings because they did not make extensive use of cutblocks. Avoidance of cutblocks by horse grazing in the winter was unexpected. If horses were to select habitats based on forage production, cutblocks should be a preferred habitat because of higher herbaceous production. The results of this study indicate winter grazing horses are not selecting habitats based on herbaceous productivity. Other potential cues that could cause selection of hygric meadows and black spruce forests are herbaceous composition, improved thermal cover, and differential snow distribution. Although herbaceous composition has been shown to be a significant factor in selection or avoidance by winter grazing horses, all three of the above factors are confounded when cutblocks are superimposed. Cutblocks only occur on areas of commercial forest while dwarf and straight Equisetum mostly occur on areas of non-commercial forest.

The question of why winter grazing horses avoid cutblocks and select hygric meadows and black spruce forests cannot be answered by this study. Other studies have alluded to the use of sheltered habitats by winter grazing horses for thermal cover (Salter and Hudson 1978, Miller 1983). The following discussion should be viewed as speculative, although it is based on actual observation. Selection for non-commercial forest by winter grazing horses cannot be explained by horses selecting areas that have improved thermal cover. On several occasions horses were observed foraging in black spruce forest on warm winter days with little wind when selection for thermal cover should not have been an important factor. Although superior thermal cover provided by non-commercial forest would be a factor in habitat selection on cold, windy days the observation that horses did not move onto cutblocks to forage on warm, windless days indicates there are other more important factors controlling selection. Distribution of snow differs between treed and treeless habitats. Conifer trees catch snow, leaving the micro-habitat under individual trees with less snow cover than the micro-habitat between individual trees or the macro-habitat of a treeless environment that occurs on cutblocks. Field observations of winter grazing horses indicated that horses cratering through snow often started their craters on the edge of the canopy of individual trees, where snow depths were least. The same area under individual trees was also observed to be free of snow earlier in the spring than adjacent areas between trees or cutblocks. The presence of trees on non-commercial forest is probably an important factor in selection by winter grazing horses. Trees re-distribute snow, the result is a micro-habitat beneath individual trees that has reduced snow loads compared to between tree spaces. Finally, horses may select areas of non-commercial forest simply because that is where dwarf and straight horsetail grow. Horses might selectively graze plants, and therefore, areas where green forage is available in the winter (Duncan 1992). Dwarf and straight horsetail are both green throughout the winter in the environment studied. Field horsetail (*Equisetum arvense*) has been noted as being highly preferred by horses (Jones 1901) as well as being poisonous, especially if consumed cured in hay (Kingsbury 1964). Observation of a group of eight horses in the spring of 1995 indicated they ate almost exclusively dwarf and straight horsetail, even though snow cover was almost gone and other plants were readily available. The toxic nature and response of grazing animals to species of horsetail other than field horsetail has not been investigated. The selective response by horses for areas where horsetail grows and the observed preference for consuming horsetails in the winter merits further investigation. Preferential consumption of plant species that are possibly poisonous is a cause of concern.

CONCLUSIONS

1. Knowledge of selective foraging patterns by winter grazing horses can be used to minimize damage to conifer seedlings. Providing horses with an alternative preferred habitat is a realistic strategy to manage horses in conjunction with newly regenerating cutblocks. Alternative preferred habitats for winter grazing horses are black spruce forests and hygric meadows, both of which have straight and dwarf horsetail as key indicator species. Caution is advised if free ranging horse are using areas that do not contain black spruce forest or hygric meadows. Although another alternative preferred habitat may exist the results from this study cannot be used for recommendations in areas of significantly different vegetation types and distribution.
2. Management strategies can be developed that will enable horse grazing in areas of cutblocks. Stocking rates for horses should be carefully monitored and maintained at a level where the forage on alternative preferred habitats meets or exceeds the requirements of the horses.

Table 2-1. Vegetation types and selected characteristics of the study area. Adapted from Corns and Annas, 1986.

Nomenclature			Topographic		Moisture
Corns and Annas 1986	Common Name	Dominant Species	Position	Drainage	Status
Lodgepole Pine/Elymus	Dry Pine	Pinus contortus var. latifolia Engelm. Elymus innovatus Beal	South Facing Slopes	Good	Dry
Lodgepole Pine/Alnus	Moist Pine	Pinus contortus var. latifolia Engelm. Alnus crispa (Ait.) Pursh	North Facing Slopes	Good	Moist
Lodgepole Pine/Black Spruce /Ledum/Pleourozium	Transition	Pinus contortus var. latifolia Engelm. Picea mariana (Mill.) BSP Ledum groenlandicum Oeder Pleurozium schreberi (Brid.) Mitt	Mid Slope	Fair	Moist
Black Spruce/Ledum/Equisetum	Black Spruce Forest	Picea mariana (Mill.) BSP Ledum groenlandicum Oeder Equisetum sylvaticum L.	Lower Slope	Poor	Wet
Muskeg[1]	Muskeg	Carex spp. L.	Depressions	Poor	Saturated
Hygric Meadows[1]	Hygric Meadow	Equisetum variagatum Schleich. Equisetum scirpoides Michx. Juncus spp. L. Agropyron spp. Gaertm. Betula glandulosa Michx.	Gentle Slopes	Fair	Seasonally Wet or Moist
Disturbed Sites[1] Cutlines Spur Roads Landings	Disturbed Sites	Festuca rubra L. Dactylis glomerata L. Trifolium repens L. Trifolium hybridum L.	All Slope Positions	Variable	Variable

[1] Not described in Corns and Annas 1986

Table 2-2. Definition and interpretation of symbols used for statistical analyses of habitat selection.

Symbol [1]	Definition	Interpretation
m_i	Number of plots sampled	Tabulation from raw data
π_i	Proportion of plots sampled	Computation from tabulated data
u_i	Number of plots used by horses	Tabulation from raw data
o_i	Proportion of plots used by horses	Computation from tabulated data
w_i	Selection Ratio, equals o_i/π_i	Computation from calculated data If > 1 indicates selection If < 1 indicates avoidance
χ^2	Pearson Chi-squared statistic	Computation from calculated data
$se(w_i)$	Standard Error of the Selection Ratio	Computation based on Poisson Distribution theorums
	Lower Confidence Limit	If>1 indicates significant selection
	Upper Confidence Limit	If<1 indicates significant avoidance

[1] Follows convention as outlined in Manly, McDonald, and Thomas 1993.

Table 2-3. Habitat selectivity by free-ranging horses for plots classified by gross physiognomy.

	m_i	π_i	u_i	o_i	w_i	χ^2	se(w_i)	Confidence Limits Lower		Upper
Forest	262	0.56	40	0.54	0.97	0.0	0.11	0.713		1.234
Cutblock	150	0.32	10	0.14	0.43	7.8	0.13	0.126	-	0.724
Meadow	37	0.08	19	0.26	3.28	30.0	0.83	1.344	+	5.206
Trail or Cutline	9	0.02	4	0.05	2.83	4.8	1.67	0.000		6.717
Muskeg	14	0.03	1	0.01	0.46	0.7	0.47	0.000		1.546
Total	472	1.00	74	1.00	7.96	43.2				

Confidence limits separated by a "+" indicate significant selection.

Confidence limits separated by a "-" indicate significant avoidance.

Follows convention as outlined in Manly, McDonald, and Thomas 1993.

Refer to Table 2-2 for interpretation guidelines.

Table 2-4. Habitat selectivity by free-ranging horses for plots classified by forest site.[1]

	m_i	π_i	u_i	o_i	w_i	χ^2	se(w_i)	Confidence Limits Lower		Upper
Dry Pine	182	0.39	15	0.20	0.53	6.4	0.12	0.218	-	0.833
Transition	91	0.19	8	0.11	0.56	2.8	0.19	0.082		1.039
Black Spruce Forest	83	0.18	21	0.28	1.61	4.9	0.34	0.781		2.447
Hygric Meadow	43	0.09	19	0.26	2.82	22.3	0.69	1.116	+	4.520
Moist Pine	31	0.07	5	0.07	1.03	0.0	0.48	0.000		2.207
Disturbed	9	0.02	4	0.05	2.83	4.8	1.67	0.000		6.934
Other	33	0.07	2	0.03	0.39	1.9	0.28	0.000		1.069
Total	472	1.00	74	1.00	9.77	43.1				

Confidence limits separated by a "+" indicate significant selection.

Confidence limits separated by a "-" indicate significant avoidance.

[1] Site classified according to Corns and Annas, 1986

Follows convention as outlined in Manly, McDonald, and Thomas 1993.

Refer to Table 2-2 for interpretation guidelines.

Table 2-5. Habitat selectivity by free-ranging horses for plots classified by dominant herbaceous species.

	m_i	π_i	u_i	o_i	w_i	χ^2	se(w_i)	Confidence Limits Lower		Upper
Hairy Wild Rye	224	0.47	21	0.29	0.61	5.1	0.12	0.318	-	0.911
Twinflower	113	0.24	17	0.24	0.99	0.0	0.22	0.417		1.556
Marsh Reed Grass	69	0.15	11	0.15	1.05	0.0	0.31	0.251		1.839
Water Sedge	59	0.13	19	0.26	2.11	11.1	0.49	0.870		3.352
Straight Equisetum	58	0.12	28	0.39	3.16	41.5	0.61	1.620	+	4.710
Dwarf Equisetum	43	0.09	14	0.19	2.13	8.4	0.60	0.614		3.655
Slender Sedge	21	0.04	7	0.10	2.19	4.5	0.91	0.000		4.504
Other Sedge	18	0.04	7	0.10	2.55	6.6	1.09	0.000		5.315
Baltic Rush	17	0.04	10	0.14	3.86	21.2	1.46	0.155		7.558
Total	472	1.32	72	1.86	18.65	98.36				

Confidence limits separated by a "+" indicate significant selection.

Confidence limits separated by a "-" indicate significant avoidance.

Follows convention as outlined in Manly, McDonald, and Thomas 1993.

Refer to Table 2-2 for interpretation guidelines.

Table 2-6. Habitat selectivity by free-ranging horses for plots classified by dominant shrub species.

	m_i	π_i	u_i	o_i	w_i	χ^2	$se(w_i)$	Confidence Limits Lower		Upper
Willow	176	0.37	28	0.39	1.04	0.0	0.17	0.644		1.442
Labrador Tea	104	0.22	11	0.15	0.69	1.5	0.20	0.210		1.177
Alder	67	0.14	7	0.10	0.68	1.0	0.26	0.066		1.304
Bog Birch	69	0.15	22	0.31	2.09	12.5	0.44	1.039	+	3.142
Bearberry	20	0.04	5	0.07	1.64	1.2	0.79	0.000		3.542
Shrubby Cinquefoil	18	0.04	8	0.11	2.91	10.1	1.18	0.077		5.750
Total	472	0.96	72	1.13	9.06	26.4				

Confidence limits separated by a "+" indicate significant selection.

Confidence limits separated by a "-" indicate significant avoidance.

Follows convention as outlined in Manly, McDonald, and Thomas 1993.

Refer to Table 2-2 for interpretation guidelines.

Table 2-7. Habitat selectivity by free-ranging horses for plots classified by percent slope.

	m_i	π_i	u_i	o_i	w_i	χ^2	se(w_i)	Confidence Limits Lower	Confidence Limits Upper
Flat	202	0.43	30	0.41	0.95	0.1	0.14	0.615	1.279
1-5 Percent	120	0.25	22	0.30	1.17	0.5	0.23	0.637	1.702
6-15 Percent	127	0.27	17	0.23	0.85	0.4	0.19	0.404	1.303
16-30 Percent	19	0.04	4	0.05	1.34	0.4	0.72	0.000	3.019
> 30 Percent	4	0.01	1	0.01	1.59	0.2	1.77	0.000	5.722
Total	472	1.00	74	1.00	5.91	1.6			

Confidence limits separated by a "+" indicate significant selection.

Confidence limits separated by a "-" indicate significant avoidance.

Follows convention as outlined in Manly, McDonald, and Thomas 1993.

Refer to Table 2-2 for interpretation guidelines.

Table 2-8. Habitat selectivity by free-ranging horses for plots classified by aspect.

	m_i	π_i	u_i	o_i	w_i	χ^2	$se(w_i)$	Confidence Limits Lower		Upper
Flat	202	0.43	30	0.41	0.95	0.1	0.14	0.597		1.298
North	50	0.11	9	0.12	1.15	0.2	0.39	0.188		2.108
South	84	0.18	19	0.26	1.44	2.6	0.32	0.658		2.228
East	15	0.03	4	0.05	1.70	1.2	0.93	0.000		3.997
West	10	0.02	1	0.01	0.64	0.2	0.66	0.000		2.272
Northeast	37	0.08	2	0.03	0.34	2.5	0.25	0.000	-	0.951
Northwest	19	0.04	3	0.04	1.01	0.0	0.61	0.000		2.515
Southeast	36	0.08	1	0.01	0.18	3.8	0.18	0.000	-	0.616
Southwest	19	0.04	5	0.07	1.68	1.4	0.82	0.000		3.689
Total	472	1.00	74	1.00	9.08	11.89				

Confidence limits separated by a "+" indicate significant selection.

Confidence limits separated by a "-" indicate significant avoidance.

Follows convention as outlined in Manly, McDonald, and Thomas 1993.

Refer to Table 2-2 for interpretation guidelines.

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3. HABITAT SELECTION AND SPRUCE SEEDLING DAMAGE AS A RESULT OF SUMMER GRAZING HORSES CONFINED TO LARGE AREAS CONTAINING CUTBLOCKS IN AN UPPER BOREAL CORDILLERAN ENVIRONMENT

INTRODUCTION

Conifer tree seedlings must survive and grow in a competitive environment. In a model of a micro-ecosystem, an individual conifer seedling must compete for light, water, space, and nutrients (Carter et al. 1984, Elliot and White 1987). In most natural systems there are three possible outcomes to competition: the conifer seedling will out compete surrounding vegetation and survive with unlimited growth, the conifer seedling will compete successfully with surrounding vegetation and survive with limited growth, and the conifer seedling will not compete successfully with surrounding vegetation and will not survive. In most natural systems the outcome of competition is not guaranteed, subtle changes in the competitive environment or even the timing of those changes can result in different outcomes of individual survival and growth.

Competing vegetation can physically modify sites to be more or less favourable for conifer seedling growth. Grasses, although an initial hindrance to conifer seedling growth, may be beneficial in the longer term by inhibiting shrub invasion (McDonald, 1986). Grasses may also stabilize sites and reduce erosion. Grasses and grass litter will modify the soil thermal regime; this modification could be either favourable or detrimental depending on the site. Plant litter has an insulating effect on the soil (Facelli 1991). On hot, dry sites this insulating effect might be beneficial by keeping the soil cool and reducing direct loss of water through evaporation. On cool, moist sites the insulating effect will be detrimental because the soil will warm slower in the spring resulting in a reduced growing season (Hogg and Lieffers 1990) and thus, a reduced growth rate for conifer seedlings. Grasses can also act as an attractant to animals and insects (McDonald 1986). Small mammals that find shelter in grass litter can girdle conifer seedlings. Large mammals may also be attracted to grasses and damage conifer seedlings directly through browsing, or indirectly by trampling. Whether the large mammals are natural, as is wildlife, or managed, as is livestock, the attractant is the same: grass production attracts herbivores.

Grazing by livestock on cutblocks could have a beneficial effect on conifer seedling growth by reducing grass competition (Karl and Doescher 1993, Doescher and Tesch 1989). However, livestock grazing also has a potential detrimental effect on conifer seedlings by trampling and browsing. For western Canada it seems trampling by livestock is more prevalent than browsing (Kingery and Graham 1990, Mclean and Clark 1980, Nordstrom 1984). In set stocking rate studies, conifer seedling damage increases with stocking rate (Newman and Wikeem 1990, King, Bailey, and Walston 1978). Field scale studies indicate that conifer seedling damage is maintained at acceptable levels when livestock are properly managed (Kingery and Graham 1990, Kosco and Bartolome 1983, Mclean and Clark 1980, Adams 1975).

Most historical studies examining livestock damage on conifer plantations have used fixed stocking rates or fixed utilization levels as correlates for resulting damage. Studies of this nature yield recommendations that apply to cutblocks that have uniform vegetation, but may give misleading results on cutblocks that have heterogeneous vegetation. Herbivores are selective (Bailey et al. 1996, Coughenour 1991, Senft et al. 1987). Herbivores select plant species from within feeding stations, feeding stations from within plant communities, plant communities from within landscapes, and landscapes from within regions (Senft et al. 1987). This sequence is defined as an ecological hierarchy; the theory is a contrast to the traditional view of herbivores interacting with their environment in terms of set stocking rates and definable areas. The application of hierarchical theory can solve ambiguities presented by the application of set stocking rate theory. In simplistic terms, even though a landscape system may have a set stocking rate of herbivores, each plant community within the landscape system will have a different stocking rate because of selection or avoidance by herbivores. By extension, each feeding station within each plant community will endure a different level of defoliation because of selection or avoidance by herbivores.

Hierarchical foraging theory can be used to explain ambiguities in the literature on the effect of livestock grazing on conifer regeneration. Several authors have noted that livestock grazing has minimal impact on conifer regeneration as long as the livestock are properly managed (McLean and Clark 1980, Kosco and Bartolome 1983, Kingery and Graham 1990, Adams 1975). The authors imply that proper management entails reducing concentrated grazing by minimizing selective grazing. Stocking levels should be set by obtaining moderate grazing pressure on preferred sites, not by obtaining moderate grazing pressure over an entire landscape.

The purpose of this study was to document summer grazing behaviour of horses confined to a large area that contained recent cutblocks in an Upper Boreal Cordilleran vegetation zone. A major goal of this study was to determine preferred summer grazing habitats of semi-confined horses. Specifically, this study addressed the question of whether semi-confined horses preferentially use specific sites on recent cutblocks or whether they graze all cutblock sites evenly. The impact of horse grazing on conifer seedling damage, survival, and growth on preferred sites was also documented.

STUDY AREA

Habitat preference of horses who had free range of cutblocks contained in a larger enclosure was studied in the Robb grazing lease, south of Hinton, Alberta, 450 km west of Edmonton, Alberta. The Robb grazing lease is about 8 square kilometres in size and contained four recent (less than five year old) cutblocks totaling about 60 ha in area. The cutblocks were planted with spruce seedlings at standard spacing, about 2500 seedlings/ha. Sampling in this study was limited to the cutblocks. The Robb grazing lease is stocked on an annual basis with about 20 horses from June 1 until October 31. The horses are unmanaged within the eight square kilometer area.

Soils in the study area are strongly influenced by parent material and topographic position. The dominant upland soil is an Orthic Gray Luvisol developed on Marlboro glacial till (Dumanski et al. 1972). Vegetation of the study area (Table 3-1) is classified as Upper Boreal Cordilleran (Corns and Annas 1986). The scope of this study was limited to four cutblocks, thus limiting the range of potential soils and vegetation types to those that occur under merchantable forest. Pre-harvest vegetation on the cutblocks consisted of three forest communities: lodgepole pine (*Pinus contorta var. latifolia*) (Moss 1983) and black spruce (*Picea mariana*) are the dominant tree species. Well drained sites are typically dominated by lodgepole pine; drier south facing slopes have a herbaceous understory consisting of hairy wild rye (*Elymus innovatus*) while moist north facing slopes have a shrub understory dominated by green alder (*Alnus crispa*) (Table 3-1). On intermediate slope positions between both dry pine and moist pine sites and black spruce forest there is a transition forest type. The transition forest type contains elements of both a typical pine and typical black spruce forest site. Disturbed areas are independent of the site they occur on. Disturbed areas, such as reclaimed power lines, spur roads, and landings are dominated by introduced herbaceous species. Disturbed areas occurred on all sites and are differentiated because of the dominance of introduced species.

METHODS

A reconnaissance survey of the cutblock portion of the Robb grazing lease was conducted in the fall of 1993. Three zones of moderate horse grazing activity were located and mapped. Horse activity was identified by evidence of grazing: tracks, fecal material, and grazed plants.

In the spring of 1994 an exclosure was constructed to exclude horses at each site of moderate grazing mapped the preceding year. Exclosures were large enough to contain 100 spruce seedlings, plus a buffer area around the outside perimeter. 100 spruce seedlings were also located outside the exclosure. All seedlings were individually identified with aluminum tags. Seedling size (diameter and height) was monitored over three growing seasons, beginning in spring, 1994. Final size measurements of all surviving seedlings were taken in the fall of 1996. Seedlings were assessed for damage in May, prior to horse introduction, and again in October, after horse removal. Damage measurements included browsing, basal scarring recorded in classes as a percent of circumference, and vertical displacement recorded in classes as degrees from vertical. The classes for basal scarring were 0, 1-10, 11-30, 31-60, and 61-100, visually estimated as a percent of circumference. The classes for vertical displacement were 0, 1-10, 11-30, 31-50, 51-75, and 76-90, estimated as degrees displaced from vertical.

Area selectivity of horse grazing was determined in June, August, and October. Used and unused habitats were surveyed using a non-mapping technique (Marcum and Loftsgaarden 1980). Surveying was limited to the cutblock area; uncut residual forest or natural herbaceous areas were not surveyed. Linear transects were run through the cutblocks and sample plots were established at 100 m intervals. At each sample plot site and vegetation was characterized and a 0.01 ha plot was assessed for horse use. Site characterization included site type (Table 3-1), aspect, and slope. Horse use was characterized as present or absent based on tracks, trailing activity, or evidence of foraging activity such as grazed plants. Site types were complex and included dry pine, moist pine, transition, and disturbed areas. Field data was tabulated and habitat preference or avoidance determined.

ANALYSES

Analysis of variance was used to examine differences in growth between seedlings exposed to grazing and those protected from grazing. Initial seedling size was uniform so initial height and diameter were not removed as co-variates. Some results were presented as simple counts or means where small count numbers or lack of true replication made statistical analyses impossible. Results presented without analyses are clearly identified and usually add supplemental information to results that could be analyzed statistically.

Selection ratios were computed from cross tabulations of raw count data. Nomenclature, symbols, and methodology followed standard convention (Manly, McDonald, and Thomas 1993). Selection ratios were computed by dividing the proportion of used units by the proportion of available units. Selection ratios greater than one indicate selection while those less than one indicate avoidance. Significant selection or avoidance was determined using Bonferonni confidence limits. If the Bonferonni confidence interval contains one there is no evidence of selection or avoidance, if the upper confidence limit is less than one there has been significant avoidance, while if the lower confidence limit is greater than one there has been significant selection.

RESULTS

Horses damaged seedlings in the semi-confined study in two ways: basal scarring and vertical displacement (Table 3-2). There was no evidence of browsing on 300 tagged trees exposed to three years of summer horse grazing. Basal scarring was a minor cause of damage, except for the June 28, 1995 sample when about 4 percent of trees exposed to horse grazing had recent basal scarring. Vertical displacement was the most common form of spruce seedling damage. There were more seedlings vertically displaced in 1994, the year of exclosure establishment, on areas exposed to horse grazing than on areas where horses were excluded. After 1994 the number of vertically displaced seedlings inside the exclosure equaled or exceeded that of outside the exclosure. All of the vertically displaced seedlings inside the exclosure occurred in one exclosure that was heavily dominated, both inside and outside, by marsh reed grass (*Calamagrostis canadensis*); the vertically displaced seedlings were smothered by grass litter. The vertical displacement recorded outside the exclosure was a result of horse damage; there were no seedlings smothered by grass litter on sites exposed to horse grazing.

There was no significant difference in either initial height and diameter of spruce seedlings, or total height and diameter growth over three growing seasons across three replicates of grazed and ungrazed exclosures (Table 3-3).

Use of cutblocks in the semi-confined area was tabulated for three years of study and three sampling times per year (Table 3-4). A total of 600 plots were recorded over three years. Of the four major sites that occurred on cutblocks, disturbed areas were significantly selected while dry pine and transition sites were neither selected nor avoided, and moist pine sites were avoided by horses. Horses used almost all disturbed sites, especially in August and October when 95 percent of disturbed sites on cutblocks had evidence of horse use. Use was found on all sites at all times of the year, but selection and avoidance patterns within year were consistent with overall yearly averages. Horses showed significant avoidance of moist pine sites, despite moist pine sites being the dominant site type within the cutblocks. Although not significant, there was a general trend of higher use of moist pine sites in June and October and lower use in August (Figure 3-1). There was a corresponding increase in selectivity of disturbed sites in August and a decrease in June and October.

DISCUSSION

Clearly, horses are a potential damage threat to spruce seedlings, but the damage levels documented in this study were relatively low. This study revealed that browsing of conifer seedlings by semi-confined horses is not a concern. The major type of damage caused by horses is trampling. Basal scarring and vertical displacement are the common types of trampling damage with vertical displacement being the most common.

Conifer tree seedlings were also damaged in the absence of grazing. Smothering of seedlings by grass litter was a common type of damage in the absence of grazing by horses. Smothering by grass litter was most common on sites dominated by marsh reed grass. Horse grazing in this study had a neutral effect on vertical displacement of spruce seedlings.

Although trailing by horses was not studied specifically, observation of trailing behaviour of horses around the exclosures was noted. Damage to conifer seedlings was usually greatest immediately after exclosure construction, when new access trails were being established by the horses to replace the ones disrupted by the exclosure. After the trails were established conifer seedling damage decreased. Trailing behaviour of horses should be considered when monitoring levels of damage. Care should be taken to weigh the relative damage along horse trails against the relative area that trails occupy in the total landscape.

Horses graze their environment selectively. Semi-confined horses showed a distinct preference for grazing disturbed areas and an equally distinct avoidance for grazing moist pine sites. Although this pattern was uniform for all months sampled, the strength of selection was greatest in August. This observation can be explained by a combination of plant phenology and growth combined with continuous selective grazing by horses. In June, which is early in the growing season within the Upper Boreal Cordilleran eco-region, herbage biomass would be sparse and juvenile across the landscape. To maintain an adequate level of consumption when forage production is low, horses would have to broaden their foraging behaviour and graze over a wider area, a process commonly referred to as switching (Senft, et al. 1987). Juvenile plant growth across the landscape, combined with low overall forage biomass, would promote habitat switching because the forage palatability would be more uniform and forage would be rapidly depleted on preferred sites. In August, which is late in the growing season in the Upper Boreal Cordilleran eco-region, herbage biomass would be heavy and would only be juvenile on sites that were grazed previously. In this situation horses could concentrate grazing on preferred sites, because forage production would be adequate and it would be maintained in juvenile growth by previous grazing. In October, which is during the dormant season, forage biomass would be high but mature across areas that were not previously grazed or light and juvenile on areas that had been selectively grazed earlier. In order to maintain consumption, horses would have to broaden their foraging behaviour, possibly because of forage disappearance from preferred habitats. Horses grazing in the Carmargue of southern France exhibited a similar grazing pattern; they were most selective when forage availability was highest and least selective when forage was limited (Duncan 1992).

CONCLUSIONS

1. Semi-confined horses were a potential source of damage for planted spruce seedlings, but the damage levels were low. Seedlings growing inside exclosures were equally susceptible to damage by vertical displacement as seedlings growing outside exclosures. Horse grazing had no effect on conifer seedling growth.

2. Horses grazed the available habitats on the cutblocks selectively, avoiding moist pine sites, selecting disturbed sites, and neither avoiding nor selecting dry pine or transition sites.

Table 3-1. Vegetation types and selected characteristics of the study area. Adapted from Corns and Annas, 1986.

Nomenclature					
Corns and Annas 1986	Common Name	Dominant Species	Topographic Position	Drainage	Moisture Status
Lodgepole Pine/Elymus	Dry Pine	Pinus contortus var. latifolia Engelm Elymus innovatus Beal	South Facing Slopes	Good	Dry
Lodgepole Pine/Alnus	Moist Pine	Pinus contortus var. latifolia Engelm Alnus crispa (Ait.) Pursh	North Facing Slopes	Good	Moist
Lodgepole Pine/Black Spruce /Ledum/Pleourozium	Transition	Pinus contortus var. latifolia Engelm Picea mariana (Mill.) BSP Ledum groenlandicum Oeder Pleurozium schreberi (Brid.) Mitt	Mid Slope	Fair	Moist
Disturbed Sites[1] Cutlines Spur Roads Landings	Disturbed Sites	Festuca rubra L. Dactylis glomerata L. Trifolium repens L. Trifolium hybridum L.	All Slope Positions	Variable	Variable

[1] Not described in Corns and Annas 1986

Table 3-2 Number of seedlings damaged by browsing, basal scarring, and vertical displacement inside and outside exclosures over three years.

		Browsing		Basal Scar		Vertical Displacement	
Year	Month	Inside	Outside	Inside	Outside	Inside	Outside
1994	Oct-10	0	0	0	2	2	9
1995	Jun-01	0	0	0	0	5	5
	Jun-28	0	0	0	12	4	3
	Oct-06	0	0	0	3	4	4
1996	Jun-28	0	0	0	1	5	2
	Oct-06	0	0	1	3	4	4

n = 300 seedlings inside and 300 outside

Table 3-4. Initial height and diameter, June 1994, and height and diameter growth from June 1994 to August 1996 inside and outside exclosures.

		Inside	Outside	Sig.	S.E.
3 Replicates	Height 1994	25.4 a	26.1 a	0.473	0.44
	Height Growth	25 a	22.3 a	0.413	0.77
	Diameter 1994	5.8 a	6.2 a	0.083	0.09
	Diameter Growth	4.9 a	5.8 a	0.297	0.16

Height and height growth are measured in cm.

Diameter and diameter growth are measured in mm.

Means within the same row followed by the same letter are not significantly different, .05 level.

Table 3-4. Habitat selectivity by semi-confined horses for plots classified by forest site. [1]

	Site [1]	m_i	π_i	u_i	o_i	w_i	χ^2	$se(w_i)$	Confidence Limits Lower		Confidence Limits Upper
All Months	Dry Pine	89	0.15	38	0.16	1.10	0.3	0.20	0.611		1.588
	Moist Pine	272	0.45	41	0.18	0.39	39.5	0.06	0.244	-	0.532
	Transition	130	0.22	56	0.24	1.11	0.6	0.16	0.721		1.497
	Disturbed	109	0.18	98	0.42	2.32	73.2	0.27	1.645	+	2.986
	Total	600	1.00	233	1.00	4.91	113.7				
June	Dry Pine	37	0.18	15	0.20	1.10	0.1	0.30	0.346		1.856
	Moist Pine	90	0.45	16	0.22	0.48	8.9	0.11	0.199	-	0.766
	Transition	45	0.22	21	0.28	1.27	1.2	0.29	0.549		1.986
	Disturbed	29	0.14	22	0.30	2.06	12.0	0.51	0.784		3.338
	Total	201	1.00	74	1.00	4.91	22.20				
August	Dry Pine	28	0.14	11	0.15	1.08	0.1	0.35	0.194		1.967
	Moist Pine	91	0.46	10	0.14	0.30	16.1	0.09	0.073	-	0.531
	Transition	41	0.21	15	0.21	1.01	0.0	0.27	0.331		1.682
	Disturbed	38	0.19	36	0.50	2.61	35.6	0.49	1.384	+	3.826
	Total	198	1.00	72	1.00	4.99	51.79				
October	Dry Pine	24	0.12	12	0.14	1.16	0.3	0.38	0.204		2.107
	Moist Pine	91	0.45	15	0.17	0.38	15.1	0.09	0.145	-	0.616
	Transition	44	0.22	20	0.23	1.05	0.0	0.25	0.427		1.673
	Disturbed	42	0.21	40	0.46	2.20	26.2	0.40	1.211	+	3.190
	Total	201	1.00	87	1.00	4.79	41.59				

Plots are combined over 3 years of use survey.

[1] Site classified according to Corns and Annas, 1986

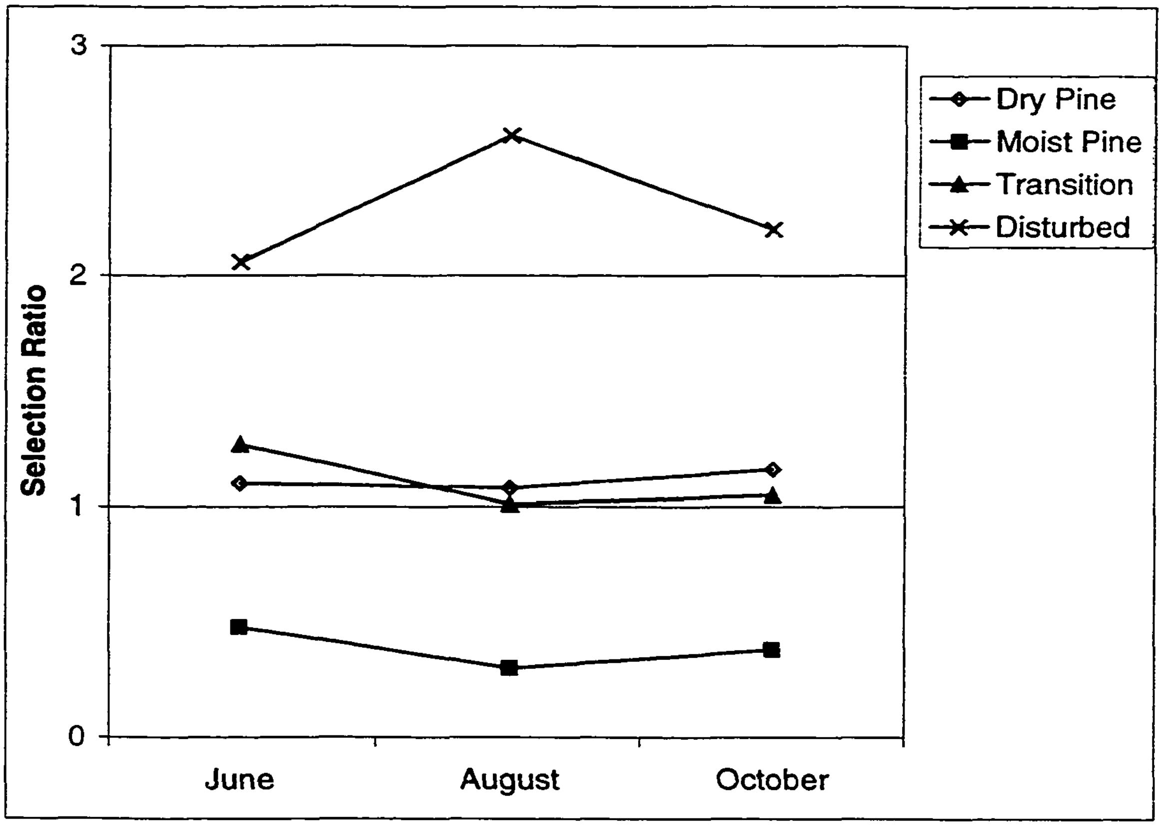
Symbol [2]	Definition		
m_i	Number of available units	w_i	Selection Ratio, equals o_i/π_i
π_i	Proportion of available units	χ^2	Pearson Chi-squared statistic
u_i	Number of used plots	$se(w_i)$	Standard Error of the Selection Ratio
o_i	Proportion of used plots		

Confidence limits separated by a "+" indicate significant selection.

Confidence limits separated by a "-" indicate significant avoidance.

Follows convention as outlined in Manly, Mcdonald, and Thomas 1993

Figure 3-1. Selection ratios arranged by month and habitat type for horses grazing during the summer under semi-confined conditions.



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4. FORAGING BEHAVIOUR AND PINE SEEDLING DAMAGE RESULTING FROM HORSES CONFINED TO CUTBLOCKS.

INTRODUCTION

Conifer tree seedlings must survive and grow in a competitive environment. In a model of a micro-ecosystem, an individual conifer seedling must compete for light, water, space, and nutrients (Carter, et al. 1984, Elliot and White 1987). In most natural systems there are three possible outcomes to competition: the conifer seedling will out compete surrounding vegetation and survive with unlimited growth, the conifer seedling will compete successfully with surrounding vegetation and survive with limited growth, and the conifer seedling will not compete successfully with surrounding vegetation and will not survive. In most natural systems the outcome of competition is not guaranteed, subtle changes in the competitive environment or even the timing of those changes can result in different outcomes of individual survival and growth.

Grasses are efficient competitors with conifer seedlings because they initiate root growth at cooler soil temperatures, have more rapid root growth after disturbance, and have an overall larger root system (McDonald 1986). Conifer seedlings planted immediately after logging can avoid competition by developing their root systems and overtopping competing vegetation before it becomes established (Eis 1980). New cutblocks are invaded by pioneer species first, followed by biennial and perennial herbaceous species, with shrubs being the last vegetative component to establish and grow. This sequence is predictable, with the rate of invasion increasing from dry to moist sites. On areas where the pre-cut canopy is relatively open, herbaceous plants and shrubs will be more competitive at a faster rate with conifer seedlings than on sites where the pre-cut canopy is closed. Open canopies have an established herb and shrub layer that is released by cutting.

Competing vegetation can physically modify sites to be more or less favourable for conifer seedling growth. Grasses, although an initial hindrance to conifer seedling growth, may be beneficial in the longer term by inhibiting shrub invasion (McDonald, 1986). Grasses may also stabilize sites and reduce erosion. Grasses and grass litter will modify the soil thermal regime which could be either favourable or detrimental depending on the site. Plant litter has an insulating effect on the soil (Facelli 1991). On hot, dry sites this insulating effect might be beneficial by keeping the soil cool and reducing direct loss of water through evaporation. On cool, moist sites the insulating effect will be detrimental because the soil will warm slower in the spring, resulting in a reduced growing season (Hogg and Lieffers 1990) and thus, a reduced growth rate for conifer seedlings.

Grasses can also act as an attractant to animals and insects (McDonald 1986). Small mammals that find shelter in grass litter can girdle conifer seedlings. Large mammals may also be attracted to grasses and damage conifer seedlings directly through browsing or indirectly by trampling. Whether the large mammals are natural, as is wildlife, or managed, as is livestock, the attractant is the same: grass production attracts herbivores.

Grazing by livestock on cutblocks could have a beneficial effect on conifer seedling growth by reducing grass competition (Karl and Doescher 1993, Doescher and Tesch 1989). However, livestock grazing also has a potential detrimental effect on conifer seedlings by trampling and browsing. For western Canada it seems trampling by livestock is more prevalent than browsing (Kingery and Graham 1990, Mclean and Clark 1980, Nordstrom 1984). In set stocking rate studies, conifer seedling damage increases with stocking rate (Newman and Wikeem 1990, King, Bailey, and Walston 1978). Field scale studies indicate that conifer seedling damage is acceptable when livestock are properly managed (Kingery and Graham 1990, Kosco and Bartolome 1983, Mclean and Clark 1980, Adams 1975).

Conifer seedlings damaged by livestock will either recover, recover with reduced growth, or die. Girdling, trampling, or defoliation are the three sources of animal damage to conifer seedlings. Controlled studies of the effect of livestock grazing on conifer plantations indicate that unless damage is severe pine seedlings have a high recovery rate (Newman and Wikeem 1990, Lewis 1980a, Lewis 1980b, Lewis 1980c). Mortality of pine seedlings is negligible until girdling approaches 100 percent (Newman and Wikeem 1990, Lewis 1980a). Basal girdling of 75 percent results in a reduction in growth but not mortality. Seedlings are more susceptible to damage when they are less than six months old (Lewis 1980a) and after bud set (Newman and Wikeem 1990). Seedlings damaged after bud set had a reduced time to recover before the onset of winter. Different species of conifers may react differently to damage. Douglas fir seedlings are more susceptible to damage than pine seedlings (Eissenstat, Mitchell, and Pope 1982); damage by livestock was most prevalent the year following planting.

Basal scarring is the major type of damage to conifer seedlings caused by livestock grazing (Newman and Wikeem 1990). Bark slipping is a well documented phenomena that can be found in numerous tree species (Zimmerman and Brown 1971). Although the term basal scarring is commonly used to describe damage by livestock, bark slipping is the accepted technical name. Bark slipping is most prevalent when diameter growth is occurring and is correlated with cell division activity in the vascular cambium. During the growth period bark can be easily peeled, leaving the underlying tissues exposed to desiccation and opening a potential site for pathogen invasion (Zimmerman and Brown 1971).

Most revious studies examining livestock damage on conifer plantations have used fixed stocking rates or fixed utilization levels as correlates for resulting damage. Studies of this nature yield recommendations that apply to cutblocks or range/forest plantations that have uniform vegetation and landscapes, but may give misleading results on cutblocks that have heterogeneous vegetation and landscapes.

Herbivores are selective (Bailey et al. 1996, Coughenour 1991, Senft et al. 1987). Herbivores select plant species from within feeding stations, feeding stations from within plant communities, plant communities from within landscapes, and landscapes from within regions (Senft et al. 1987). This sequence is defined as an ecological hierarchy and contrasts the traditional view of herbivores interacting with their environment in terms of set stocking rates within definable areas. The application of hierarchical theory can solve ambiguities presented by the application of set stocking rate theory. In simplistic terms, even though a landscape system may have a set stocking rate of herbivores, each plant community within the landscape will have a different stocking rate because of selection or avoidance by herbivores. By extension, each feeding station within each plant community will endure a different level of defoliation because of selection or avoidance by herbivores.

Hierarchical foraging theory can be used to explain ambiguities in the literature on the effect of livestock grazing on conifer regeneration. Several authors have noted that livestock grazing has minimal impact on conifer regeneration as long as the livestock are properly managed (McLean and Clark 1980, Kosco and Bartolome 1983, Kingery and Graham 1990, Adams 1975). The authors are implying that proper management entails reducing concentrated grazing by minimizing selective grazing. Stocking levels should be set by obtaining moderate grazing pressure on preferred sites, not by obtaining moderate grazing pressure over an entire landscape.

Grazing capacity has been defined as the maximum number of animals that can graze an area for a specific period of time without inducing a downward trend in forage production, forage quality, or soil (Stoddard, Smith, and Box 1975). Historically, grazing capacity has been considered only from a forage (herbaceous) productivity viewpoint. In multiple use situations other site parameters have to be considered. On tree plantations, grazing levels that are sustainable in terms of forage production might result in serious damage to tree seedlings. If tree seedling damage is an issue, grazing capacity should be set based on acceptable damage levels and will likely be less than if based on forage productivity. If seedling damage is not an issue, then grazing capacity can be set based on forage production (the traditional method).

Horse grazing within areas managed for timber resources is an established land use, and may increase in the future. Tourist activities, many of which rely on horses, are expected to increase, and western Alberta is an attractive location. Local research is required to coordinate horse grazing with regeneration efforts. Although previous studies have focused on the negative interactions between forestry and grazing interests, this study will determine the common ground on which forestry and horse grazing can be coordinated.

The purpose of this study was to document summer grazing behaviour of horses in an Upper Boreal Cordilleran vegetation zone where the horses were confined to recent cutblocks for predetermined periods of time. A major goal of this study was to determine preferred summer grazing habitats of horses that were confined and limited to grazing recent cutblocks. Specifically, this study will answer the questions of whether confined horses exhibit selective grazing behaviour and whether their grazing behaviour resulted in damage to regenerating pine seedlings. The influence of site on possible seedling damage and on subsequent recovery will also be studied.

STUDY AREA

Habitat preference of horses confined to cutblocks was studied south of Hinton, 450 km west of Edmonton, Alberta, in the foothills of the Rocky Mounaiins. The area has a continental climate, with cold winters and warm summers (Dzikowski and Heywood undated). The study area receives about 600 mm of precipitation annually of which 70 percent falls as rain and 30 percent falls as snow (Dumanski et al. 1972, Anonymous 1982, Dzikowski and Heywood undated). July is the warmest month with a mean temperature of 15° C, while January is the coldest month with a mean temperature of -12° C (Dumanski et al. 1972).

Soils in the study area are strongly influenced by parent material and topographic position. The dominant upland soil is an Orthic Gray Luvisol developed on Marlboro glacial till (Dumanski et al. 1972). Gleysolic soils are often associated with seeps and springs and are commonly located in the toe slope position. Vegetation of the study area (Table 4-1) is classified as Upper Boreal Cordilleran (Corns and Annas 1986). The scope of this study was limited to three cutblocks, thus limiting the range of potential soils and vegetation types to those that occur under merchantable forest. Pre-harvest forest can be classified into four types. Well drained sites are typically dominated by lodgepole pine (*Pinus contorta var. latifolia*), drier south-facing slopes have a herbaceous understory consisting of hairy wild rye (*Elymus innovatus*) while moist north-facing slopes have a shrub understory dominated by green alder (*Alnus crispa*) (Table 1). Black spruce (*Picea mariana*) forests are common on gentle slopes that are poorly drained. There is a transition forest type on intermediate slope positions between either dry pine or moist pine sites and black spruce forest. Transition forest contains elements of a typical pine and typical black spruce forest. Disturbed areas are independent of the site they occur on. Disturbed areas, such as cutlines, spur roads, and landings are dominated by introduced herbaceous species. Disturbed areas occurred on all site types and are differentiated because of the dominance of introduced species.

METHODS

Three replicates of cutblocks with well established pine seedlings and moderate levels of herbaceous production, visually estimated to be about 500 kg/ha, were selected for study. Cutblocks with natural pine regeneration that varied from 10 to 120 cm in height were selected. Two grazing times, June and August, and two grazing intensities, 40 and 70 percent herbaceous removal, were generated in 1994 and 1995 by confining small groups of horses using electric fence to enclose small areas. The area of each replicate varied, but averaged about 1 ha for each seasonal grazing treatment.

Moderate grazing intensity was generated by stocking at a rate of about 9 horse days/ha while heavy grazing intensity received about 18 horse days/ha. Grazing treatments were conducted in 1994 and 1995.

Prior to introducing horses each replicate was stratified into 6 vegetation types: dry pine, moist pine, transition, hygric meadows, residual black spruce forest, and trails/cutlines (Table 4-1). In each dry pine, moist pine, and transition site, two 10 x 10 metre macroplots were established prior to grazing in 1994. All coniferous seedlings within the macro-plot were tagged and basal diameter and height measurements taken. After each replicate had been moderately grazed, about 9 horse days per hectare, one macro-plot was fenced, the remaining macroplot remained unfenced until the replicate was heavily grazed, about 18 horse days per hectare. Grazing treatments were repeated on the same areas in 1995.

After the grazing operation was complete all tagged seedlings in the macroplots were assessed for damage. Damage measurements included browsing, basal scarring measured as a length and percent of circumference, and vertical displacement measured as degrees from vertical. For ease of recording and measurement basal scarring and vertical displacement were estimated in classes. For basal scarring the classes were no basal scarring, 1-10, 11-30, 31-60, and 61-100 percent of the basal circumference. For vertical displacement the classes were no vertical displacement, 1-10, 11-30, 31-50, 51-75, and 76-90 degrees displaced from vertical. Diameter and height of all seedlings were measured once per year. All seedlings tagged in 1994 and subjected to two years of grazing treatments were assessed in 1996 for survival and growth. Measurements in 1996 were height and basal diameter for all trees and displacement and basal scar healing for damaged seedlings.

Horse grazing behaviour was documented by observing horses during the primary foraging bout each day, usually from 8:00 AM until 12:00 noon. Activity and habitat for each horse was recorded at ten minute intervals. Recording started when the horses initiated a foraging bout and continued until the foraging bout ceased, signaled by prolonged standing by the horses. Consistency between observers and between days of observation was accomplished by mapping the sites before horse introduction and using the maps to classify habitats during recording. Determination of threshold or edge observations was at the discretion of the observer and was assumed to be random.

ANALYSES

Four types of analyses were used to categorize and address treatment effects in this study: simple presentation of counts and means, logistic regression (Norusis 1997), selection ratios (Manly, McDonald, and Thomas 1993), and analyses of covariance (SPSS Inc. 1988).

Some results are presented as simple counts or means. Results presented without analyses are clearly identified and used as an introduction to more complex analysis or to add supplemental information to results that could be analyzed statistically. Small count numbers or lack of true replication made statistical analyses impossible in some instances.

Logistic regression was used to determine significant effects for conifer seedling damage and mortality. Analyses followed convention using the logistic regression module of SPSS (Norusis 1997, Table 4-2). While linear regression predicts a relationship between variables by minimizing the squares of deviations, logistic regression predicts non-linear relationships by a process know as maximum likelihood. Variables are included or excluded from the logistic regression model depending on the contribution they make for maximizing the likelihood that the response variable will change from absent to present. Binomial response variables were damage, a seedling was either damaged or not damaged, and mortality, a seedling either lived or died. Categorical variables, variables that were described by categories, were changed to binomial variables, presence or absence, using dummy variables (Norusis 1997). For example, the categorical variable site had three categories: dry pine, moist pine and transition, identified by categories 1, 2 and 3, respectively. Site was described using three binomial dummy variables, each of which could be zero or one. A dry pine site would then be described as 1-0-0, a moist pine site as 0-1-0, and a transition site as 0-0-1. Thus, a categorical variable with three levels was described by using three dummy binomial variables with zero indicating absence and one indicating presence. Dummy variables were also used to generate interaction terms between categorical main effects.

An initial logistic regression model was developed using a forward stepwise conditional selection method with all main effects available for model selection: site, season of grazing, grazing intensity, seedling size, and year. Main effects selected in the initial model formulated the first block for final model building. The second block of the logistic regression model was defined by adding interaction terms, again by a forward stepwise conditional selection method. The second block of the model, the interaction terms, was evaluated against the initial model, the significant main effects, by comparing the -2 Log Likelihood statistic generated by SPSS. The interaction terms were excluded from the model if the –2 Log Likelihood statistic was less than 5 percent greater than the main effects model. Only variables that added significant information to the logistic regressions were presented in tables, non-significant variables were not.

Logistic regression compares all levels of a variable against a reference level, usually the first or last level (arbitrarily chosen for presentation purposes). The p-value displayed is also known as the Wald Statistic; a significant p-value indicates the coefficient for that level is significantly different from the coefficient of the reference level. The odds ratio for a variable level is the ratio of the odds if the variable level is present to the odds if the reference level is present. The odds ratios of non-reference variable levels can be directly interpreted as the relative importance compared to the reference level. An odds ratio of 2.4 for a non-reference variable level means the presence of that level increases the likelihood of the binary response variable changing from zero to one (absent to present) 2.4 times compared to if the reference variable level was present. Two non-reference variable levels can be compared by dividing the odds ratios. If level 2 and 3 have odds ratios of 2 and 4, respectively, the presence of level 3 doubles the odds ratio as compared to the presence of level 2. By default, the logistic regression coefficient for the reference variable level is set to zero and the odds ratio is one. All other levels of the variable are then compared against the reference level.

Selection ratios to quantify horse grazing behaviour were computed from cross tabulations of raw count data. Nomenclature, symbols, and methodology followed standard convention (Manly, McDonald, and Thomas 1993). Each replicate was mapped and drawn to scale; a calibrated planimeter was then used to measure the area of each forest site. The actual area of each habitat type was used to define habitat availability. Habitat use was determined by tabulating the observational data. Habitat use was tabulated across year and replicate to yield one composite for June and one for August grazing seasons. A problem was encountered when the standard error of the selection ratios was computed where the actual habitat areas were used to define available units. The problem occurred because the magnitude of the actual areas was much less than the observed counts. This was addressed by multiplying the actual habitat areas by 1000, yielding available resource units that were about the same magnitude as used resource units. Selection ratios were then computed as the proportion of used units in a habitat divided by the proportion of available units. Overall variation from random habitat selection was evaluated using the Pearson Chi-squared statistic (Manly, McDonald, and Thomas 1993). Bonferroni confidence limits were used to determine significant selection or avoidance for individual habitats.

Analyses of covariance was used to detect differences in growth of damaged and undamaged seedlings. Given that initial seedling size was variable, height and diameter growth were analyzed with initial height and diameter as covariates, respectively.

RESULTS

Seedling Damage

During 2 years of monitoring horses damaged tree seedlings during grazing in two ways: scarring at the base caused by hoof impact or vertical displacement caused by being pushed over (Figure 4-1). Only one of 1212 conifer tree seedlings exposed to two years of horse grazing had evidence of browsing. Tree seedling mortality on ungrazed sites averaged 5 percent (0-8 percent range) and on grazed sites averaged 5-10 percent (0-11 percent range) (Tables 4-3 and 4-4). Horses consistently damaged more tree seedlings by vertical displacement than by basal scarring; this trend was evident in both June and August grazing treatments and on all three sites. Horses caused less tree seedling damage when grazing in August as compared to grazing in June, although there was no apparent difference in tree seedling mortality.

June horse grazing resulted in significantly more seedling damage, both basal scarring and vertical displacement, than August horse grazing (Table 4-5 and 4-7). When the odds ratios were compared, tree seedlings were about 2.5 times more likely to be damaged through both basal scarring and vertical displacement by horses grazing in June as opposed to August. Although smaller seedlings were generally more susceptible to damage, the pattern of damage was slightly different between basal scarring and vertical displacement. Comparison of the odds ratios clearly shows smaller trees were damaged significantly more by vertical displacement (Table 4-7 and 4-8), while middle sized seedlings, 31-50 cm in height, were damaged most by basal scarring (Table 4-5 and 4-6). Basal scarring and vertical displacement of tree seedlings greater than 70 cm in height was minimal. Site was not a significant effect for basal scarring but was for vertical displacement. Seedlings growing on moister sites, either moist pine or transition areas, were damaged more by vertical displacement than seedlings growing on dry pine sites. Grazing intensity and year were not significant main effects for damage by either basal scarring or vertical displacement.

Seedling Mortality

Site and the degree of damage had an effect on conifer seedling survival (Tables 4-9 and 4-11). There was a consistent mortality of about 5 percent over three years of study for seedlings that had been exposed to grazing but had not been damaged by horses (Tables 4-10 and 4-12). Percent mortality increased with aridity; dry pine sites had the highest seedling mortality and transition sites had the lowest. Mortality also increased with increasing level of damage (Table 4-9 and 4-11). The odds ratios and p-value (Wald Statistic) show there was a significant increase in mortality when basal scarring exceeded 10 percent and when vertical displacement exceeded 10 degrees as compared to trees with no damage.

Although there was a significant increase in mortality associated with damage, the effect of that increase on overall mortality should be weighted against the probability of damage (Table 4-13). A significant increase in expected mortality with increasing levels of damage was mitigated somewhat by decreasing numbers of seedlings in the higher damage classes. Mortality was about 7 percent for the entire seedling population, 19-20 percent for damaged seedlings and 4-5 percent for seedlings not damaged by horses. Although damaged seedlings had 15 percent higher mortality than undamaged seedlings, horse grazing in this study resulted in an increase in overall mortality of only 2-3 percent (Table 4-13).

Seedling Growth

Basal diameter growth of seedlings that survived damage was not reduced compared to undamaged seedlings (Table 4-14) while height growth of damaged seedlings was affected by damage (Table 4-15). Confidence limits were used to determine the level of damage above which significant growth reduction occurred. If the confidence limits for a damage level did not contain the mean of undamaged seedlings, a significant difference was declared. Seedlings that had a basal scar greater than 10 percent of their circumference had significantly less height growth than seedlings that were not damaged, or received a maximum scar less than 10 percent of the basal circumference. Any vertical displacement greater than 10 degrees resulted in a significant decline in height growth (Table 4-15). For both basal scarring and vertical displacement there was a general trend of declining growth with increasing severity of damage, but the sample numbers in the higher damage classes were too small to generate concrete conclusions.

Grazing Behaviour

Horses exhibited selective grazing behaviour in both June (Table 4-16) and August (Table 4-17) grazing treatments. Horses showed a significant selective response for disturbed areas, hygric meadows and dry pine sites, and a significant avoidance response for moist pine and transition sites. Horses did not use residual black spruce forest except in August when they entered the forest to forage on woodland horsetail or for shade on extremely hot days.

DISCUSSION

Clearly, horses are a potential damage threat to conifer seedlings. Browsing is not a concern with horses; the major type of damage caused by horses is trampling. Of the two types of trampling damage, basal scarring and vertical displacement, vertical displacement is the most common. Vertical displacement has not been reported previously as a significant type of damage caused by livestock grazing tree plantations. Maximum damage recorded in this study was about 30 percent of seedlings exposed to confined horse grazing, with typical damage levels being between 10 and 20 percent. About one half of damaged seedlings received light or moderate damage, and had a high percentage of survival and recovery. However, seedlings that received severe damage, either basal scarring or vertical displacement, had lower survival.

Basal scarring and vertical displacement are both significant types of seedling damage caused by horses. Although similarities in likelihood of damage by basal scarring and vertical displacement exist, there are also some disparities evident from this study. Both basal scarring and vertical displacement are affected by seedling size. In general, larger seedlings are less likely to be damaged. Intermediate sized seedlings are most likely to be damaged by basal scarring while there is a strong relationship between decreasing size and damage from vertical displacement. Intermediate sized seedlings were damaged more by basal scarring because of an interaction between stem characteristics and horse grazing behaviour. It appears seedling stems must reach a critical size before they have the strength to resist direct contact with a horse hoof. Tree seedlings increase in diameter and height with age. Continual cell division in the vascular and cork cambiums result in increased stem diameter. Increased stem diameter is accompanied by more support tissues, lignified xylem cells, and thicker bark (Zimmerman and Brown 1971). Larger tree seedlings were less susceptible to physical damage because they have increased stem strength and thicker bark. The smallest seedlings exposed to horse grazing were damaged less by basal scarring because the stems would bend when contacted by a horse hoof, which would make them more susceptible to vertical displacement. Once seedlings were big enough and stem strength was high enough to resist displacement, they became more susceptible to basal scarring. Larger seedlings, although more susceptible to basal scarring because of stem strength, become less likely to be contacted by a horse hoof, probably because horses begin to walk around the seedlings rather than over them. There is a strong relationship of decreasing vertical displacement with increasing seedling size. This is probably due to similar factors already discussed for basal scarring, except that increasing stem strength would decrease the likelihood of vertical displacement. Larger seedlings would also have more developed root systems than smaller seedlings. The root systems of tree seedlings increase in size through terminal extension and radial growth in a similar fashion to above ground shoots (Zimmerman and Brown 1971). Larger tree seedlings would be more firmly rooted by larger diameter roots that extend further into the soil. Larger seedlings with corresponding larger root systems would be less susceptible to vertical displacement.

Season of horse grazing had a significant effect on subsequent damage levels. Horse grazing in June always resulted in significantly higher levels of both basal scarring and vertical displacement damage. A seasonal difference in damage is likely caused by a combination of both plant and soil factors. Conifer seedlings would be more succulent in June than August and would be more susceptible to damage by both basal scarring and vertical displacement. The period of cambium growth has been associated with bark peeling and slipping (Zimmerman and Brown and Brown 1971). Spring cambial growth is accompanied by increased cell water content, a thinning of the cell walls, and a decrease in density of cell contents. These factors lead to increased susceptibility of conifer seedlings to basal scarring by a physical impact such as a horse hoof. Cambial growth is initiated in the early spring, and generally ceases at the end of the growing season. Although cambial activity was likely occurring during the August grazing treatment of this study, peak cambium growth is much earlier, in late spring or early summer (Savidge and Wareing 1984). Increased basal scarring during the June grazing treatment would coincide with peak cambium growth; cambium growth would be slowing in August and basal scarring would be less prevalent. The soil that supports the seedling would also be typically wetter in June than August and would have less soil strength. Inter-particle moisture films weaken the particle to particle bonds and act as a lubricant in the soil matrix (Hillel 1982). Seasonally wetter soils earlier in the growing season would have less soil strength, provide less root support and result in an increased susceptibility to vertical displacement.

There was a complex interaction between site and type of seedling damage. If seedlings begin and stop cambial growth at the same time of year, regardless of site, the incidence of basal scarring should not be affected by site. However, seedlings would be expected to start and stop growth earlier on dry pine (Hart 1885) compared to moist pine and transition sites, which should have led to a site effect for basal scarring. It is possible that the length of grazing treatments applied in this study, roughly one month in duration for both June and August, was long enough that site determined initiation and cessation of growth was not manifested in a detectable difference in basal scarring. Shorter, more intense grazing treatments by horses may have resulted in site effects for basal scarring, particularily if they were timed when cambial growth had initiated or stopped on one site but not another.

A significant site effect on vertical displacement was likely due to soil strength. Soil strength would be highest on dry pine sites, intermediate on moist pine sites, and lowest on transition sites. Decreasing soil strength from dry to moist sites would be caused in part by an increasing duff and moss layer (Corns and Annas 1986) and in part by higher soil water content (Hillel 1982). Both conditions would lead to less soil strength and a higher probability of vertical displacement of tree seedlings. A moss layer would provide poor support for tree seedlings and may even increase the susceptibility to damage. A horse hoof striking close to a tree seedling on solid ground would not cause damage, while a similar contact on an area with a moss layer may cause vertical displacement because depressing the moss would pull the seedling over. Presence of a moss layer could further increase the likelihood of vertical displacement by insulating the soil against evaporation resulting in seasonally wetter soils as compared to areas with no moss layer. Further evidence of increased susceptibility of seedlings growing on moist sites to damage is provided by horse grazing behaviour. Seedlings on moist pine and transition sites received more damage even though these sites were avoided by horses. In effect, less grazing pressure caused more damage. This can only be explained by an increased susceptibility of tree seedlings to damage caused by site factors.

There was an anomaly in this study in that there was no apparent difference in seedling damage between heavy and moderate stocking levels of horses. This might be caused by a study design with insufficient sampling to detect a significant difference, or it could be explained by horse grazing behaviour. Horses are trailing animals (Salter 1978), and when exposed to a new environment they explore and establish a network of trails that they use until they are moved to a different environment. Once horses are accustomed to an area they spend less time walking and more time resting and standing (Olson-Rutz et. al. 1996). It is possible that the majority of seedling damage occurred during the initial stages of exploration and trail establishment. Damage levels in this study were not closely related to stocking rate, probably because of the grazing behaviour of horses.

The effect of damage on seedling mortality did not follow patterns documented in previous research (Newman and Wikeem 1990, Lewis

1980a). Previous research indicates that seedling survival and growth are not affected until basal scarring approaches 100 percent, in contrast to the results of this study which found a significant increase in mortality for even moderately damaged seedlings. Other research has concentrated on girdling, and most studies use artificial methods to generate girdling treatments. The difference in observation between this and previous studies could be explained by the way in which the basal scars were administered. A natural basal scar caused by a horse hoof impact would do more stem and root damage than a scar administered artificially by scraping the bark. Internal damage and root disruption probably occur in conjunction with a natural basal scar, even if no vertical displacement is detected. Although the reasons may be unclear from this study, there is strong evidence that basal scarring has a larger impact on growth and survival than has previously been reported in the literature.

This study has clearly shown that vertical displacement is an important damage type that has not been investigated. Vertical displacement is not listed as a damage type in previous research on the effect of livestock grazing on tree plantations. Results from this study indicate vertical displacement is more prevalent and a more severe type of damage than basal scarring. Trees that are vertically displaced would probably have disrupted root systems. This could lead to decreased uptake of water and nutrients and an interruption of plant hormonal control of which the root system is an important component. However, this study was not designed to investigate the degree of root disruption associated with varying degrees of vertical displacement. Further research is required in controlled studies to investigate the role of vertical displacement on tree seedling growth and development.

Despite confinement to cutblocks, horses in this study were only responsible for an increase of about 1 percent pine seedling mortality per year. Land resource managers will have to determine if statistical significance and biological significance are synonymous terms. Although horses caused statistically significant levels of damage, and damaged tree seedlings had statistically significantly higher levels of mortality, the biological significance of horse grazing is questionable. One percent increased mortality for pine seedlings per year exposed to horse grazing should be a level that forest managers can tolerate, especially when increased mortality is only anticipated during the first ten years of conifer growth. Cutblocks that are marginally stocked with conifer seedlings, contain large areas of wet soils, or have low conifer seedling growth potential would warrant increased scrutiny. For most of the cutblocks used as sample units in this study a one percent increase in conifer seedling mortality per year exposed to horse grazing was not a biologically significant event.

Horses were selective in their grazing habits. Horses preferentially grazed disturbed sites in the summer, probably because disturbed sites consisted of seeded tame species of grass and legumes. Cutlines, spur roads, landings and road sides were all disturbed sites seeded to an agronomic grass mix. Agronomic grass species such as timothy, creeping red fescue and Kentucky blue grass are more palatable during the summer than are the native grasses, hairy wild rye and marsh reed grass, that usually grow on cutblocks. Horses grazing in the summer were also selective for hygric meadows, probably because they supported a dense stand of lush herbaceous vegetation. Although not tested, observation indicated that dry pine sites were selected or avoided by horses depending on what other habitats were available. In the presence of unused trails and cutlines or hygric meadows, dry pine sites were avoided by horses, and in their absence they were selected. Wet pine sites and transition areas between pine sites and black spruce forest were avoided. The selection and avoidance of habitats by horses in this study is indicative of a foraging hierarchy (Bailey et al. 1996, Coughenour 1991, Senft et al. 1987). The existence of a foraging hierarchy can be used to formulate grazing management strategies that will minimize the potential damage to conifer seedlings, as well as other resource values. When developing grazing management plans, prospective areas should be site mapped and only the available forage on preferred sites should be included in the calculation of grazing capacity. For horses, this would be the forage produced on disturbed areas, dry pine sites, and hygric meadows. If the forage on avoided sites is included in the calculation of grazing capacity, the preferred sites will be heavily grazed and the risk of conifer seedling damage will increase.

Horse stocking rate is of less importance in predicting potential conifer seedling damage than knowledge of available habitats and how horses will exploit those habitats. The preferred alternative habitat concept can be used to minimize conflicts between horse grazing and conifer regeneration. The preferred alternative habitat concept is relatively simple; if horses prefer to graze areas that have relatively low damage risk and avoid areas that have higher damage risk then a preferred alternative habitat exists. The preferred alternative habitat concept parallels traditional and non-traditional range management terminology. Primary and secondary range are names applied to preferred and avoided grazing areas (Adams 1981). Grazing animals will normally graze secondary range only after primary range is over utilized. Similar theories are presented in most contemporary range management texts (Vallentine 1990, Holechek et al. 1989, Stoddart et al. 1975); none use the terminology forwarded by Adams (1981). For horses grazing in Upper Boreal Cordilleran forest, disturbed areas and hygric meadows are primary range. In the terminology promoted here they are also preferred alternative habitats. Disturbed areas and hygric meadows draw horse grazing away from dry pine, moist pine, and transition sites thereby reducing damage risk to these sites. In complex vegetation, set stocking rate theory is insufficient for predicting conifer seedling damage. In-depth knowledge of foraging hierarchies, the types and availability of habitats, and the latent susceptibility of each habitat to damage is required to effectively manage horse grazing in heterogeneous vegetation and topography.

Horses were responsible for damage to, and mortality of, conifer seedlings. Forest land managers will have to determine if the expected levels of damage and mortality are acceptable risks before entering into land agreements that include horse grazing on cutblocks. This study clearly indicates that cutblocks that are adequately stocked with conifer seedlings 50 cm in height or greater will have minimal damage caused by horses. Caution should be exercised where cutblocks have seedlings that are less than 50 cm in height, contain large areas of moist sites or are not adequately stocked with conifer seedlings. Even with a higher expected damage and mortality for small seedlings less than 30 cm in height, horse grazing may be an acceptable land use on cutblocks where conifer seedling stocking is high. In some cases horse grazing may actually provide some beneficial thinning. Even if seedling size is small and seedling stocking level is marginal, horse grazing could be an acceptable land use if the area contains alternative preferred habitats for horses such as cutlines and re-vegetated spur roads.

CONCLUSIONS

1. Natural mortality in natural regeneration pine cutblocks was about 5 percent over 3 years, while mortality on sites grazed by horses was about 7 percent.
2. Seedlings above 50 cm in height were damaged less than those below 50 cm in height.
3. Damage by horses consisted of 2 types: basal scarring and vertical displacement. Damage by browsing was negligible in all parts of this study.
4. Maximum probability of damage caused by horses in this study was 37 percent, for 10-30 cm pine seedlings exposed to June horse grazing. Average damage was about 20 percent overall, one half of which was classed as moderate damage or less.

5. Seedling mortality was associated with degree of damage and forest site. Drier sites had higher seedling mortality than moister sites. Although moderate levels of seedling damage by basal scarring or vertical displacement resulted in higher mortality levels, the overall mortality increase caused by horses was small because of decreasing numbers of seedlings in higher damage classes.

6. Horses exhibited selective grazing patterns that can be used to minimize damage to conifer seedlings. Providing horses with an alternative preferred habitat is a realistic strategy to manage horses in conjunction with newly regenerating cutblocks. Alternative preferred habitats for summer grazing horses are disturbed areas and hygric meadows.

7. Management strategies can be developed that will enable horse grazing in areas of cutblocks. If no alternative preferred habitat exists, the impacts of horse grazing could be decreased by deferring grazing until later in the season or restricting grazing completely until the regeneration is 50 cm in height. On sites that are overstocked with conifer seedlings, horse grazing could be used as an additional land use and a method of early stand thinning.

Table 4-1. Vegetation types and selected characteristics of the study area. Adapted from Corns and Annas, 1986.

Nomenclature					
Corns and Annas 1986	Common Name	Dominant Species	Topographic Position	Drainage	Moisture Status
Lodgepole Pine/Elymus	Dry Pine	Pinus contortus var. latifolia Engelm. Elymus innovatus Beal	South Facing Slopes	Good	Dry
Lodgepole Pine/Alnus	Moist Pine	Pinus contortus var. latifolia Engelm. Alnus crispa (Ait.) Pursh	North Facing Slopes	Good	Moist
Lodgepole Pine/Black Spruce /Ledum/Pleourozium	Transition	Pinus contortus var. latifolia Engelm. Picea mariana (Mill.) BSP Ledum groenlandicum Oeder Pleurozium schreberi (Brid.) Mitt	Mid Slope	Fair	Moist
Black Spruce/Ledum/Equisetum	Black Spruce Forest	Picea mariana (Mill.) BSP Ledum groenlandicum Oeder Equisetum sylvaticum L.	Lower Slope	Poor	Wet
Hygric Meadows[1]	Hygric Meadow	Equisetum variagatum Schleich. Equisetum scirpoides Michx. Juncus spp. L. Agropyron spp. Gaertm. Betula glandulosa Michx.	Gentle Slopes	Fair	Seasonally Wet or Moist
Disturbed Sites[1] Cutlines Spur Roads Landings	Disturbed Sites	Festuca rubra L. Dactylis glomerata L. Trifolium repens L. Trifolium hybridum L.	All Slope Positions	Variable	Variable

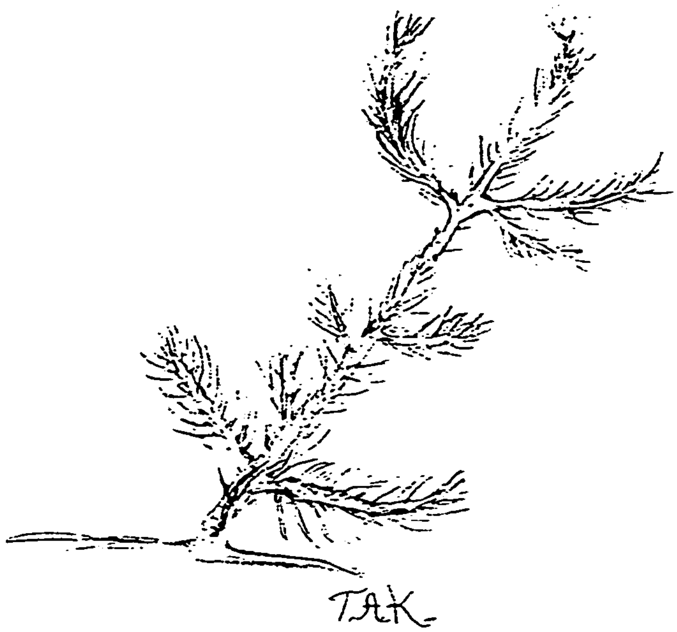
[1] Not described in Corns and Annas 1986

Table 4-2. **Definitions of headings used in statistical tables for logistic regression analyses.**

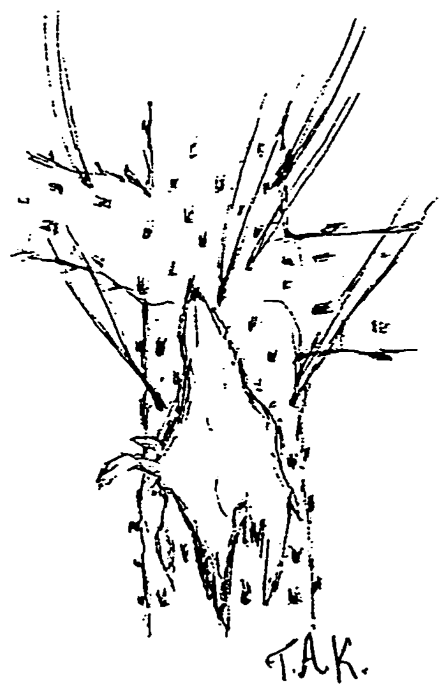
Heading	Definition
Variable	Independent variable used in analyses
Coefficient	Logistic regression coefficient for the independent variable. The coefficient for the reference level will always be equal to 0.0
S.E.	Standard Error of the regression coefficient
p Value	Significance of the regression coefficient. If the p value is <0.05 the regression coefficient is significantly different from 0.0, the reference level coefficient value.
Odds Ratio	Ratio of the odds if a variable is present to the odds if a variable is absent. Dividing one odds ratio by another yields the relative importance of two levels of a variable. For example, if seedling size is used to predict the liklihood of damage and the odds ratio for seedlings in class A is 0.6 and for class B is 0.3, a seedling in class A is twice as likely (0.6/0.3) to be damaged than a seedling in class B.
Confidence Limits	Confidence limits of the Odds Ratio. If the upper and lower confidence limits do not contain 1, the variable level is significantly different than the reference level. If the confidence limits of Level B do not contain the Odds Ratio of Level A, the Odds Ratio of Level A and Level B are significantly different.

[1] Follows convention as outlined in Norusis 1997.

Figure 4-1. Typical vertical displacement (A) and basal scarring (B) damage caused by horses.



A



B

Table 4-3. Trees damaged (%) by basal scarring and vertical displacement or killed (% mortality) during June grazing by horses.

		Grazing Level								
		Moderate			Heavy			None		
Site	Percent	94	95	96	94	95	96	94	95	96
Dry Pine	Basal Scarring	12	14	0	9	10	0	0	0	0
	Vertical Displacement	19	17	0	21	10	0	0	0	0
	Mortality	1	8	11	0	10	11	0	0	2
Moist Pine	Basal Scarring	10	14	0	11	6	0	0	0	0
	Vertical Displacement	16	10	2	16	10	0	0	0	1
	Mortality	0	2	8	1	6	9	0	0	0
Transition	Basal Scarring	7	11	0	1	15	0	0	0	0
	Vertical Displacement	21	21	4	6	14	0	0	0	0
	Mortality	0	3	6	1	1	1	0	0	0

Note: Mortality is calculated as dead trees after grazing in 94 and 95 and dead trees at time of measurement in 96.

Table 4-4. Trees damaged (%) by basal scarring and vertical displacement or killed (% mortality) during August grazing by horses.

		Grazing Level								
		Moderate			Heavy			None		
Site	Percent	94	95	96	94	95	96	94	95	96
Dry Pine	Basal Scarring	3	2	0	8	5	0	0	0	0
	Vertical Displacement	3	4	0	7	7	0	0	0	0
	Mortality	3	7	10	1	5	10	0	7	8
Moist Pine	Basal Scarring	4	5	0	0	0	0	0	0	0
	Vertical Displacement	8	7	0	5	10	0	0	1	0
	Mortality	1	1	3	0	4	5	0	4	5
Transition	Basal Scarring	4	3	0	3	2	0	0	2	0
	Vertical Displacement	11	13	0	12	12	0	0	2	0
	Mortality	0	5	5	1	2	4	0	1	2

Note: Mortality is calculated as dead trees after grazing in 94 and 95 and dead trees at time of measurement in 96.

Table 4-5. Results from fitting a logistic regression equation predicting basal scarring from season of grazing by horses and seedling size.

Variable	Coefficient	S.E.	p Value	Odds Ratio	95% Confidence Limits Lower		Upper
Constant	-2.6190	0.1830	0.00				
SEASON							
June	0.0000			1			
August	-1.0470	0.1770	0.00	0.351	0.2	-	0.5
SIZE							
10-30 cm	0.0000			1			
31-50 cm	0.5680	0.2140	0.01	1.765	1.2	+	2.7
50-70 cm	0.1430	0.2530	0.57	1.154	0.7		1.9
70+ cm	-0.7850	0.2760	0.00	0.4565	0.3	-	0.8

Confidence limits separated by a "+" indicate a significant increase in likelihood when compared to the reference level.

Confidence limits separated by a "-" indicate a significant decrease in likelihood when compared to the reference level.

Table 4-6. Calculated percent probabilities for a tree seedling receiving a basal scar based on the logistic regression equation for basal scarring.

Tree Size	June	August
10-30 cm	6.8	2.5
31-50 cm	11.4	4.3
51-70 cm	7.8	2.9
70+ cm	3.2	1.2

Table 4-7. Results from fitting a logistic regression equation predicting vertical displacement from forest site, season of grazing, and seedling size over two years of grazing treatments.

Variable	Coefficient	S.E.	p Value	Odds Ratio	95% Confidence Limits Lower		Upper
Constant	-1.0880	0.1510	0.00				
SITE							
Dry Pine	0.0000			1.0			
Moist Pine	0.3360	0.1780	0.06	1.4	1.0		2.0
Transition	0.3630	0.1560	0.02	1.4	1.1	+	2.0
SEASON							
June	0.0000			1.0			
August	-0.8550	0.1380	0.00	0.4	0.3	-	0.5
SIZE							
10-30 cm	0.0000			1.0			
31-50 cm	-0.4970	0.1560	0.00	0.6	0.4	-	0.8
50-70 cm	-1.2350	0.2110	0.00	0.3	0.2	-	0.4
70+ cm	-0.2210	0.2420	0.00	0.1	0.1	-	0.2

Confidence limits separated by a "+" indicate a significant increase in likelihood when compared to the reference level.

Confidence limits separated by a "-" indicate a significant decrease in likelihood when compared to the reference level.

Table 4-8. Calculated percent probabilities for a tree seedling receiving a vertical displacement based on the logistic equation for vertical displacement.

	June			August		
Tree Size	Dry Pine	Moist Pine	Transition	Dry Pine	Moist Pine	Transition
10-30 cm	25.2	32.0	32.6	12.5	16.7	17.1
31-50 cm	17.0	22.3	22.8	8.0	10.9	11.1
51-70 cm	8.9	12.1	12.3	4.0	5.5	5.7
70+ cm	3.5	4.9	5.0	1.5	2.1	2.2

Table 4-9. Results from fitting a logistic regression equation predicting mortality in 1996 from forest site and maximum basal scar of conifer seedlings exposed to grazing by horses.

Variable	Coefficient	S.E.	p Value	Odds Ratio	95% Confidence Limits Lower		Upper
Constant	-2.5140	0.1760	0.00				
SITE							
Dry Pine	0.0000			1.0			
Moist Pine	-0.5340	0.2820	0.06	0.6	0.3		1.0
Transition	-0.8590	0.3010	0.00	0.4	0.2	-	0.8
MAXIMUM BASAL SCAR							
No Scar	0.0000			1.00			
1-10 Percent	0.6000	0.5460	0.27	1.82	0.6		5.3
11-30 Percent	1.4220	0.3300	0.00	4.41	2.2	+	7.9
31-60 Percent	1.9470	0.4750	0.00	7.01	2.8	+	17.8
61-100 Percent	4.3960	1.1150	0.00	81.1	9.1	+	720.8

Confidence limits separated by a "+" indicate a significant increase in likelihood when compared to the reference level.

Confidence limits separated by a "-" indicate a significant decrease in likelihood when compared to the reference level.

Table 4-10. Calculated percent probabilities for a tree seedling mortality based on the logistic equation for maximum basal scar in either 1994 or 1995.

Maximum Basal Scar	Site: Dry Pine	Moist Pine	Transition
No Scar	7.5	4.5	3.3
1-10 Percent	12.9	8.0	5.9
11-30 Percent	25.1	16.4	12.4
31-60 Percent	36.2	25.0	19.4
61-100 Percent	86.8	79.4	73.6

Table 4-11. Results from fitting a logistic regression equation predicting mortality in 1996 from forest site and maximum vertical displacement of conifer seedlings exposed to grazing by horses.

Variable	Coefficient	S.E.	p Value	Odds Ratio	95% Confidence Limits Lower		Upper
Constant	-2.6400	0.1840	0.00				
SITE							
Dry Pine	0.0000			1.0			
Moist Pine	-0.6470	0.2840	0.02	0.5	0.3	-	0.9
Transition	-1.1560	0.3060	0.00	0.3	0.2	-	0.6
MAXIMUM VERTICAL DISPLACEMENT							
0 Degrees	0.0000			1.0			
1-10 Degrees	0.9820	0.5050	0.05	2.7	1.0	+	7.2
11-30 Degrees	1.4390	0.3570	0.00	4.2	2.1	+	8.5
31-50 Degrees	1.7820	0.3650	0.00	5.9	2.9	+	12.2
51-75 Degrees	2.5090	0.4290	0.00	12.3	5.3	+	28.5
76-90 Degrees	2.6360	0.6790	0.00	14.0	3.7	+	52.9

Confidence limits separated by a "+" indicate a significant increase in likelihood when compared to the reference level.
Confidence limits separated by a "-" indicate a significant decrease in likelihood when compared to the reference level.

Table 4-12. Calculated percent probabilities for a tree seedling mortality based on the logistic equation for maximum vertical displacement in either 1994 or 1995.

Maximum Vertical Displacement	Site: Dry Pine	Moist Pine	Transition
0 Degrees	6.7	3.6	2.2
1-10 Degrees	16.0	9.1	5.7
11-30 Degrees	23.1	13.6	8.7
31-50 Degrees	29.8	18.2	11.8
51-75 Degrees	46.7	31.5	21.6
76-90 Degrees	49.9	34.3	23.9

Table 4-13. Number and predicted mortality of pine seedlings by maximum basal scar and maximum vertical displacement.

		Number	Expected Mortality[1]	Calculated Mortality[2]	Weighted Mortality[3]
Maximum Scar	No Scar	1064	5.1	54.0	5.1
	1-10 Percent	42	8.9	3.7	
	11-30 Percent	75	18	13.5	20.1
	31-60 Percent	24	26.9	6.5	
	61-100 Percent	7	79.9	6.0	
	Total	1212		83.7	6.9
Maximum Displacement	0 Degrees	978	4.2	41.0	4.2
	1-10 Degrees	44	10.3	4.5	
	11-30 Degrees	86	15.1	13.0	
	31-50 Degrees	62	19.9	12.3	18.8
	51-75 Degrees	34	33.3	11.3	
	76-90 Degrees	8	36	2.9	
	Total	1212		85.0	7.0

Total Number is the number of seedlings at the start of the study.

Maximum scar and displacement is the maximum scar and displacement damage received in either 1994 or 1995.

[1] Expected Mortality is the average mortality across site, taken from Tables 4-9 and 4-11 expressed as a percent

[2] Calculated Mortality = Expected Mortality x Number in class

[3] Weighted Mortality = (Expected Mortality / Total Number in class) x 100

Table 4-14. Comparison of diameter growth (mm) between damage classes, 1994-1996.

			95% Confidence Limits			
		Growth[1]	Lower	Upper	Count	Statistics
Maximum Scar	No Scar	19.0	18.7	19.3	1011	p = 0.280
	1-10 Percent	20.8	18.9	22.8	38	
	11-30 Percent	19.8	18.4	21.2	61	
	31-60 Percent	20.2	17.7	22.7	17	
	61-100 Percent	15.1	NA	NA	1	
Maximum Displacement	0 Degrees	19.2	18.9	19.5	938	p=0.559
	1-10 Degrees	20.0	18.4	21.7	39	
	11-30 Degrees	19.2	17.9	20.5	74	
	31-50 Degrees	18.4	16.8	20.0	50	
	51-75 Degrees	17.9	15.2	20.5	22	
	76-90 Degrees	18.0	NA	NA	5	

Count is the number of seedlings alive at the end of the study.

[1] Presented means are modified by analysis of covariance taking out initial diameter in 1994 as a covariate.

NA Confidence Limits are not applicable because of small sample size.

Table 4-15. Comparison of height growth (cm) between damage classes, 1994-1996.

		Growth[1]	95% Confidence Limits Lower	Upper	Count	Statistics
Maximum Scar	No Scar	37.1	36.0	38.1	1011	p = 0.022
	1-10 Percent	36.7	29.9	43.4	38	
	11-30 Percent	29.9	25.1	34.6	61	
	31-60 Percent	30.5	NA	NA	17	
	61-100 Percent	13.0	NA	NA	1	
Maximum Displacement	0 Degrees	37.8	36.7	38.9	938	p=0.015
	1-10 Degrees	32.8	27.2	38.3	39	
	11-30 Degrees	32.9	28.4	37.4	74	
	31-50 Degrees	29.1	23.8	34.4	50	
	51-75 Degrees	31.6	NA	NA	22	
	76-90 Degrees	28.6	NA	NA	5	

Count is the number of seedlings that finished the study alive.

[1] Presented means are modified by analysis of covariance taking out initial height in 1994 as a covariate.

NA Confidence Limits are not applicable because of small sample size.

Table 4-16. Habitat selection by horses confined to cutblocks in June, for 1994 and 1995.

	m_i	π_i	u_i	o_i	w_i	χ^2	$se(w_i)$	Confidence Limits Lower		Confidence Limits Upper
Disturbed Areas	70	0.02	276	0.14	6.40	1,257.0	0.84	4.392	+	8.405
Black Spruce Forest	130	0.04	0	0.00	0.00	80.1	NA	NA		NA
Dry Pine	820	0.26	700	0.36	1.39	75.0	0.06	1.244	+	1.527
Moist Pine	820	0.26	209	0.11	0.41	173.8	0.03	0.342	-	0.485
Transition	1000	0.32	244	0.13	0.40	224.9	0.03	0.334	-	0.458
Hygric Meadow	300	0.10	506	0.26	2.74	557.8	0.18	2.298	+	3.176
Total	3140	1.00	1935	1.00	11.3	2368.6				

NA Cannot calculate because of a zero value

Confidence limits separated by a "+" indicate significant selection.

Confidence limits separated by a "-" indicate significant avoidance.

Symbol [1]	Definition
m_i	Actual area in hectares multiplied by 1000
π_i	Proportion of actual area
u_i	Observational counts
o_i	Proportion of observational counts
w_i	Selection Ratio, equals o_i/π_i
χ^2	Pearson Chi-squared statistic
$se(w_i)$	Standard Error of the Selection Ratio

[1] Follows convention as outlined in Manly, McDonald, and Thomas 1993.

Table 4-17. Habitat selection by horses confined to cutblocks in August, for 1994 and 1995.

	m_i	π_i	u_i	o_i	w_i	χ^2	se(w_i)	Confidence Limits Lower		Upper
Disturbed Areas	60	0.02	287	0.13	7.76	1,690.8	1.08	5.166	+	10.359
Black Spruce Forest	240	0.07	87	0.04	0.59	25.1	0.07	0.416	-	0.761
Dry Pine	1210	0.34	1015	0.46	1.36	97.3	0.04	1.254	+	1.469
Moist Pine	800	0.22	190	0.09	0.39	186.2	0.03	0.315	-	0.456
Transition	860	0.24	157	0.07	0.30	262.4	0.02	0.238	-	0.355
Hygric Meadow	410	0.11	470	0.21	1.86	187.0	0.12	1.584	+	2.137
Total	3580	1.00	2206	1.00	12.3	2448.9				

Symbol [1]	Definition
m_i	Actual area in hectares multiplied by 1000
π_i	Proportion of actual area
u_i	Observational counts
o_i	Proportion of observational counts
w_i	Selection Ratio, equals o_i/π_i
χ^2	Pearson Chi-squared statistic
se(w_i)	Standard Error of the Selection Ratio

[1] Follows convention as outlined in Manly, McDonald, and Thomas 1993.

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5. THE SCIENCE AND ART OF MANAGING HORSE GRAZING COINCIDENTALLY WITH REFORESTATION IN A MANAGED FOREST

THE SCIENCE

The ultimate question that needs to be answered is whether horses damage conifer seedlings or not. There is no simple answer to this question. Horses are a potential damage threat to conifer seedlings; the ultimate level of damage is determined by a complex interaction between damage type, seedling size, season of grazing, site and horse grazing behaviour. This interaction has probably been responsible for the misunderstandings and lack of trust between forest companies and horse owners in the past. When this study was initiated, representatives of the forest company show-cased cutblocks that were not sufficiently stocked with conifer regeneration and they were convinced the cause was horses. Conversely, representatives of horse owners show-cased cutblocks subjected to continuous horse grazing where conifer seedlings were adequately stocked and undamaged. Who was right, who was wrong, and why? Individual factors will be briefly discussed followed by an in-depth discussion of their interactions.

Damage Type

Based on this research, there is no evidence that horses browse conifer seedlings. The major types of damage documented in this study are basal scarring and vertical displacement. Vertical displacement was the most common type of damage and resulted in the most conifer seedling mortality. Tree seedlings are damaged as a result of horses seeking forage, either walking while feeding or walking between feeding sites. Managing horses that selectively forage on conifer seedlings would be impossible, managing horses where damage to conifers seedlings is incidental to foraging activity is possible, but complex.

Seedling Size

Smaller seedlings are more susceptible to damage by horses. Although a one percent increase in mortality for each year exposed to horse grazing was not biologically significant in this study, if all the seedlings exposed to grazing had been 10 cm tall, the conclusion might have been different. If it takes 10 years for a seedling to grow from 10 to 70 cm tall, an increase in mortality of 10 percent would be associated with continual horse grazing as applied in this study. Ten percent incidental mortality may be biologically and economically significant on cutblocks that have marginal conifer seedling stocking. On cutblocks that have overstocking of conifer seedlings, 10 percent incidental mortality is unlikely to be biologically significant, and may even be beneficial as a mechanism for thinning.

Season of Grazing

Conifer seedlings are damaged more by early season than late season horse grazing. Simply changing from June to August grazing will result in a reduction in seedling damage of 2.0 – 2.5 times. Reducing maximum damage levels from 32 percent when grazed in June to 15 percent when grazed in August is biologically significant.

Forest Site

Although seedlings growing on moist sites have a higher rate of damage caused by grazing horses, they also have a lower rate of subsequent mortality. Moist sites, with decreased soil strength and an increased incidence of a moss layer do not support conifer seedlings as well as dry sites. However, damaged seedlings have a higher rate of recovery, probably because of increased soil water and the insulating effect of the moss layer.

Grazing Behaviour

Horse grazing behaviour should be a consideration for every confinement strategy in every environment. Although grazing behaviour will not be the same if the location changes, because of a different array of available habitats, this study has established some consistent behavioural patterns that can be used in the development of forest grazing plans. Clearly, the preferred habitats for horses grazing during the summer are disturbed sites. The presence of disturbed sites will attract horses away from grazing on other sites, such as newly established conifer plantations. Disturbed sites are an important alternative preferred habitat and land managers can use them to minimize conifer seedling damage on adjacent cutblocks. Hygric meadows are also an important preferred alternative habitat, especially for free-ranging horses grazing in the winter. Given that hygric meadows are not commercial forest, they could be a significant area of land that could be used for horse grazing. Hygric meadows are also a preferred alternative habitat for horses grazing in the summer. Although water levels may limit horse use of hygric meadows in some years, heavy, lush herbaceous production is an attractant to summer grazing horses. Both disturbed sites and hygric meadows have low conifer regeneration potential: disturbed sites because of soil compaction and increased access for recreational vehicles, and hygric meadows because of high water tables. Therefore, horses grazing on disturbed sites and hygric meadows present low damage potential to conifer seedlings.

Factor Interactions

The existence or lack of an alternative preferred habitat has a major effect on conifer seedling damage. Seedlings cannot be damaged by horses selectively grazing areas where there are no seedlings. Seedling size, season of grazing, and site are irrelevant until the stocking rate of horses exceeds the carrying capacity of the preferred alternative habitat. Even if the preferred alternative habitat is large enough to support a horse population for part of the growing season, seedling damage would be reduced because conifer seedlings would not be exposed to horse damage during the critical portion of the season (June and July) when seedling growth is rapid and soil strength is low.

A simple scenario, presented in Tables 5-1 and 5-2, illustrates the projected effect of the presence of a preferred alternative habitat in combination with various levels of horse stocking rate. Assume a hypothetical 80 hectare cutblock has four forest sites: a disturbed site with low conifer seedling stocking and three undisturbed sites with adequate stocking of 10-30 cm tall lodgepole pine regeneration (Table 5-1). Five hypothetical stocking rates for horses, with varying horse numbers and duration of grazing are also presented (Table 5-2). Scenario 1 and 2 are projected to have minimal conifer seedling damage because the total stocking rate for horses is equal to the carrying capacity of the preferred alternative habitat, the disturbed site. Although the horse stocking rate of scenario 3 exceeds the carrying capacity of the disturbed sites, it would take 90 days, June 1 to August 31, for the 2 horses to totally utilize the available carrying capacity of the disturbed site. For the remaining 90 days, September 1 to November 30, the horses would have to graze the other three sites. Scenario 3 would in effect defer grazing on the three forest sites until later in the season when the susceptibility of conifer seedlings to damage is lower. Scenarios 4 and 5 have total horse stocking rates equal to scenario 3, but the number of horses is increased and the length of the grazing period is decreased. As horse numbers increase the forage on the disturbed site would be used faster, and the horses would switch grazing to lesser preferred habitats earlier in the growing season. Conifer regeneration growing on forest sites that are grazed earlier in the growing season are very susceptible to damage. Thus, horse stocking rate is not the ultimate determinant of conifer seedling damage. The availability and size of preferred alternative habitats in combination with horse numbers and timing of grazing are important considerations

Horse grazing on areas with no alternative preferred habitat can be coordinated with conifer regeneration efforts. Although seedling damage and mortality was low in all studies conducted, all areas investigated contained a preferred alternative habitat to absorb most of the horse grazing pressure. If no alternative preferred habitat exists, seedling size, density, and season of grazing will be important factors for consideration. Areas with no alternative preferred habitat could still be grazed if the conifer seedlings were overstocked, or greater than 50 cm in height, or the season of grazing was deferred until the conifer seedlings were not growing and the soil was dry. Minimal conifer seedling damage would be expected, even if an alternative preferred habitat did not exist.

Confinement Strategy

Confining horses did not change their overall grazing behaviour. Similar grazing patterns on preferred habitats surfaced for all studies of different horse confinement strategies. Confinement can have a significant effect on horse grazing behaviour and conifer seedling damage by including or excluding important habitats. Free-ranging horses have uncontrolled access to the widest array of available habitats. Free-ranging horses grazing in the summer on large areas with cutlines, permanent roads, and logging roads would do very little damage to conifer seedlings growing on adjacent cutblocks. Significant conifer seedling damage would be expected only when horse stocking exceeded carrying capacity of the disturbed areas, as illustrated above. Confining horses would not necessarily increase conifer seedling damage unless the area the horses were confined to did not contain a preferred alternative habitat. Confinement is not the primary factor determining conifer seedling damage, grazing behaviour is more important and is predictable, regardless of the level of confinement.

THE ART

There are several issues involved with horse grazing in Upper Boreal Cordilleran forests that cannot be investigated and resolved by science. Probably the most significant issue that needs to be resolved is the risk of vehicular collisions with free ranging horses. This risk is greatest surrounding population centers, relatively high along primary and secondary highways, moderate along main haul roads, and low along feeder roads in the remote parts of a managed forest. The solution seems simple; all horses in areas that have a high risk of vehicular collision should be confined, free-ranging horses should be limited to areas of moderate and low collision risk. Most owned horse herds consist of a variety of horses, ranging from docile and easy to catch to flighty and difficult to catch. Collision risk could be reduced by grazing flighty free-ranging horses in areas of moderate collision risk and docile free-ranging horses in areas of low collision risk. Docile horses would spend more time grazing along roads and would be less likely to move from roadsides when vehicles approach than flighty horses. Temperament of free-ranging horses could be used to reduce the risk of road collisions.

Grazing horses using a free-ranging strategy may be the easiest program to implement in areas that have a low collision risk. In this study area, winter free-ranging horses prefer non-commercial habitats and avoid grazing cutblocks. Horses grazing in the summer prefer disturbed sites and hygric meadows. Early spring grazing (late April and early May) is the only time period that was not studied. In the Upper Boreal Cordillera Eco-region, herbaceous growth starts in early May but is slow because of cool soil temperatures. During this brief time period horses could be expected to disperse to take advantage of sparse, juvenile plant growth. Grazing on cutblocks is a possibility, but the grazing pressure, and the potential for damage, would be spread over a wide area. A key consideration for free-ranging horse grazing would be balancing the number of horses with the size and availability of a preferred alternative habitat: hygric meadows in the winter and disturbed areas in the summer.

Confining horses in areas of high collision risk would require some investment in infrastructure (fencing) from horse owners, some cooperation from the forest company and some coordination from the government resource management personnel. There is still risk that confined horses will escape and wander onto adjacent highways or railroads, but the risk is no greater than in numerous areas of western Canada where livestock is raised in close proximity to population centers. Confining horses requires formal agreements based on consensus of land users. In the past, the forest industry has resisted the establishment of areas to confine and manage horses. The result has been horse owners turning their horses out for free grazing under free-ranging conditions. It is a situation where everyone is part of the problem, yet no one assumes responsibility for the ultimate resolution. The science clearly shows that horse grazing and conifer regeneration can be coordinated, the art of managing horses in a commercial forest will require the cooperation of horse owners, representatives from the forest company, and government resource management personnel.

Confining horses needs to be economical and practical. Horses are easier to confine than other types of livestock and require a less rigorous fence. Horses were readily confined using single strand electric fence to administer the grazing treatments in this study. Electric fence is a psychological barrier; horses trained to electric fence are reluctant to even cross a wire laying on the ground. Wild ungulates, elk and moose, pose a problem for confining horses, even close to population centers and main roads. If elk or moose knock a fence down, the horses confined within the fence can easily escape. Electric fence alleviates some of this concern; even if the wire was knocked to the ground horses trained to electric fence would be less likely to cross it than horses accustomed to normal fence. Several miles of electric fence can be easily checked by testing the voltage; if the voltage drops below a definable level, part of the fence is grounded and further checking would be warranted. Electric fence can be checked from one location, rather than having to check the entire perimeter. Electric fence has the added benefit that it can be let down in non-use periods, thus allowing free wild ungulate passage with minimal disturbance to the fence.

Easily constructed fence would allow flexible management of horses on conifer cutblocks. Commercial forestry has existed in Western Alberta for over 40 years; there is a continuous array of cutblocks between 1 and 40 years old. If no alternative preferred habitat existed, electric fence could be used to confine horses to cutblocks where the conifer regeneration was taller than 50 cm. Once the regenerating forest grew and the canopy closed to the point where forage became a limiting factor, perhaps 15-20 years later, the fence and the horses could be moved to a new area, with conifer regeneration greater than 50 cm.

The science explored in this study shows horse grazing can be coordinated with conifer regeneration efforts. The art of implementation is up to three sectors of the local society: the forest companies, horse owners and government resource management personnel. All parties must choose honest cooperation and accept appropriate levels of financial and managerial responsibilities. Without cooperation, the current pattern of illegal free-ranging horse grazing accompanied by mistrust and name calling is likely to continue. Horse grazing can be a legitimate forest land use based on scientific evidence and should be recognized as such. The art of implementation is up to the people who manage the land.

CONCLUSIONS

1. The science clearly indicates horse grazing and conifer regeneration efforts can be coordinated. Knowledge provided by this study can be used to minimize the impacts of horse grazing on conifer regeneration. Damage to conifer seedlings can be minimized by applying the alternative preferred habitat concept in conjunction with known horse grazing behaviour. Seedling size, season of grazing, forest site and confinement strategy are also important factors in minimizing conifer seedling damage.

2. Regardless of the science, success or failure of horse management schemes will ultimately be determined by the art of management. Honesty and cooperation between horse owners, forest companies, and government resource management personnel is required. In the absence of honest cooperation the current practice of illegal free-ranging horse grazing will continue, nothing will change.

Table 5-1. Vegetation types and areas of a hypothetical cutblock in west-central Alberta.

Vegetation Type	Area ha	Carrying Capacity Horse days/ha	Recommended Stocking Rate Horse Days
Disturbed	10	18	180
Dry Pine	10	9	90
Moist Pine	30	9	270
Transition	30	9	270
Total	80	10	810

Table 5-2. Management scenarios for a hypothetical cutblock in west-central Alberta.

Scenario	Entry Date	Number of Horses	Number of Days	Stocking Rate[1]	Predicted Seedling Damage
1	1-Jun	2	90	180	Low
2	1-Jun	4	45	180	Low
3	1-Jun	2	180	360	Low
4	1-Jun	4	90	360	Moderate
5	1-Jun	8	45	360	High

[1] Stocking rate expressed in Horse days.