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THE RESPONSE OF MATURE DECADENT AND HEALTHY SAPLING ASPEN FOREST COMMUNITIES TO PRESCRIBED BURNING AND CONTROLLED LIVESTOCK GRAZING

BY

MICHAEL JOHN ALEXANDER ©

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

IN
RANGE SCIENCE

DEPARTMENT OF PLANT SCIENCE

EDMONTON, ALBERTA
FALL 1995

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ISBN 0-612-01576-9

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DEGREE: MASTER OF SCIENCE

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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 RESPONSE OF MATURE DECADENT AND HEALTHY SAPLING ASPEN FOREST COMMUNITIES TO PRESCRIBED BURNING AND CONTROLLED LIVESTOCK GRAZING here submitted by MICHAEL JOHN ALEXANDER in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in RANGE SCIENCE.

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Dr. A.W. Bailey, Supervisor

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Dr. R.T. Hardin

....
Dr. S.E. Macdonald

Dated: Jan 17 1995

This thesis is dedicated to my mother and father
Terry & Peter Alexander

A special thanks for all your love and support

ABSTRACT

In the Aspen Parkland of Central Alberta, drought and tent caterpillar epidemics during the late 1980's and early 1990's resulted in significant mortality to aspen trees growing on marginal sites. A study was initiated to determine if the stresses caused by drought and repeated tent caterpillar defoliation influenced the response of this mature decadent aspen forest community to prescribed burning and controlled livestock grazing compared to a healthy sapling aspen forest community. Comparisons were made of understory biomass production, forage utilization, woody species composition and the ability of aspen to regenerate vegetatively. The study site was located in Central Alberta on Kuntz Brothers' Farms, a private cattle ranch 160 km east of Edmonton (52° 02"N 111° 33"W).

Following prescribed burning, understory standing crop production was similar between the two forest types and increased over time. Production of herbage, aspen and other woody components, however, differed. Herbaceous and other woody components dominated production in the mature decadent forest while aspen suckers dominated the healthy sapling forest. Average aspen sucker densities in the healthy sapling forest (19.4 stems m^{-2}) were much higher than in the mature decadent forest (1.1 stems m^{-2}).

In the sapling forest, prolific aspen suckering was influential in determining the understory community which developed. In this forest type it appeared that interspecific competition between aspen suckers and herbage limited herbaceous production. In the second year following burning herbaceous production was 840 kg ha^{-1} in the sapling forest, whereas in the decadent forest herbaceous production was 2,260 Kg ha^{-1}.

Tender aspen suckers which had not begun to lignify were palatable forage for cattle. In the sapling forest, grazing removed some of the aspen competition. After one season of grazing, herbaceous production in the ungrazed and grazed treatments were 850 Kg ha^{-1} and 1,360 Kg ha^{-1}, respectively.

Following burning the density of woody species declined over the two year study on both forest types. Grazing further decreased the density of woody species, and also controlled their height. Both moderate and heavy grazing were equally effective in controlling aspen. Total nonstructural carbohydrate (TNC) concentrations were similar between the two forest types, however, burning and grazing the year before, resulted in lower TNC concentrations (19.7 vs 26.1 %). Under etiolated conditions, excised roots from the decadent forest produced fewer new suckers than the sapling forest, however, the differences were not as great as those which occurred under natural conditions.

ACKNOWLEDGEMENTS

This thesis would not have been possible without the help and support of a great number of people. I would like to thank Dr. Art Bailey my program supervisor for his encouragement, advice and guidance throughout my masters program. This project would not have been possible without the help of Mr. Barry Irving. Barry's expert advice and invaluable field experience helped to make my project run smoothly. Barry also provided labour and constructive criticism above and beyond the call of duty, for which I am extremely grateful.

To the members of my supervisory committee, I would like to thank them for their efforts. Dr. R.T. Hardin for the many hours he spent helping me with my experimental design and statistical analysis, and to Dr. Jane King for her friendly pieces of advice and helpful guidance. Thanks is also due to Dr. Ellen Macdonald who was extremely helpful in the development of suitable methodology and providing expertise in the growing of excised aspen roots.

To Kuntz Brothers' Farms, particularly Doyle and Norman Kuntz, I am grateful not only for their financial contribution that made the study possible but also for their great hospitality and outstanding cooperation. I would also like to acknowledge the financial contribution made by NSERC which helped to make this study possible.

Many other people made substantial contributions for which I am thankful. To Dr. Peter Blenis of Plant Science and Ray Weingardt of Animal Science I would like to thank them for their statistical expertise. I would like to thank Bruce Alexander who took care of my etiolated growth study. I would also like to thank Paul Shippy for his help in collecting field data.

Finally I would like to thank my family, for their help and support thoughout. To my mother, I would like to thank her for all the hours she spent, when I was younger, at the dining room table helping me; without that help none of this would have been possible. Not many people would have spent the time and I am eternally grateful that she did. To my father I am thankful for all the special efforts that were made to make sure I had everything I needed and many things I didn't really need. A special thanks also goes to Shelly Miller for all her patient help in the final preparation of my thesis.

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I. INTRODUCTION:

The Aspen Parkland association of Central Alberta and Saskatchewan is a transition zone with the Mixed Prairie to the south and the Boreal Forest to the north (Sanborn and Pawluk 1983, Pettapiece 1969, Moss 1934). The vegetation of the Aspen Parkland is in dynamic equilibrium with constantly changing environmental factors. Anthropogenic and pyrogenic forces, along with cyclical climatic variations have been responsible for shaping this extremely dynamic ecotone (Dormar and Lutwick 1966, Bird 1961, Fidler 1792-93). The vegetation that has developed in this association is a grassland-forest mosaic, ranging from stands dominated by grassland to groves of aspen (*Populus tremuloides* Michx.) forest. The vegetation on any specific site is determined by microtopography and how climatic, edaphic, anthropogenic and pyrogenic forces have influenced that site.

The Influence of Climate on the Vegetation of the Aspen Parkland:

The climate of the Aspen Parkland is cool, continental, with a sub-arid to sub-humid moisture regime (Pettapiece 1969). The annual precipitation of the Aspen Parkland region ranges from 400-450 mm (Strong and Leggat 1992, Smoliak et al. 1988), with levels of precipitation highest in the northwest and lowest in the southeast corners of the Parkland (Wyatt et al. 1944). Annual potential evaporation in the Aspen Parkland is between 380 and 500 mm (Smoliak et al. 1988), giving the region a precipitation to potential evapotranspiration (P:E) ratio of 0.85 - 1.1 (Bothe and Abraham 1990, Smoliak et al. 1988). This range of P:E ratios is generally considered to be the lower end of moisture regimes suitable for forest development. Therefore, environmental conditions over most of the Aspen Parkland would appear to favor forest domination. However, the soils of the region (Sanborn and Pawluk 1983, Pettapiece 1969, Dormaar and Lutwick 1966, Moss 1934) and historical observations of the vegetation, (Hind 1859, Fidler 1792 & 93) reveal that historically grasslands predominated and aspen forests occurred only in small groves.

The Influence of Micro Topography on the Vegetation of the Aspen Parkland:

In the Aspen Parkland, micro topography plays an important role in shaping vegetation. Much of the Aspen Parkland has a topography that is classified as morainal hummocky (Howitt et al. 1988); it is characterized by hummocks with short steep slopes and numerous pothole lakes interspersed between hummocks. The variability of the topography results in micro sites with their own soil micro climate. Soil micro climate influences vegetation development. It is because of the different soil micro climates created by micro topography that aspen grows on mesic sites around sloughs, in depressions, and on north-facing slopes (Scheffler 1976). Grasslands normally dominate the drier more exposed sites of hilltops and south facing slopes.

The Influence of Fire and Bison on the Historical Vegetation of the Aspen Parkland:

There is substantial evidence which shows that historically, fire and heavy bison grazing were influential in shaping the type of plant community that dominated the Aspen Parkland prior to European settlement. When Peter Fidler traveled through the Aspen Parkland in 1792-93 he described a landscape dominated by grasslands, with groves of aspen dominated shrubland dispersed throughout (Fidler 1792 -93). Several authors have presented evidence to indicate that the frequent occurrence of fire, both natural and man made, played a significant role in controlling the amount and type of woody vegetation prior to European settlement (Anderson and Bailey 1980, Nelson and England 1971, Pettapiece 1969, Bird 1961).

There is evidence that animals contributed to the suppression of aspen. Gruell and Loope (1974) reported that heavy browsing by wintering elk can result in substantial suppression of aspen suckering. Bird (1961) postulated that bison herds would have suppressed aspen as they sought shade and rubbing posts. He failed to recognize that the bison herds typically utilized the Aspen Parkland during winter (Roe 1951). However, this observation only strengthens the reasoning that massive herds of wintering bison would have had a strong influence on the forest community. Not only would the bison have used aspen for shelter from winter storms, it is also likely that they would have browsed extensively as well as rubbed trees and trampled suckers and saplings.

Prior to European settlement the Aspen Parkland was dominated by grasslands (Fidler 1792-93). The aspen dominated shrubland was only able to develop into groves on the most suitable sites. Since the time of European settlement however, a policy of fire suppression and the eradication of free ranging bison herds, has removed the influence of these natural forces.

Influence of Vegetation on Soils of the Aspen Parkland:

The dominant soil types of the Central Alberta Aspen Parkland are the Black or Dark Brown Great Groups of the Chernozemic Order (Howitt et al. 1988). These soils developed under a grassland vegetation and are characterized by a Chernozemic Ah horizon. Under temperate grasslands, large amounts of organic material are added to the soil through surface and subsurface contributions. Particularly important to the development of a Chernozemic soil is the large annual addition of organic matter from grass roots. The average grass tiller has a life span of approximately ninety days (Tainton 1981). The tiller, and its associated root system dies and is decomposed by heterotrophic, meso and micro fauna (Tisdale et al. 1985). Organic matter is important to soil development, playing a role in soil structure, nutrient storage, cation exchange capacity, water holding capacity and soil buffering capacity. The high organic matter and good structure of these soils makes them extremely fertile, highly productive and prized as both rangelands and croplands.

When the influences of fire and heavy bison grazing were removed from the Aspen Parkland ecosystem, the process of forest invasion began. Aspen h[illegible] the Black and Dark Brown Chernozemic soils (Anderson and B[illegible]ettapiece 1969, Moss 1934). Under aspen forests, the fertile Bla[illegible]rown Chernozemic soil undergoes physical and chemical chang[illegible]e effects of aspen encroachment on Black Chernozemic soils is first demonstrated by some graying in the lower portion of the Ah horizon

(Pettapiece 1969). These changes to the soil occur rapidly and have been noted as early as 50 years after forest encroachment (Dormaar and Lutwick 1966). The degradative processes which occur on Chernozemic soils are influenced by the organic matter deposited by forest vegetation. Forest vegetation deposits less organic matter than grassland vegetation. More importantly, with forest vegetation organic matter is primarily added to the soil surface as leaf litter (Cryer and Murray 1992, Jones and DeByle 1985a). The leaf litter of aspen is rich in phenolics (Novak and Smeck 1991, Sanborn and Pawluk 1983). High concentrations of phenolic compounds are toxic to earthworms so they are not active in these soils (Pettapiece 1969). The absence of earthworms means that organic debris is not incorporated through physical and chemical mixing into the A horizon. The thick leaf mat that develops on a forest vegetated soil is decomposed primarily by fungi, which convert the organic material to simple organic acids. These organic acids are responsible for a decrease in soil pH which promotes a more rapid breakdown of organic matter in the Ah horizon and the breakdown of the organo-clay complex which is important to the structure of the Chernozemic Ah. The breakdown of this complex means that the clay particles are freed and can be leached down the soil profile. The result of these processes is a decline in soil fertility and organic matter as the soil gradually takes on characteristics of a Luvisol (Sanborn and Pawluk 1983, Scheffler 1976, Pettapiece 1969, Dormaar and Lutwick 1966, St Arnaud and Whiteside 1964).

Aspen Encroachment in the Grassland Soils of the Aspen Parkland:

Since the early 1900's, aspen encroachment has been widespread and extremely rapid (FitzGerald 1982, Scheffler 1976, Bailey and Wroe 1974, Coupland and Maini 1961). Scheffler (1976) compared field notes of the legal land survey of 1903 with aerial photographs taken in 1963 of the same area. She found that in 1903 aspen forest occupied 6.7% of the land area. In 1963, on the same transect lines, aspen occupied 52.2% of the land area.

The encroachment of aspen since the settlement of western Canada by Europeans coincides with the policy of fire suppression introduced by the European settlers (Bailey and Bailey 1994, Bird 1961, Moss 1934). With the removal of fire and bison grazing from the ecosystem, aspen sucker survival has been favored along the tension zone between forest and grassland (FitzGerald 1982, Scheffler 1976). The result has been a steady encroachment of aspen forest into grassland. The spread of aspen forest into the grasslands of the Aspen Parkland has been primarily through vegetative suckering (Anderson and Bailey 1980, Scheffler 1976). Historically, aspen forest groves occupied the sites with the greatest soil moisture such as around sloughs, in lowland depressions, and on north-facing slopes (Bird 1961). Today however, aspen has moved outwards from these more moist sites into lands that are marginal for tree growth because of limited soil moisture. Scheffler (1976) and Hilton (1970) recorded this gradual expansion of an aspen grove from a wet lowland outward. Hilton (1970) identified three plant communities within an aspen grove. In the centre of the grove, the wettest site, was the poplar-willow type, the next plant community encountered was the large poplar community, followed by the small poplar community on the forest-grassland interface. Scheffler (1976) further refined the plant communities that Hilton (1970) first described. Starting at the slough and moving progressively upslope and away from the slough, Scheffler (1976) identified the communities as the *Salix* spp. (willow), the *Salix - Populus tremuloides* (willow - aspen), the large *Populus tremuloides* (large aspen), the medium *Populus tremuloides* (medium aspen), the small *Populus tremuloides* (small aspen), and eventually the shrub and the grassland communities. Scheffler noted that there was a difference in the age of the aspen trees between communities, with the oldest trees being in the large aspen and the youngest in the small aspen community.

Reproduction of Trembling Aspen:

Aspen rarely reproduces from seed (Shier 1976, Moss 1938, Baker 1918), instead reproduction is primarily through vegetative suckering (Schier 1985, Schier et al. 1976, Maini and Horton 1966, Zahner and Crawford 1965, Baker 1918). This pattern of vegetative reproduction causes aspen to occur in clones (Schier 1976, Zahner and Crawford 1965) of genetically identical individuals propagated vegetatively from a single individual of seedling origin (Jones and DeByle 1985b; Zahner and Crawford 1965). The size of an aspen clone varies from a few stems to several thousand stems. The largest reported aspen clone consisted of some 47,000 mature stems, and covered an area of 43 ha (Kemperman and Barnes 1976).

New aspen shoots originate as root suckers, which develop primarily from newly initiated meristems, and preexisting primordia (Schier et al. 1985, Schier 1973). Many suppressed shoot primordia can be found on roots of most aspen clones (Schier et al. 1985). Under a healthy aspen stand, new shoots are suppressed by the existing stems and very few aspen suckers are produced (Schier et al. 1985, Schier 1976, Schier 1973;). When existing stems of the clone are cut, the root primordia are no longer suppressed and new aspen suckers are produced (Schier et al. 1985, Bartos and Mueggler 1982, DeByle 1976, Jones 1975).

Factors Controlling Vegetative Reproduction of Aspen:

The major factors controlling the stimulation of aspen sucker development are hormonal control and soil temperature (Peterson and Peterson 1992, Schier et al 1985). Growth regulating hormones, particularly auxins and cytokinins work to control aspen suckering (Peterson and Peterson 1992, Schier 1976, Steneker 1974). Auxins, produced by apical meristems, are transported to the roots where they suppress sucker development (Schier et al. 1985, Steneker 1974, Farmer 1962). Auxins are relatively unstable hormones that are rapidly inactivated, therefore if their influence is to be maintained, the supply of auxin to the root must be continuous. Cytokinins are growth promoting hormones, produced in the root meristems, that are involved in promoting sucker development (Schier et al. 1985). When there are high ratios of cytokinins to auxins, aspen shoot development is promoted while low ratios suppress shoot development.

Aspen suckering is promoted by warmer soil temperatures (Peterson and Peterson 1992, Zasada and Schier 1973, Maini and Horton 1966) which promote cytokinin production and may increase the rate of auxin degradation (Schier et al. 1985). This increase in the cytokinin to auxin ratio stimulates suckering. Schier et al. (1985) noted that warmer soils as well as low auxin concentrations at the root tips, may in part account for aspen sucker invasions onto grasslands adjacent to aspen stands.

Following aspen shoot initiation, root carbohydrate reserves supply the energy necessary for shoot growth (Schier et al. 1985, Schier and Zasada 1973, Zahner and Debyle 1965). Root carbohydrate reserves supply the energy requirements of the developing sucker until it emerges from the soil surface and develops a self supporting photosynthetic system. Aspen suckers are heavily dependent on the parent root system even after their leaves begin to photosynthesize (Barring 1988, Zahner and DeByle 1965). New roots contribute little to sucker growth during the first 6 years (Zahner and DeByle 1965). Repeated destruction of new aspen suckers, by repeated browsing, cutting, burning, or herbicide spraying, can result in the exhaustion of root carbohydrate reserves (Schier et al. 1985). This can drastically reduce the ability of the parent root system to produce additional suckers (Schier et al. 1985, Sampson 1919, Baker 1918).

Substantial variation in sucker production occurs between clones (Schier 1976, 1974; Zasada and Schier 1973). This variation is due to differences in genotypic and non-genotypic factors such as clone history, stem age, clone age from seed, and site (Schier 1976).

The depth and diameter of parent roots affects aspen suckering. Most aspen suckers develop along horizontal and lateral roots that grow at a depth between 4 and 12 cm (Peterson and Peterson 1992, Schier et al. 1985). In Utah, Schier and Campbell (1978) reported the maximum depth of parent roots to be 28 cm. They also found that parent root diameter influences suckering. The range in diameter of roots producing suckers was 0.1 cm to 9 cm, with 93% of the roots producing new shoots having a diameter between 0.4 cm and 3 cm.

The Drought of the Late 1980's and Early 1990's:

The Aspen Parkland is an area of transition between forest and grassland because soil moisture conditions tend to be low for tree growth and precipitation is cyclical. Over the past 100 years there have been several periods in which precipitation has exceeded the long term average, and there have also been periods of drought (Atmospheric Environment Services 1991).

During the wet periods, soil moisture generally increases and tree growth is promoted.

In the late 1980's, the Aspen Parkland of Central Alberta, experienced a period of severe droughts. Drought is defined as prolonged dry weather when precipitation is less than 75% of the long-term average (Holechek et al. 1989). Precipitation records from Kinsella and Ranfurly, the two closest permanent weather stations (Atmospheric Environment Services 1991), and growing season precipitation (Alberta Hail and Crop Insurance Corporation 1993) of 5 farms, within the same township as the study site (Tp 48, R10&11 W4M), were compared to the 30 year long-term average precipitation. Analysis of precipitation records from 1985 - 1991 showed that the only year which could be classified as a drought was 1987, when actual annual precipitation (309 mm) was only 70% of the long-term average annual precipitation for Ranfurly (439 mm). However, when growing season precipitation was analyzed, it was determined that 1986, 1987, 1989, 1990 and 1991 all experienced growing season (May - August) droughts. For 1986 and 1987, precipitation was well below average for the entire growing season. Although 1988 was not a drought year, the bulk of the growing season precipitation fell during June while May and July were extremely dry. The years of 1989 and 1990 experienced a severe early growing season drought (May and June). Although the precipitation was close to normal for the latter half of the growing season, the moisture came too late for plants to recover from the severe moisture deficit encountered during the spring. In 1991, May was a very wet month but precipitation levels were very low during June and July, thus creating drought conditions.

Effect of Forest Tent Caterpillar Infestations on Aspen:

The forest tent caterpillar (*Malacosoma disstria* Hubner) is the most serious defoliator of trembling aspen in the Aspen Parkland (Moody and Amirault 1992, Peterson and Peterson 1992, Ives and Wong 1988, Hildahl and Campbell 1975). Tent caterpillar outbreaks typically last 4-5 years and reoccur at irregular intervals ranging from 6 to 16 years (Moody and Amirault 1992, Peterson and Peterson 1992, Hildahl and Campbell 1975). Tent caterpillar outbreaks originate following a single year with a relatively cool winter and an unusually warm spring (Hildahl and Campbell 1975). It then takes 4-6 years for caterpillar numbers to increase to the point where severe defoliation occurs.

The life cycle of the forest tent caterpillar involves one generation per year. The larvae hatch in the early spring, usually coinciding with aspen leaf flush, but will hatch as late in the season as late June (Peterson and Peterson 1992, Hildahl and Campbell 1975). The larvae feed for a period of 5-8 weeks depending on local temperatures, then pupate for about 10 days before emerging as adult moths (Hildahl and Campbell 1975). The moths live 5-10 days when the female deposits eggs around a small twig in a band containing between 50 and 200 eggs (Peterson and Peterson 1992).

Tent caterpillar outbreaks are usually brought under control by natural means. The population tends to increase to the point that the larvae exhaust the food supplies before they are mature enough to pupate. The consequence is mass starvation (Hildahl and Campbell 1975). Viral and fungal diseases also control caterpillar numbers, especially in older infestations. The forest tent caterpillar has over 40 known species of insect parasites which attack it during the various stages of development. Cold weather shortly after egg hatch in the spring is also an effective population control (Peterson and Peterson 1992).

Light defoliation by forest tent caterpillars has little or no effect on tree growth (Ives and Wong 1988). Two or more years of moderate to severe defoliation can, however, cause a serious reduction in radial growth (Moody and Amirault 1992, Peterson and Peterson 1992, Ives and Wong 1988, Hildahl and Campbell 1975), and may cause considerable branch and twig mortality. In general, tent caterpillar outbreaks do not cause serious tree mortality, because the trees usually produce new leaves and carry on essential photosynthesis (Moody and Amirault 1992, Ives and Wong 1988). However, Hildahl and Campbell (1975), indicated that if complete defoliation occurs for more than four consecutive seasons, aspen mortality can be as high as 80%. Moody and Amirault (1992) stated that the actual level of mortality caused by tent caterpillars is difficult to determine because often the stresses created by tent caterpillar defoliation weakens the tree and predisposes it to infection by other diseases.

The Effect of Drought and Tent Caterpillars on the Aspen Parkland During the Late 1980's and Early 1990's:

The droughts of the late 1980's and early 1990's were stressful to the aspen groves of the Aspen Parkland, particularly the trees which had encroached onto sites that were marginal for tree growth[1 2]. Coupled with the droughts was a forest tent caterpillar epidemic. Forest tent caterpillars repeatedly defoliated the aspen forest of Central Alberta between 1980 and 1991 (Cerezke et al. 1991, Emond and Cerezke 1990, Cerezke and Emond 1989, Emond and Cerezke 1989, Cerezke and Moody 1987, Moody and

[1] A.W. Bailey, Personal communication January 27 1992
[2] B.D. Irving, Personal communication April 23 1992

Cerezke 1986, Moody and Cerezke 1985, Moody and Cerezke 1984, Moody and Cerezke 1983, Hiratsuka 1982, Hiratsuka et al. 1981). The first evidence of the beginning of a forest tent caterpillar infestation in this region came during the period between 1980 and 1982 (Moody and Cerezke 1983, Hiratsuka 1982, Hiratsuka et al. 1981). During this time there were small, isolated areas in central Alberta which experienced moderate to severe defoliation, and there was a documented trend towards an increasing caterpillar population. During 1983 and 1984 caterpillar numbers continued to increase and the amount of moderate to severe defoliation increased, particularly along the Alberta/ Saskatchewan border in the parklands (Moody and Cerezke 1985; 1984). From 1985 to 1989 tent caterpillar infestation was severe throughout central Alberta and resulted in complete defoliation of most aspen forests (Emond and Cerezke 1990; 1989, Cerezke and Emond 1989, Cerezke and Moody 1987, Moody and Cerezke 1986) The decline in caterpillar numbers was first documented in 1989, although much of the central Alberta region experienced moderate to severe defoliation up until 1991 (Cerezke and Gates 1992, Cerezke et al. 1991, Emond and Cerezke 1990). By 1991 forest tent caterpillar numbers had declined significantly and very little severe defoliation caused by tent caterpillars occurred in Central Alberta (Cerezke and Gates 1992).

The environmental stresses experienced by the aspen groves during this time has resulted in the mortality of many trees growing in the Central Alberta Aspen Parkland. Today, forest canopy cover ranges from 20-90% of a healthy aspen forest. This more open canopy allows light to penetrate into the understory. The result has been a substantial increase in the productivity of the understory vegetation. Bailey and Wroe (1974) reported that the herbaceous production under a healthy aspen forest canopy in the Aspen Parkland averaged 154 kg/ha. Studies into the effects of competition for space, light, water and nutrients between overstory trees and herbaceous understory plants, have shown that understory production is closely related to the density of overstory cover (Woods et al. 1982). Hilton and Bailey (1974), in a study carried out in the Aspen Parkland, reported that defoliation of the aspen forest by a single application of 2,4-D, increased annual understory herbaceous production from 211 kg/ha to 979 kg/ha.

Since the dieback of the aspen canopy, grasses and other palatable herbaceous species make up a substantial portion of the new understory plant community. However, the high mortality of aspen trees which allowed the new understory to develop, creates other serious management problems. Many of the trees that were killed during the period of drought and tent caterpillar infestation have fallen. These fallen trees create a barrier to livestock movement. The result is that utilization of this new source of forage is minimal[3].

Clear and Break:

The traditional method used to remove aspen forest for the purpose of forage production for livestock grazing has been clearing and breaking (Bailey 1986, Bailey 1972). Clearing and breaking provides the manager with an open and productive stand of tame forage. However, clearing and breaking is costly (Bailey 1986), and involves the loss of at least one year's worth of grazing while the seeded forage stand becomes established. This method normally removes all brush cover from the landscape, reducing the value of the land as wildlife habitat; it may also be undesirable from a management point of view as some cover is important for livestock. The high costs and the loss of grazing

[3]Doyle and Norman Kuntz, Personal communication April 1992.

associated with clearing and breaking have resulted in the search for alternative methods of brush control.

Prescribed Burning

Prescribed burning has been used effectively to eliminate the barrier effect created by aspen forest (Bailey 1986, Wright and Bailey 1982, Anderson and Bailey 1980, Bailey and Anderson 1979, Bailey 1978). However, the major woody plant species of the Aspen Parkland, aspen, western snowberry (*Symphoricarpos occidentalis* Hook.), wild rose (*Rosa acicularis* Lindl., Rosa *woodsii* Lindl.), and wild raspberry (*Rubus idaeus* L.), are well adapted to fire, and respond quickly to recolonize following fire disturbance. The time of year, and the severity of the burn will have an effect on how the site recovers. Subsequent suckering quickly eliminates any temporary increase in forage production resulting from the burn (Irving and Bailey 1985, Bailey 1972). Research into the use of prescribed burning as a method to convert healthy aspen forest to a grassland-shrubland mosaic has revealed that heavy grazing following prescribed burning can be used to assist in forage establishment (FitzGerald and Bailey 1983), to control aspen suckering (Bailey 1986, FitzGerald and Bailey 1984), and to increase forage production (Bailey et al. 1990).

THE STUDY SITE:

At Kuntz Brothers ranch near Minburn, in Central Alberta, a situation exists which provides an opportunity to compare the effects of prescribed burning on the aspen forest community and the ability of aspen to sucker in both a mature decadent aspen forest and a young, healthy aspen forest. The years of drought and repeated defoliations by forest tent caterpillars during the late 1980's and early 1990's, have changed a healthy mature aspen forest into a decadent state. On an area adjacent to the mature decadent aspen site, the aspen groves were cleared by bulldozer in 1983. This location is now dominated by dense, healthy, aspen saplings 3-6 m tall. During the tent caterpillar epidemics, Messrs. Doyle and Norman Kuntz observed that this young forest type was not seriously defoliated by forest tent caterpillars.

OBJECTIVES

The primary objective of this experiment was to determine the responses of a decadent, mature aspen forest and a young, healthy vigorously growing aspen forest to prescribed burning and controlled livestock grazing. Studies were initiated to address the following research objectives:

1.) To determine if the condition of the aspen forest prior to burning has an effect on the ability of aspen to reproduce vegetatively.

2.) To determine if the condition of the aspen forest prior to burning influences the ability of the herbaceous component to compete.

3.) To evaluate the ability of the woody component to compete with the herbaceous component following burning. To determine whether the condition of the forest prior to burning affects this competitive ability.

4.) To investigate how grazing affects the competitive ability of the different components of the regenerating plant community.

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II. DIFFERENCES IN BIOMASS PRODUCTION BETWEEN DECLINING DECADENT AND HEALTHY SAPLING ASPEN FORESTS FOLLOWING PRESCRIBED BURNING

INTRODUCTION:

The Aspen Parkland Association of central Alberta and Saskatchewan is a transition zone between the Mixed Prairie to the south and the Boreal Forest to the north (Strong and Leggat 1992, Sanborn and Pawluk 1983, Pettapiece 1969). The vegetation of the region is a grassland-forest mosaic, ranging from stands dominated by grassland, to groves of aspen (*Populus tremuloides* Michx.) forest. Climatic conditions over most of the Aspen Parkland would appear to favor forest domination, however, the Black and Dark Brown Chernozemic soils of the region (Sanborn and Pawluk 1983, Pettapiece 1969, Dormaar and Lutwick 1966, Moss 1934) and historical observations of the vegetation (Hind 1859, Fidler 1792-93) reveal that historically grasslands predominated and aspen forest only occurred in small groves.

Prior to European settlement, fire (Anderson and Bailey 1980, Nelson and England 1971, Pettapiece 1969, Bird 1961) and heavy bison grazing controlled aspen and its associated woody vegetation, resulting in aspen dominated shrubland developing in groves only on the most suitable sites. Since European settlement, however, a policy of fire suppression and the eradication of free ranging bison herds has removed the influence of these natural forces (Bailey and Bailey 1994, Bird 1961, Moss 1934).

In the Aspen Parkland of Central Alberta, herbage production on good condition native grasslands averages 2000 kg ha^{-1} (Whysong and Bailey 1975, Bailey and Wroe 1974, Hilton and Bailey 1974). On lands where aspen has encroached, however, shading from a healthy forest canopy causes a significant reduction in forage production. Bailey and Wroe (1974) reported that understory forage production under healthy aspen forest ranged from 10-25% (154-298 Kg ha^{-1}) of what an adjacent grassland produced. Similar negative effects of the aspen forest canopy on understory forage production have been reported by Whysong and Bailey (1975), Hilton and Bailey (1974), Johnston and Smoliak (1968).

Various techniques have been used to remove the aspen canopy and re-establish a productive grassland sward, the traditional method being clearing and breaking (Bowes 1982, Bailey 1972). Selective herbicides such as 2, 4-D and Picloram (Bartos and Lester 1984, Bowes 1976, Hilton and Bailey 1974, Hilton 1970), as well as prescribed burning either in combination with herbicides (Irving and Bailey 1985, Bailey and Anderson 1979, Hilton and Bailey 1974), or on its own (Bailey et al. 1990, FitzGerald et al. 1986, FitzGerald and Bailey 1984) have also been effective in removing the aspen canopy.

The major woody species of the Aspen Parkland, aspen, western snowberry (*Symphoricarpos occidentalis* Hook.), wild rose (*Rosa woodsii* Lindl. and *Rosa acicularis* Lindl.), and wild raspberry (*Rubus idaeus* L.), are all well adapted to fire, and quickly recolonize following fire disturbance through vegetative suckering (Irving and Bailey 1985, Bailey and Anderson 1979, Bailey 1972). Therefore, for prescribed burning to be successful in the conversion of aspen forest to a grassland-shrubland mosaic, some type of post burn vegetation management is necessary. Heavy livestock grazing following prescribed burning has been shown to be effective in controlling aspen suckering, and promoting herbaceous forage establishment (Bailey et al. 1990; Bailey 1986; FitzGerald and Bailey 1984, 1983).

Within the past ten years many of the aspen stands growing in the Aspen Parkland of Central Alberta have started to die out[1]. Drought and tent caterpillar epidemics during the late 1980's and early 1990's were extremely stressful to aspen groves that were growing on sites marginal for tree growth (Chapter 1). These stresses resulted in substantial aspen mortality, creating a more open forest canopy, and a more productive understory.

Within the Aspen Parkland there are examples of healthy sapling aspen forests. Most of these stands are the result of failed attempts to convert aspen forests to grassland. These sapling forests which developed through vegetative suckering from the remnant root system of a mature forest are less susceptible than mature forests to the effects of drought because they have higher root to leaf area ratios (Peterson and Peterson 1992). The understory plant community found under these aspen saplings is sparse (Brown and Simmerman 1986) because the high density of saplings produces a dense overstory canopy cover which outcompetes other species for light, space, water and nutrients (Woods et al. 1982). Bailey and Gupta (1973) showed that aspen competition can reduce herbage production. The effect of aspen competition on herbage production appears to be related to aspen stand density, particularly when densities are high (Woods et al. 1982). The low forage production combined with the barrier effect to livestock grazing created by the dense aspen stand (Bailey 1970) reduces the value of these sites for grazing livestock.

The understory plant community of the mature, decadent aspen forests of the Aspen Parkland appears to be much more productive than the understory production when these stands were healthy (Bailey and Wroe 1974). However, due to the barrier effect of fallen trees and branches, livestock utilization of the

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[1]Cerezke, personal communication December, 1993.

increased herbage production is poor.[2] This management problem is further exacerbated when poor utilization results in the build up of unpalatable litter. The substantial fuel load caused by the build-up of litter and deadfall makes this type of forest well suited to prescribed burning (Peterson and Peterson 1992). Prescribed burning will remove most of the litter and deadfall which appears to be inhibiting utilization.

A study was developed to determine how understory biomass production in decadent mature aspen versus healthy sapling aspen communities responded following prescribed burning and controlled livestock grazing.

OBJECTIVES:

1. To determine the differences in biomass production of herbaceous, aspen, and other woody components between a mature decadent and a healthy sapling aspen forest following prescribed burning.

2. To determine the response of biomass production over time by vegetation classes (herbaceous, aspen, other woody), following prescribed burning.

3. To determine if post-burn grazing has an effect on biomass production of herbaceous, aspen, and other woody components in a mature decadent and a healthy sapling aspen forest.

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[2] Norman and Doyle Kuntz, personal communication April, 1992.

STUDY AREA:

The study site was located on Kuntz Brothers' Farms (52°02"N latitude and 111°33"W longitude), a private cattle ranch 160 kilometers east of Edmonton and approximately ten kilometers south of Minburn, Alberta.

Climate:

The climate is continental, characterized by warm summers and relatively cold winter temperatures (Wyatt et al. 1944). Average annual precipitation is 432mm with seventy five percent occurring during the growing season (May - September) as rain and 25% as snow during the dormant season (October-April) (Atmospheric Environment Services 1991). The average annual temperature is 1.9^0 and the average frost free period is 100 days. The growing season begins between April 21 and 26, and averages between 165 and 170 days in length (Horton 1991).

On average, potential evapotranspiration exceeds precipitation for every month of the growing season except June, and the long term precipitation to potential evapotranspiration ratio during the growing season ranges between 0.65 and 1.1 (Horton 1991).

Geology:

The bedrock geology of the study area is of the Belly River formation (Howitt et al. 1988). This formation is made up of Upper Cretaceous rock (Wyatt et al. 1944), consisting of sandstones, mudstones and siltstones deposited in a non-marine environment (Howitt et al. 1988). The bedrock of the area is overlain with a thick layer of glacial till, which was deposited by the Keewatin ice sheet about 10,000 years ago (Wyatt et al. 1944). The topography of the study site is classified as morainal hummocky (Howitt et al. 1988). It is characterized by hummocks with short steep slopes and numerous pothole lakes or sloughs interspersed between hummocks. The topography is often referred to as Knob and Kettle. The Kettles (depressions) being formed when huge blocks of stagnant ice mixed with morainal material melted.

Soils:

The soils of the study site are dominated by well drained fine loams and are classified as Orthic Black Chernozems (Howitt et al. 1988). These soils occupy the mid and upper slope positions on the landscape. Soils of the lowland depressions, which make up 15 - 20% of the area, tend to be poorly drained and are either classified under the Gleysolic Order or under a gleyed Subgroup of the Chernozemic Order.

Vegetation:

The study site was located within the Aspen Parkland vegetation association. This association is a transitional zone between the grassland dominated Mixed Prairie Association to the south and the Boreal Forest Association to the north (Strong and Leggat 1992). The areas of the Aspen Parkland which have not been disturbed by cultivation are characterized by a mosaic of aspen groves and open grasslands. The aspen groves and their associated shrub communities have historically occupied the moister sites while grasslands occupied the drier more exposed sites. Today, because of the elimination of natural pyrogenic and anthropogenic forces (Dormaar and Lutwick 1966; Bird 1961), aspen and shrub communities have invaded onto soils that were historically dominated by grasslands. Aspen and its associated shrub species now occupy between 75 and 85 percent of the land area on the study site. The woody communities are dominated by trembling aspen

(*Populus tremuloides* Michx.) western snowberry (*Symphoricarpos occidentalis* Hook.), wolf willow (*Elaeagnus commutata* Bernh.), common wild rose (*Rosa acicularis* Lindl. and Rosa *woodsii* Lindl.), wild raspberry (*Rubus idaeus* L.), gooseberry (*Ribes hirtellum* Michx.), saskatoon (*Amelanchier alnifolia* Nutt.), and choke cherry (*Prunus virginiana* L.). The most common understory grasses are smooth brome (*Bromus inermis* Leyss.), blue grasses (*Poa spp.* L.), and reed grasses (*Calamagrostis spp.* Adans.). The open grasslands which occupy south facing slopes and flat areas are dominated by a *Festuca - Stipa* plant community (Looman 1981). On ungrazed sites, plains rough fescue *Festuca halli* ((Vasey) Piper) predominates.

SITE SELECTION:

The study site consisted of a half section (130 ha.) of native rangeland dominated by mature decadent aspen forest (decadent), and an adjacent 25 ha. area dominated by a healthy sapling aspen forest (sapling). The decadent forest was dominated by 30 to 60 year old aspen trees which were left in a declining and decadent state following the droughts and tent caterpillar epidemics of the late 1980's and early 1990's. The sapling forest was dominated by dense vigorous aspen saplings 3 - 6 m tall, which developed after mature aspen groves were cleared by bulldozer in 1983. During the tent caterpillar epidemics, the sapling forest type was not seriously defoliated by forest tent caterpillars[3].

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3 Doyle and Norman Kuntz, Personal communication April 1992.

METHODS

Approximately 1/3 of each forest type (mature decadent and healthy sapling aspen forest) was burned In the spring of 1992 and another 1/3 was burned in 1993. Each year following burning, four different groves (sites) within the burned area in each forest type which met the standards of a selection criterion were randomly selected for sampling. The selection criteria used were:

1. All sites must have been burned uniformly.
2. Sites were located on gentle slopes to avoid environmental extremes.
3. Sites were large enough to contain a macro plot 33m x 14m within an area of homogeneous vegetation.
4. In the decadent aspen forest, sampling sites were located in the portion of the aspen grove that was termed the Small Aspen type by Scheffler (1976). This forest type is the most uniform, and most extensive portion of each grove. It usually occupies about 60 - 70 percent of the aspen forest and was dominated by 30 - 40 year old trees prior to the droughts and tent caterpillar epidemics of the late 1980's and early 1990's.

On each site the following treatments were established:

1. burned, ungrazed,
2. burned, moderately grazed (50% removal of herbaceous forage),
3. burned, heavily grazed (70% removal of herbaceous forage).

Areas burned in the spring of 1992 were grazed in 1992 and 1993. The areas burned in 1993 were grazed in 1993, following burning. Cattle grazing of the burned sapling forest type was initiated on 6 July, 1992 and on 1 July, 1993.

The area was grazed by a herd of 300 cow calf pairs for approximately 5 days. On the decadent forest cattle grazing began on 11 July and the cattle grazed the area for a period of 18 days. The stocking rates for the sapling and decadent forest were 2.4 and 1.7 AUM/ha, respectively.

Data Collection:

In each forest type, the four groves (sites) were defined as replications. Each site was subdivided into three macro plots of 11 x 14 m, with one of the grazing treatments randomly applied to each macro plot. Each year, within each macro plot, six new micro plot locations of 1.5 X 1.5 m were randomly established (old micro plots were marked and were avoided when new micro plots were established). Within these micro plots, a 1 m X 0.5 m production clip (1 cm stubble height) was taken between the dates of 10 July and 15 July. During the grazing period, cages were used to exclude grazing from the portion of the micro plot which was to be used to determine production. In 1992 biomass production was hand sorted into herbaceous, and woody components. In 1993, biomass production was hand sorted into 3 categories: herbaceous, aspen, and other woody species. Clip samples were oven dried (70°C) for 48 hours and weighed.

Utilization on the macro plots receiving grazing treatments within each site was monitored visually. Production cages were used to exclude grazing so that there was a baseline from which comparisons could be made to make the estimates. When it was determined that utilization of herbaceous material was approximately 50 %, the macro plot selected for moderate utilization was fenced to exclude further grazing. Grazing on the rest of the field was continued until utilization of the herbaceous material was approximately 70 percent .

Experimental Design and Data Analysis:

The experimental design was a split plot (Steel and Torrie 1980). Whole plots consisted of 2 forest types (mature decadent and healthy sapling), 2 years of burning treatment (1992 and 1993), and 4 replications (groves) per year per forest. The subplots consisted of 3 grazing treatments per replication per year per forest. From each macro plot, six production clips were hand sorted into herbaceous and shrub components in 1992 and into 3 vegetation classes (herbaceous, aspen and other woody) in 1993. Dry matter production of each component was measured.

Sources of variation for analysis of data for ungrazed conditions were: year of burning (y=2), forest (f=2), groves within forest (g=4), micro plots within groves (m=6), vegetation class (v=3) and the interactions of vegetation classes. Whole plots were groves within forest and split plots were the three vegetation classes of each micro plot.

The sources of variation for analyses of data where the grazing treatments had been introduced were: forest (f=2), groves within forest (g=4), grazing treatments (macro plots) within groves (t=3), the interactions of grazing treatment with the above sources, micro plots within grazing treatments (m=6), vegetation classes (v=3) and the interactions of vegetation classes. Whole plots were groves within forest, and split plots were the 3 grazing treatments. Split split plots were the 3 vegetation classes of each micro plot.

Computations for statistical analysis were made using the above models in the GLM procedure of SAS (SAS Institute, Inc. 1989). Fisher's protected LSD was used to determine differences ($P<0.05$) among means in the presence of a significant F test.

RESULTS:

Understory production on ungrazed decadent and sapling aspen forests:

Forests burned in 1992 produced more biomass in the second year (1993) than in the first year (1992) (Table 2.1). Similarly 1993 standing crop production, from groves burned in 1992, was greater than standing crop production from groves burned in 1993 (Table 2.2). Both herbaceous production and aspen (sucker) production was greater the second year following burning than in the first year.

Under ungrazed conditions, the 1993 total understory biomass production did not vary between mature decadent and healthy sapling aspen forest types in either first (Table 2.3, Figure 2.1) or second year burns (Table 2.4, Figure 2.2). However, when the vegetation classes of the understory vegetation were analyzed separately, differences were found. Understory herbaceous production was much greater in the decadent forest type, while aspen biomass production was greater in the sapling forest (Figure 2.1 & 2.2). These differences were greater in the second year after burning. A significant forest type by vegetation class interaction occurred in both the first (Table 2.3) and second year after burning (Table 2.4). The interaction was the result of high herbaceous production but low aspen production in the decadent forest, and high aspen production but low herbaceous production in the sapling forest.

The effect of grazing on understory production:

When the two aspen forest conditions were analyzed together, the total biomass production was found to be lower on grazed sites than on ungrazed sites (Table 2.5). Grazing also reduced aspen standing crop (Figure 2.3).

When the effects of the grazing treatments were compared by forest type, grazing caused a significant reduction in herbaceous production in the decadent forest, but a significant increase in herbaceous production in the sapling forest (Figure 2.4).

DISCUSSION:

Prior to burning, herbaceous production in unburned mature decadent aspen forest was much higher[4] than what has typically been recorded for healthy mature aspen stands (Whysong and Bailey 1975, Bailey and Wroe 1974, Hilton and Bailey 1974, Johnston and Smoliak 1968). The high herbaceous production in the decadent forest was postulated to be related to the more open canopy which developed as a result of high aspen mortality during the droughts and tent caterpillar epidemics of the late 1980's and early 1990's. Comparisons between the decadent forest and the healthy sapling forest appear to support this hypothesis. The herbaceous component of the decadent forest plant community was well established prior to burning and remained productive following burning. In the healthy sapling forest, the tree overstory seriously affected understory vegetation prior to burning. Following burning, first year herbaceous production was low in the sapling forest because herbaceous components were not well established.

This study reveals that following prescribed burning, the mature decadent and healthy sapling forests produce about the same understory biomass. However, the composition of the understory vegetation varies considerably between the two forest types. The mature decadent understory was dominated by herbaceous and shrub components. These components

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[4] Bailey, Alexander and Irving 1993, 1992. Unpublished data. University of Alberta, Edmonton Alberta.

were well established prior to burning and because of their adaptations to fire, were not seriously damaged by burning.

Aspen is also well adapted to fire and is normally a very aggressive competitor which often out competes other components of the plant community (Peterson and Peterson 1992, DeByle 1976). However, forest condition affects the ability of the aspen forest to produce new suckers (Schier 1976, 1975). The mature decadent forest did not sucker vigorously; this inability to produce high densities of suckers limited the importance of aspen following burning.

In the healthy sapling forest, the dominant vegetation class (by biomass production), the first year following burning, was other woody species. This class of vegetation was dominated by western snowberry, with substantial contributions from wild rose and wild raspberry. Aspen suckered prolifically following burning and became the dominant vegetation class by the second year. Aspen biomass made up over half of the total production and because of its strong competitory effects did not allow herbaceous or other woody production to increase. In contrast, in the decadent forest where aspen sucker density was not high enough to cause serious competition, herbaceous and other woody components increased substantially during the second year. Pyke and Archer (1991), reported that interactions between plant species growing together may occur and these interactions can be antagonistic. The effects of interspecific competition can range from reductions in biomass production of one or both species to competition related mortality of the weaker competitor. Production of both grass and woody plant species is reduced when they are grown in competition with one another, and the level of competition is related to the density of the competing species (Bailey and Gupta 1973).

Livestock grazing significantly affected development of the post burn plant community. Aspen and herbaceous vegetation were readily consumed by livestock. Aspen standing crop production was severely reduced by grazing, whereas herbaceous biomass production was not as severely affected. Differences in the location of meristematic tissues between aspen and herbaceous vegetation (Bailey 1988) affect the way these vegetation types respond to grazing. The majority of grass species, and many of the forbs which grow in the Aspen Parkland, have meristems either below ground or close to the ground surface, and grazing normally does not damage or remove meristematic tissues. Conversely, the meristematic tissues in aspen are at the shoot tips. Therefore, livestock browsing of these young suckers greatly reduces their growth potential and decreases shoot vigor.

In this study, livestock grazing was an effective tool to limit the competition created by aspen suckers on the herbaceous components of the community. When aspen competition was reduced, herbaceous vegetation became better established and more productive.

One year of grazing treatments suggests there is no real difference in the effectiveness of heavy versus moderate grazing in post burn management of competing woody vegetation. In fact, in the decadent forest, where aspen competition does not appear to be a serious problem, there appears to be a negative relationship between grazing intensity and herbaceous production. Therefore on this forest type it would appear that 50% utilization of the herbaceous vegetation will be sufficient to control woody vegetation and also maintain the herbaceous vegetation in a productive state.

Table 2.1 A comparison of 1992 and 1993 total understory production (kg ha^{-1}) without grazing in forests burned in the spring of 1992

Year data collected	Mean biomass production
	(kg ha^{-1})
1992	3,000
1993	4,900
SEM	392
P>F	0.002

Table 2.2 The effect of year burned on 1993 standing crop biomass production (kg ha^{-1}) under ungrazed conditions

Year burned	Total production	Herbaceous production	Aspen production	Other woody production
	(kg ha^{-1})	(kg ha^{-1})	(kg ha^{-1})	kg ha^{-1})
1992	4,600	1,550	1,430	1,600
1993	2,500	880	350	1,220
SEM	363	106	258	284
P>F	0.001	0.001	0.012	0.37

Table 2.3 The effect of the forest type by vegetation class interaction on first year biomass production in ungrazed sites burned in 1993

	Forest type	
Vegetation component	Decadent	Sapling
	(kg ha^{-1})	(kg ha^{-1})
Total	2,520^{x1}	2,390^{x}
Herbaceous	1,230^{ax}	540^{ay}
Aspen	60^{bx}	640^{ax}
Other woody	1,240^{ax}	1,210^{ax}
SEM	222	
P>F^{2}	0.045	

1 Means within the same columns followed by the same letter (a,b) and means within the same rows followed by the same letter (x,y) are not significantly different (P<0.05).
2 Probability of a significant vegetation class by forest type interaction.

Table 2.4 The effect of the forest type by vegetation class interaction on 1993 standing crop production in ungrazed sites burned in 1992

	Forest tyne	
Vegetation component	Decadent	Sapling
	(kg ha^{-1})	(kg ha^{-1})
Total	4,830^{x1}	4,317^{x}
Herbaceous	2,260^{ax}	840^{by}
Aspen	480^{by}	2,380^{ax}
Other woody	2,090^{ax}	1,100^{abx}
SEM	425	
P>F^{2}	0.004	

1 Means within the same columns followed by the same letter (a,b) and means within the same rows followed by the same letter (x,y) are not significantly different (P<0.05).
2 Probability of a significant vegetation class by forest type interaction.

Table 2.5 The effect of grazing treatment on second year (1993) biomass production for sites burned in 1992

Grazing Treatment	Total	Herbaceous	Aspen	Other woody
	(kg ha^{-1})	(kg ha^{-1})	(kg ha^{-1})	(kg ha^{-1})
Ungrazed	4,574[a1]	1,549	1,429[a]	1,595
Moderate	3,630[b]	1,683	414[b]	1,533
Heavy	3,222[b]	1,575	227[b]	1,420
SEM	258	90	258	135
P>F	0.009	0.56	0.005	0.66

1. Means within the same vegetation class followed by the same letter are not significantly different (P<0.05)

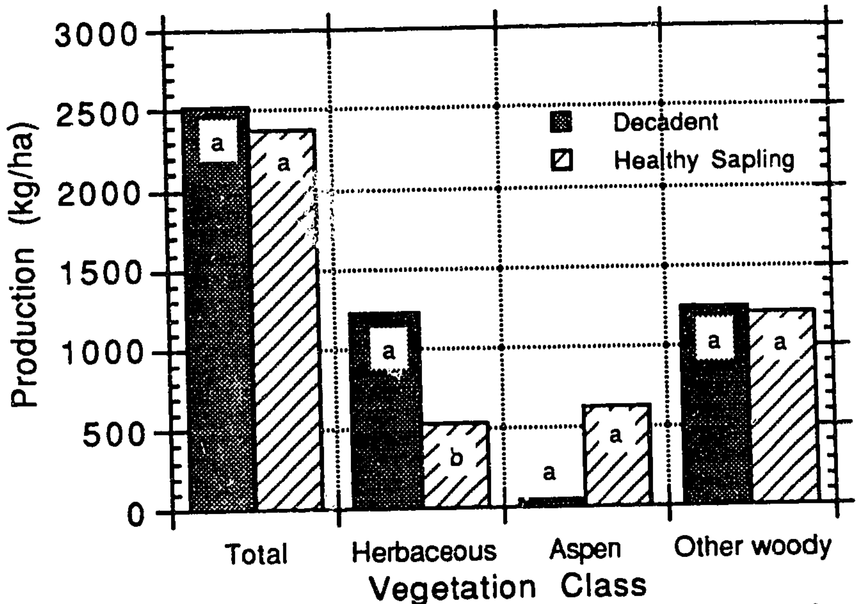

Figure 2.1 The effect of the forest type on vegetation class biomass production on first year burns. Production differences between forests within the same vegetation component marked with the same letter are not significantly different (P<0.05).

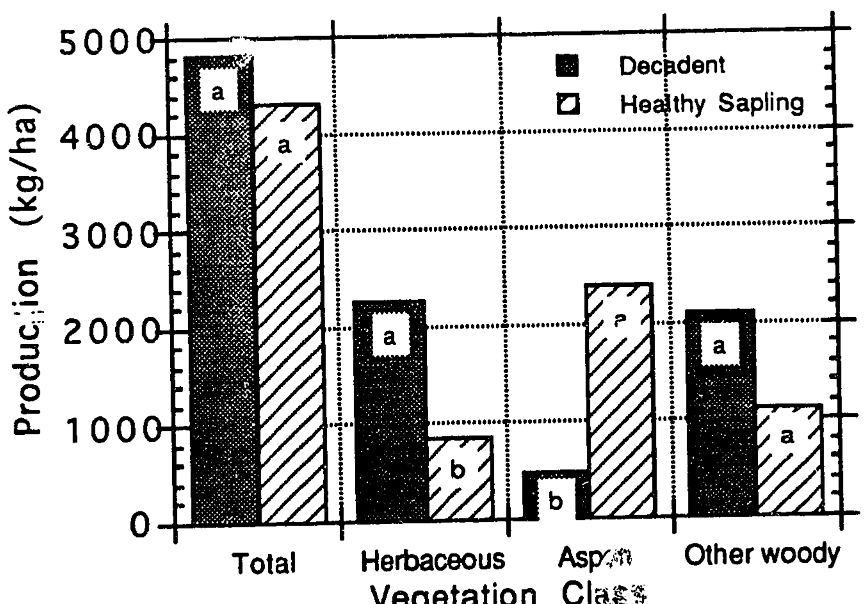

Figure 2.2 The effect of the forest type on vegetation class biomass production on second year burns. Production differences between forests within the same vegetation component marked with the same letter are not significantly different (P<0.05).

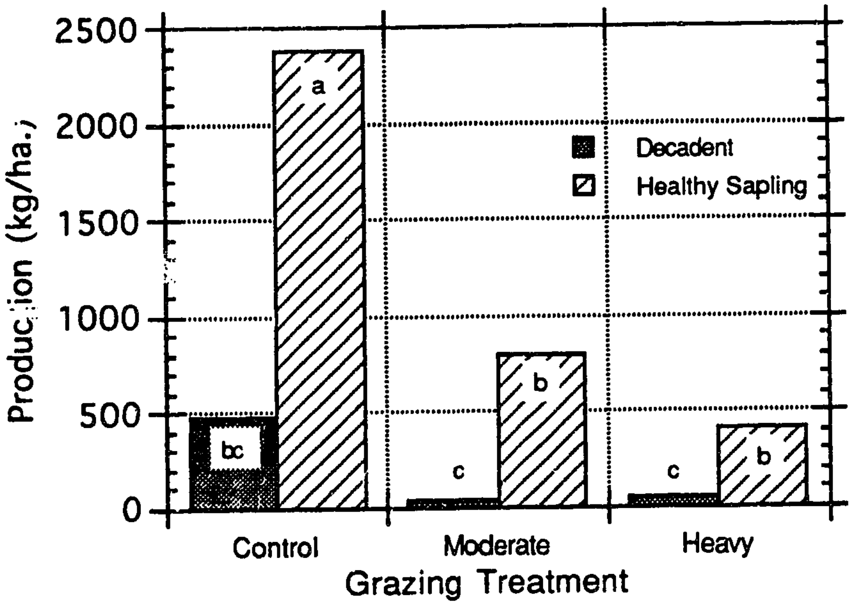

Figure 2.3 The effect of forest type and grazing treatment on aspen biomass production. Columns marked with the same letter are not significantly different (P<0.05).

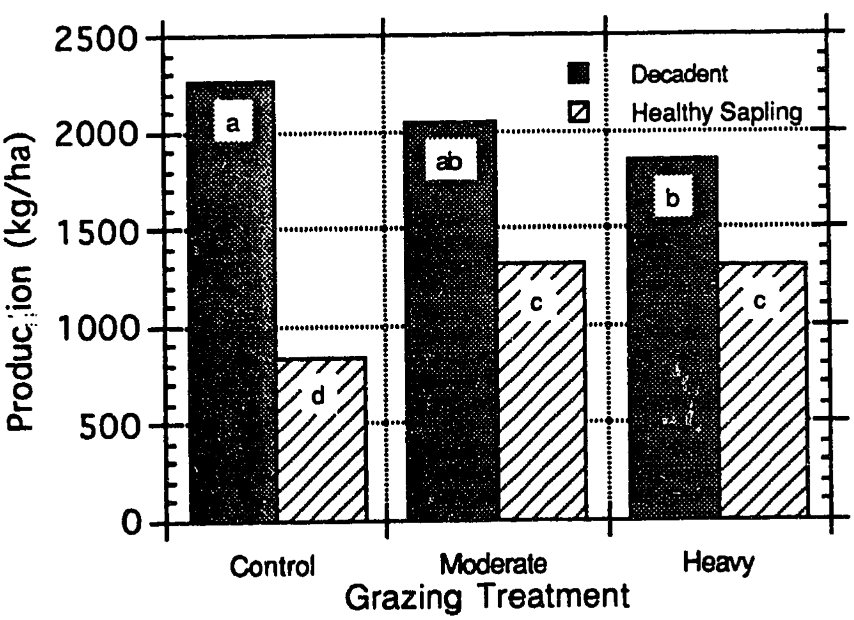

Figure 2.4 The effect of forest type and grazing treatment on herbaceous biomass production. Columns marked with the same letter are not significantly different (P<0.05).

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III. DIFFERENCES IN UTILIZATION BETWEEN DECLINING DECADENT AND HEALTHY SAPLING ASPEN FORESTS FOLLOWING PRESCRIBED BURNING

INTRODUCTION:

Aspen (*Populus tremuloides* Michx.) encroachment into native grasslands of the Aspen Parkland of Alberta has been a serious management problem for livestock producers. Forage production under a healthy aspen forest canopy was reported as 10 - 50% of that produced in adjacent grasslands (Whysong and Bailey 1975, Bailey and Wroe 1974, Hilton and Bailey 1974, Johnston and Smoliak 1968). Removal of the aspen forest canopy and re-establishment of a productive grassland sward can increase carrying capacity of this rangeland (FitzGerald et al. 1986). Clearing of the aspen forest has traditionally been carried out by mechanical means, followed by breaking and seeding of cereals or a forage crop (Bailey 1972, Bowes 1982). Due to the high costs related to clearing and breaking, other techniques of removing the aspen forest canopy have been tested. These include the use of selective herbicides, such as 2,4-D (Bartos and Lester 1984, Hilton and Bailey 1974, Hilton 1970) and the use of prescribed burning, either in combination with herbicides (Irving and Bailey 1985, Bailey and Anderson 1979, Hilton and Bailey 1974) or on its own (Bailey et al. 1990, FitzGerald et al. 1986, FitzGerald and Bailey 1984).

The effectiveness of prescribed burning as a means to return aspen forest to a grassland sward is complicated by the ability of aspen and other associated woody species to sprout vigorously following disturbance. Western snowberry (*Symphoricarpos occidentalis* Hook.), wild rose (*Rosa acicularis* Lindl. *and Rosa woodsii* Lindl.), and wild raspberry (*Rubus idaeus* L.), are all well adapted to fire, and quickly recolonize following burning (Irving and Bailey 1985, Anderson and Bailey 1980, Bailey 1972). Therefore, post burn vegetation management is necessary to control woody sucker growth. Herbicides such as 2,4-D and picloram have been used to some degree of success to control aspen and other woody regrowth competition (Bowes 1982, Bowes 1976, Waddington and Bittman 1987). An alternative to herbicides is controlled livestock grazing following the prescribed burning treatment (Bailey et al. 1990, Bailey 1986, FitzGerald and Bailey 1984, FitzGerald and Bailey 1983). Heavy grazing treatments are effective in controlling aspen sucker development and in helping to promote herbaceous forage establishment.

In the Aspen Parkland of Central Alberta, drought and tent caterpillar epidemics during the late 1980's and early 1990's have resulted in substantial mortality to aspen groves growing on marginal sites (Chapter 1). A more open forest canopy has permitted the devel opment of a more productive grass-shrub understory. However, many of the dead trees have fallen creating a barrier which limits livestock utilization.

Within the Aspen Parkland there are cases where healthy stands of aspen saplings exist adjacent to mature decadent stands. The understory of the healthy sapling forest is relatively unproductive due to the competition created by the dense overstory canopy cover (Brown and Simmerman 1986). Low forage production combined with the barrier to grazing created by the high density of woody stems (Bailey 1970), makes the rangeland of low value to grazing livestock. Although the mature, decadent and healthy sapling forest have different understory plant communities, both forests present a similar management problem. Lands which are potentially very productive for livestock have become secondary or non-use rangeland. Prescribed burning removes overstory competition and barriers created by tree deadfall and litter, improving grazing potential.

Historically, the most widely used technique to determine forage utilization has been the cage comparison method (Cook and Stubbendieck 1986). Quadrats protected by cages are clipped and compared with a paired quadrat from an adjacent grazed area. The difference in yield between the two quadrats is considered to be the forage consumed. The technique is labor intensive and time consuming because of the large number of quadrat pairs required to obtain an accurate estimate.

Double sampling is a technique often used when the variable to be sampled is difficult to measure whereas another variable which is relatively easy to measure is closely related to the variable of interest (Cook and Stubbendieck 1986). Double sampling to determine forage production involves visually estimating forage production for every quadrat, and clipping a percentage of the quadrats for comparison (Cook and Stubbendieck 1986, Ahmed et al. 1983, Ahmed and Bonham 1982). Regression equations are developed with visually estimated production as the dependent variable and clipped weights as the independent variable. The regression is then used to adjust the visual estimates of production. The use of a double sampling technique to estimate utilization decreases the high labor requirements associated with the cage comparison technique.

A study was initiated to evaluate the utilization of mature decadent versus healthy sapling aspen forest following prescribed burning and controlled livestock grazing.

OBJECTIVES:

1. To compare visual and clipped estimates of utilization and determine the suitability of a double sampling technique.

2. To determine if utilization by livestock of the herbaceous, aspen and other woody vegetation classes is influenced by forest type, following burning.

3. To determine if time since burning will affect livestock utilization of the various vegetation components of the decadent forest type.

STUDY AREA:

The study site (52°02"N latitude and 111°33"W longitude) was located on Kuntz Brothers' Farms, a private cattle ranch 160 kilometers east of Edmonton and approximately ten kilometers south of Minbur. , Alberta.

Climate:

The climate is continental, characterized by warm summers and relatively cold winter temperatures (Wyatt et al. 1944). Average annual precipitation is 432mm with seventy five percent occurring during the growing season (May - September) as rain and 25% as snow during the dormant season (October-April) (Atmospheric Environment Services 1991). The average annual temperature is 1.9^0 and the average frost free period is 100 days. The growing season begins between April 21 and 26, and averages between 165 and 170 days in length (Horton 1991).

On average, potential evapotranspiration exceeds precipitation for every month of the growing season except June, and the long term precipitation to potential evapotranspiration ratio during the growing season ranges between 0.65 and 1.1 (Horton 1991).

Geology:

The bedrock geology of the study area is of the Belly River formation (Howitt et al. 1988). This formation is made up of Upper Cretaceous rock (Wyatt et al. 1944), consisting of sandstones, mudstones and siltstones deposited in a non-marine environment (Howitt et al. 1988). The bedrock of the area is overlain with a thick layer of glacial till, which was deposited by the Keewatin ice sheet about 10,000 years ago (Wyatt et al. 1944). The topography of the study site is classified as morainal hummocky (Howitt et al. 1988). It is characterized by hummocks with short steep slopes and numerous pothole lakes or sloughs interspersed between hummocks. The topography is often referred to as Knob and Kettle. The Kettles (depressions) being formed when huge blocks of stagnant ice mixed with morainal material melted.

Soils:

The soils of the study site are dominated by well drained fine loams and are classified as Orthic Black Chernozems (Howitt et al. 1988). These soils occupy the mid and upper slope positions on the landscape. Soils of the lowland depressions, which make up 15 - 20% of the area, tend to be poorly drained and are either classified under the Gleysolic Order or under a gleyed Subgroup of the Chernozemic Order.

Vegetation:

The study site was located within the Aspen Parkland vegetation association. This association is a transitional zone between the grassland dominated Mixed Prairie Association to the south and the Boreal Forest Association to the north (Strong and Leggat 1992). The areas of the Aspen Parkland which have not been disturbed by cultivation are characterized by a mosaic of aspen groves and open grasslands. The aspen groves and their associated shrub communities have historically occupied the moister sites while grasslands occupied the drier more exposed sites. Today, because of the elimination of natural pyrogenic and anthropogenic forces (Dormaar and Lutwick 1966; Bird 1961), aspen and shrub communities have invaded onto soils that were historically dominated by grasslands. Aspen and its associated shrub species now occupy between 75 and 85 percent of the land area on the study site. The woody communities are dominated by trembling aspen (*Populus tremuloides* Michx.) western snowberry (*Symphoricarpos occidentalis* Hook.), wolf willow (*Elaeagnus commutata* Bernh.), common wild rose (*Rosa acicularis* Lindl. and Rosa *woodsii* Lindl.), wild raspberry (*Rubus idaeus* L.), gooseberry (*Ribes hirtellum* Michx.), saskatoon (*Amelanchier alnifolia* Nutt.), and choke cherry (*Prunus virginiana* L.). The most common understory grasses are smooth brome (*Bromus inermis* Leyss.), blue grasses (*Poa spp.* L.), and reed grasses (*Calamagrostis spp.* Adans.). The open grasslands which occupy south facing slopes and flat areas are dominated by a *Festuca - Stipa* plant community (Looman 1981). On ungrazed sites, plains rough fescue *Festuca halli* ((Vasey) Piper) predominates.

SITE SELECTION:

The study site consisted of a half section (130 ha.) of native rangeland dominated by mature decadent aspen forest (decadent), and an adjacent 25 ha. area dominated by a healthy sapling aspen forest (sapling). The decadent forest was dominated by 30 to 60 year old aspen trees which were left in a declining and decadent state following the droughts and tent caterpillar epidemics of the late 1980's and early 1990's. The sapling forest was dominated by dense vigorous aspen saplings 3 - 6 m tall, developing after mature aspen groves were cleared by bulldozer in 1983. During the tent caterpillar epidemics, the sapling forest type was not seriously defoliated by forest tent caterpillars[1].

METHODS

In the spring of 1992 and 1993, 1/3 of each forest type (mature decadent and healthy sapling aspen forest) was prescribed burned. Each year following burning, four groves (sites) within each forest type which met the standards of a selection criteria were randomly selected for sampling. The selection criteria used were:

1. All sites must have been burned uniformly.
2. Sites were located on gentle slopes to avoid environmental extremes.
3. Sites were large enough to contain a macro plot 33m x 14m within an area of homogeneous vegetation.
4. In the decadent aspen forest, sampling sites were located in the portion of the aspen grove that was termed the Small Aspen type by Scheffler (1976). This forest type is the most uniform, and most extensive portion of each grove.

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[1] Doyle and Norman Kuntz, Personal communication April 1992.

On each site the following treatments were established:

1. burned, moderately grazed (50% removal of herbaceous forage),
2. burned, heavily grazed (70% removal of herbaceous forage).

Cattle grazing of the burned sapling forest type was initiated on 6 July, 1992 and on 1 July, 1993. The site was grazed by a herd of 300 cow calf pairs for approximately 5 days. In the decadent forest cattle grazing began on the 11 July and lasted for 18 days in both 1992 and 1993.

DATA COLLECTION:

Parts 1&2: A comparison of forage utilization between the decadent and the sapling forest for 1992 & 1993.

In each forest type, in both 1992 and 1993, four different groves (sites) which had been burned were selected to provide four replications. Each site was subdivided into two macro plots of 11 by 14 m. Each grazing treatment was then randomly applied to one of the macro plots within each site. Forage utilization was determined at the end of the grazing period by comparing 6 adjacent paired grazed and ungrazed quadrats/ macro plot. In 1992, utilization was determined by harvesting a 1m x 0.5m area (1cm stubble height) on each of the grazed and ungrazed paired quadrats. The clips were hand sorted into woody and herbaceous components, oven dried (70°C) for 48 hours, and the dry matter weight determined. Utilization (%) was determined as follows: [Production (g) - Utilization (g)] / Production (g)]* 100 = % Utilization. During this first field season, the overriding importance of aspen on the community was recognized. Therefore, in 1993, biomass production was hand sorted into 3 categories, herbaceous species, aspen, and other woody species.

In 1993, utilization was determined by a double sampling technique. Utilization of the herbaceous, aspen and other woody components of the plant community was visually estimated by comparing the grazed and ungrazed quadrats for all 6 quadrat pairs per macro plot (grazing treatment) per site. Two randomly selected quadrat pairs were then harvested (1 cm stubble height) and utilization was determined as in 1992. These clipped estimates of utilization were to be used to adjust visual utilization estimates through regression. Visual estimates of utilization were made in 5, 10, 15, 20, 30, 40, 50, 60, 70, 80 and 90 percent utilization increments.

Part 3: Livestock utilization patterns in the decadent forest

A study was initiated in 1993 to determine cattle utilization patterns within the mature decadent aspen forest. The three conditions studied were: (a) unburned forest (control), (b) forest burned in 1993 (1 year old burn), and (c) forest burned in 1992 (2 year old burn). Four sites were randomly selected from each forest condition. Six cages/site were established prior to grazing. These cages provided a baseline from which comparisons could be made to estimate utilization. On days 6,11,14 and 18 of the grazing period, visual utilization estimates were made adjacent to each cage for herbaceous, aspen and other woody components.

Field notes about cattle usage patterns were recorded throughout the study period.

Part 4: Forage utilization patterns in a two year old burned sapling forest

A study was established in 1993 to evaluate utilization of the 1992 burned sapling forest (2 year old burn). Four sites were selected and 2 plots/site were established. Visual estimates of utilization were made in micro plots located adjacent to production cages. Visual utilization estimates were made on days 2, 3, 4 and 5. Utilization was estimated for herbaceous and woody vegetation classes. These broad categories were further subdivided and visual utilization estimates made for aspen, snowberry, raspberry, rose, grasses and legumes. Detailed field notes about utilization patterns were recorded throughout the study period.

Experimental Design and Data Analysis:

Parts 1&2: A comparison of forage utilization between the decadent and the sapling forest for 1992 & 1993

The experimental design was a split plot (Steel and Torrie 1980). Whole plots consisted of two forest types (mature decadent and healthy sapling), two years of burning treatment (1992 and 1993), and four replications (groves) per year per forest type. The subplots consisted of two grazing treatments per replication per year per forest type.

The sources of variation, within year, for analysis of 1992 and 1993 forage utilization were: forest (f=2), groves within forest (g=4), grazing treatments (t=2), paired quadrats within grazing treatments (q=6), and the interactions of grazing treatments. Whole plots were groves within forest and split plots were the two grazing treatments in each grove.

The sources of variation for analyses of the comparison of 1993 utilization between groves burned in 1992 and groves burned in 1993 on the decadent forest were: year burned (y=2), groves within year burned (s=4), grazing treatments (macro plots) within site (t=2), the interactions of grazing treatment with the above sources. Whole plots were groves within year burned and split plots were the three grazing treatments.

Computations for statistical analysis were made using the above models in the GLM procedure of SAS (SAS Institute, Inc. 1989). Fisher's protected LSD was used to determine differences (P<0.05) among means in the presence of a significant F test.

RESULTS:

Part 1: Comparison of visual and clipped utilization estimates for shrub and herbaceous vegetation under moderate and heavy grazing regimes.

Clipped utilization estimates showed high levels of variation between micro plots. Most regression equations developed for the double sampling adjustment of visual utilization estimates were not significant. Of the 12 regression equations developed for the woody species component, not one was significant. For herbaceous species, the few significant regression equations that were developed, had poor R^2 values, and the equations did not adjust visual utilization estimates by greater than 5 percent. Since visual estimates were made in increments not smaller than 5%, the use of adjusted values was considered to be unnecessary.

In general, clipped and visual estimates of average herbaceous species utilization were similar (Figure 3.1-3.6), and had similar standard errors. Clipped and visual estimates of woody species utilization, however, were more variable (Figure 3.1-3.6). The standard error of the mean for estimated utilization of woody species determined by clipping was larger than it was for visual estimates. The large standard error values for clipped estimates as compared to visual estimates, was caused by differences in estimated utilization between individual clip plots. In some instances the clipped estimate of utilization for a specific plot was negative. With visual estimates, the level of variation between plots was not as extreme.

Part 2: A comparison of the effects of time since burning, forest type, and intensity of grazing on forage utilization

In 1992, utilization was determined by clipping. Utilizatio of herbaceous forage on sites that had been burned that spring was similar between the decadent and sapling forest types (Table 3.1). Shrub utilization, on the otherhand, was greater in the sapling forest than the decadent forest. As grazing intensity increased, total utilization also increased (Table 3.2). The utilization of herbaceous material under the moderate and heavy grazing treatment was 53% and 73%, respectively. These utilization rates were very close to the 50% and 70% utilization rates that had been set as management goals and estimated visually.

In 1993 utilization was estimated visually. The 1993 estimates of utilization in second year burns also included aspen (Table 3.3). Although aspen suckers were the dominant forage type in the burned sapling forest (Chapter 2), aspen sucker density and production in the burned decadent forest were low, making utilization estimates difficult. In 1993, utilization of other woody species was greater in the sapling forest than in the decadent forest.

Utilization of all vegetation classes increased as grazing intensity increased (Table 3.4). Aspen utilization estimates were not possible for the decadent forest because there were too few suckers present to obtain an accurate estimate. Therefore the comparison of the effects of moderate and heavy grazing on aspen utilization were made using data from the sapling forest. There were no significant forest type-by-grazing treatment interactions for either the herbaceous or the other woody vegetation components. There was insufficient aspen sucker utilization data in the decadent forest to determine if there was a significant forest type-by-grazing treatment interaction for aspen.

In 1993, in the mature decadent forest, utilization of herbaceous and other woody components under moderate grazing were similar betweeen first and second year burns (Table 3.5). Under heavy grazing, greater utilization occurred on first year burns than second year burns; (76 vs 65%) for herbaceous components and (43 vs 19%) for other woody components (Table 3.5).

Part 3. Livestock utilization patterns in the burned decadent forest

Between Day 1 and Day 6, cattle grazed first year burned sites (Burned 1993) in preference to second year burns or unburned sites (Figures 3.7 and 3.8). By Day 6 utilization of herbaceous forage in first year burns (Burned 1993), had reached 50% and the utilization of woody species was approximately 18%.

As forage availability decreased on the first year burns (Burned 1993), the utilization of herbaceous forage on second year burns (Burned 1992) increased (Figure 3.7). By the end of the grazing period (Day 18) herbaceous material on both first and second year burns had been heavily utilized, and utilization rates were similar (Figure 3.7). The utilization of woody species on second year burned sites was significantly lower than on first year burned sites (Figure 3.8). On unburned sites, at the end of the grazing period, herbaceous forage utilization was only 20%, and woody species utilization was negligible (Figures 3.7 and 3.8).

Part 4. Forage utilization patterns in second year burned sapling forest

During the first 2 days of grazing little forage utilization occurred in the 2 year old burned sapling forest, as cattle preferentially grazed the one year old burned forest. Concentrated forage utilization on second year burns began on Day 3 (Figure 3.9). More use was made of herbage than of woody species. However, utilization of woody species was surprisingly high early in the grazing period, and paralleled herbaceous forage utilization for Days 2, 3 and 4 (Figure 3.9). Cattle utilized legumes (primarily *Vicia americana* Muhl. and *Lathyyrus venosus* Muhl.) more heavily than any other vegetation component. (Figure 3.10). The utilization rate of grass was consistent from Day 2 through to the end of the grazing period. With aspen, the rate of utilization of suckers was very high until utilization reached 60%, then it declined.

The wild raspberry and wild rose stems that grew tall were browsed heavily, whereas the many low growing plants received little utilization, resulting in a low overall utilization (Figure 3.10). Western snowberry was the forage type which received the lowest level of utilization.

Standing, fire-killed, saplings created a physical barrier to grazing. Forage close to the bases of these saplings was not utilized as heavily as forage in the spaces between saplings.

DISCUSSION:

In the Aspen Parkland rangeland, high variation in vegetation productivity commonly occurs over distances of less than 1m (Irving, 1992). The variability which occurred between adjacent quadrats made estimating utilization of the aspen forest understory vegetation difficult. The greatest variability between quadrats occurred within the woody vegetation component. Competitive relationships between woody and herbaceous components, however, also caused herbaceous species to exhibit substantial variability.

Double sampling was ineffective in improving visual utilization estimate accuracy because high variability between quadrats prevented the development of a suitable regression equation. Other studies have shown that double sampling was effective for production estimates on relatively homogenous grasslands (Amed et al. 1983, Tadmor et al. 1973), but the effectiveness of double sampling decreased markedly when there was variability in species composition, phenological stage or growth form.

When visual estimates of utilization were compared with clipped estimates it was found that, as sample size increased, so did the similarity of the average utilization estimates. The sample variances for visual utilization estimates tended to be smaller than those for clipped quadrats. Shoop and McIlvain (1963) stated that because there is a tendency to underestimate production on the most productive sites and to overestimate production on the lower producing sites, variances for ocular estimates tend to be lower than those for clipped quadrats. In the current study, however, the lower variance that occurred with visual estimates of utilization as compared to clipping was likely due to the ability of the estimator to take into account some of the variation in productivity that occurred between grazed and ungrazed quadrats.

Both the visual and clip plot methods of estimating utilization have deficiencies. With clipping, it is assumed that forage production where the production clip was taken was equivalent to the production where the clip of the residual forage was taken following grazing. With visual estimates, one is relying on a subjective estimate of utilization which is dependent on the skills of the estimator. Although neither method is perfect, visually estimating utilization adjacent to an ungrazed production cage should provide utilization estimates suitable for management decisions, with a minimal time and labour investment. From a practical point of view, the ability to fit utilization estimates into the 3 broad classes, light (0-40% herbaceous removal), moderate (40-60%), and heavy (60-80%) is sufficient to make management decisions (Irving 1992).

Livestock utilization patterns on the sapling and decadent aspen forest types

The two forest types were subjected to different grazing management regimes. The sapling forest was a relatively small area (25 ha) and was grazed with high animal densities for a short duration of time. The decadent forest was roughly five times the size of the sapling forest, therefore, stocking densities were lower and the grazing period was longer. The utilization of woody species was greater in the sapling forest than in the decadent forest. This may be the result of the different grazing regimes. Another important factor contributing to the difference in woody species utilization between the two forests were differences in the woody components of the two forests (Chapter 4). The woody understory of the burned decadent forest was dominated by western snowberry whereas the burned sapling forest was dominated by aspen suckers. In this study, young aspen suckers which had not lignified proved to be a highly palatable forage whereas western snowberry shoots were not as palatable.

For the sapling forest, levels of aspen sucker utilization occurring in this study are higher than levels reported in previous studies (Hilton and Bailey 1974, Smith et al. 1972, Sampson 1919). Aspen suckers made up a substantial proportion of the available forage in the sapling forest, and the abundance may have promoted these high levels of utilization. In the burned sapling forest, aspen sucker utilization rates were extremely high early in the grazing period.

This high rate of utilization was likely related to the removal of the young, tender, first year aspen shoots. Field notes show that by the time herbaceous utilization was estimated to be 50%, first year aspen sprouts had been virtually removed from the plant community. The current annual growth was browsed heavily on one year old aspen suckers, while two year old growth was not readily used. Insufficient data relating utilization to availability were collected to determine relative preferences for individual forage species. As a result, no assumptions or inferences could be made about forage preferences. However, FitzGerald et al. (1986), looked at preferences of cattle in regenerating aspen forests following burning. They reported that generally wild rose and wild raspberry were preferred over aspen while aspen was preferred over western snowberry.

Burning improved forage utilization. On both forest types, cattle preferred forage growing on sites burned that spring. Sites burned the previous year were sought next and unburned areas were the least preferred. Willms et al. (1981a) reported similar preferences for cattle and deer grazing bluebunch wheatgrass (*Agropron spicatum*) grasslands. They showed that burning raised the mineral concentration and decreased the proportion of cell wall in the foliage. This change in forage quality likely improves palatability. Burning also removes unpalatable litter and increases availability of highly palatable new shoots (Willms et al. 1979).

Woody shoots were utilized heavily in the first growing season, when they were tender, though by the second growing season, woody stems had started to lignify and utilization decreased. Utilization levels of wild rose and wild raspberry in the second growing season following burning were lower than had been expected. Field notes show that rose, and to a lesser extent, wild raspberry, were utilized very heavily in the first year following burning. After this heavy browsing, many of the rose and raspberry plants took on a growth form close to the ground. These plants were not easily prehended by grazing cattle.

Woody plant species often contain secondary metabolites which serve as antiherbivory defenses (Bryant et al. 1992, Bryant et al. 1991, Reichardt et al. 1987, Coley et al. 1985, Bryant and Kuropat 1980). Woody stems in the juvenile stage of development tend to be most highly defended against herbivory (Bryant et al. 1992). Aspen is no exception and is known to contain antiherbivory secondary metabolites particularly in juvenile stages (Basey et al. 1990). However, in the present study, the effects of antiherbivory agents were not obvious. Coley et al. (1985), reported that the complexity of the defense system developed by a plant is related to the plants' growth rate and growth form. Slow growing plants tend to develop an antiherbivory defence composed of immobile compounds. This form of defense is highly effective but energetically expensive to develop. In contrast , the chemical defenses of fast growing plants, such as aspen, are made up of a vast array of diverse chemicals which have high turnover rates. This high turnover rate of defense compounds allows the plant a greater plasticity in the level of commitment towards defense. This allows the plant to place a low emphasis on chemical defense when resources are abundant and competition is high, then increase the emphasis on defense when the plant experiences stresses.

In this study the sapling aspen stands have developed under high levels of competition. In order to be successful in this highly competitive environment, the most effective way to compete was to have an extremely rapid growth rate. There are large energy costs associated with developing chemical defenses. Because of these costs which could result in a reduction in growth rate it would not be advantageous for these plants to produce chemical defenses while growing in this nutrient rich but highly competitive environment.

Table 3.1 Clipped estimates of forage utilization (% of available biomass) in 1992 for first year burned decadent and sapling aspen forests.

Forest type	Total	Herbaceous	Woody
	(%)	(%)	(%)
Decadent	45	62	28
Sapling	60	64	57
SEM	3.1	5.3	8.5
P>F	0.01	0.7	0.003

Table 3.2 Effect of grazing treatment on utilization (% of available biomass) in 1992 for first year burned forests.

Forest type	Total	Herbaceous	Woody
	(%)	(%)	(%)
Moderate	45	53	35
Heavy	61	73	49
SEM	2.6	3.0	5.6
P>F	0.004	0.0001	0.08

Table 3.3 Visually estimated forage utilization (% of available biomass) in 1993 for second year burned mature decadent and healthy sapling aspen forests.

Forest type	Herbaceous	Aspen	Other woody
	(%)	(%)	(%)
Decadent	55	-	14
Sapling	60	61	24
SEM	1.4	3.9	1.3
P>F	0.03	-	0.0016

Table 3.4 Effect of grazing treatment on utilization (% of available biomass) in 1993 for second year burned aspen forests.

Treatment	Herbaceous	Aspen[1]	Other woody
	(%)	(%)	(%)
Moderate	47	55	14
Heavy	68	67	25
SEM	1.4	2.5	1.0
P>F	0.0001	0.05	0.0003

1 Because there were too few aspen suckers present on the decadent forest to accurately estimate aspen utilization on this forest type, the aspen utilization values presented in this table were derived from sapling forest data only.

Table 3.5 Effect of two grazing treatments on utilization (%) in 1993 for herbaceous and woody plant components within the mature decadent aspen forests burned in 1992 or 1993

Year burned	Treatment	Herbaceous	SEM	Other woody	SEM
		(%)		(%)	
1992	Moderate	45a[1]	1.8	10a	2.1
	Heavy	65b	1.8	19b	2.1
1993	Moderate	49a	1.8	16ab	2.1
	Heavy	76c	1.9	43c	2.2
P>F[2]		0.04		0.0001	

[1] Means within the same column followed by the same letter do not differ significantly $P<0.05$

[2] The probability of a significant interaction between year burned and grazing treatment

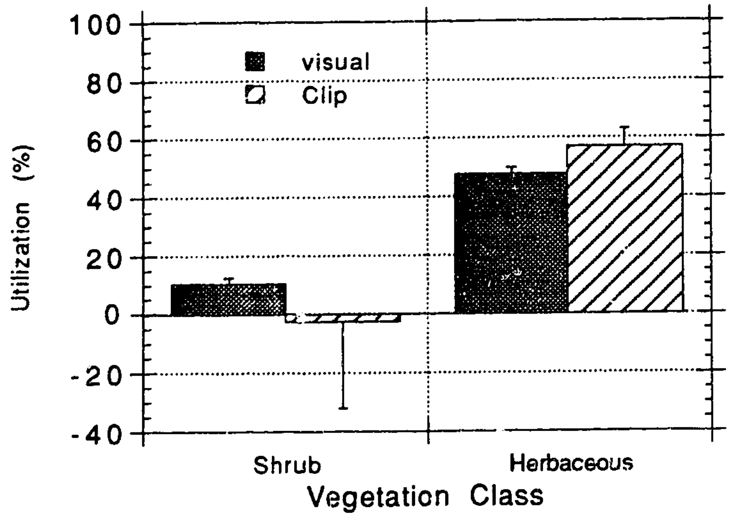

Figure 3.1. A comparison of visual and clipped utilization estimates in 1993 for moderately grazed sites in two year old burned decadent aspen forests. Bars represent 95% confidence intervals.

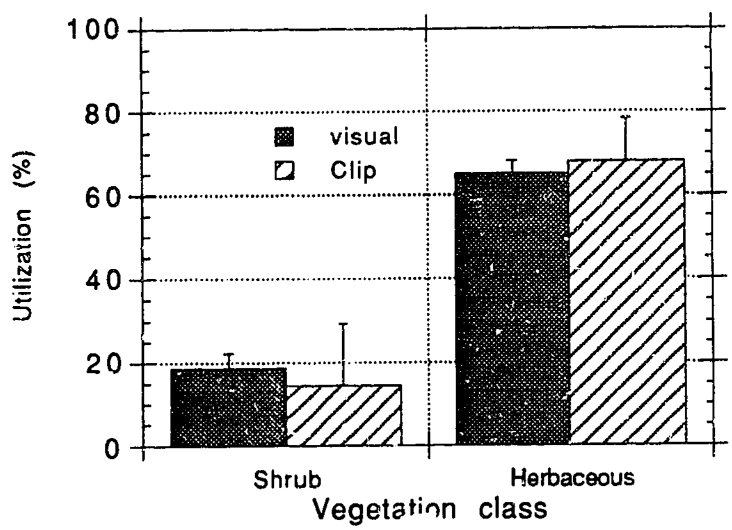

Figure 3.2. A comparison of visual and clipped utilization estimates in 1993 for heavily grazed sites in two year old burned decadent aspen forests. Bars represent 95% confidence intervals.

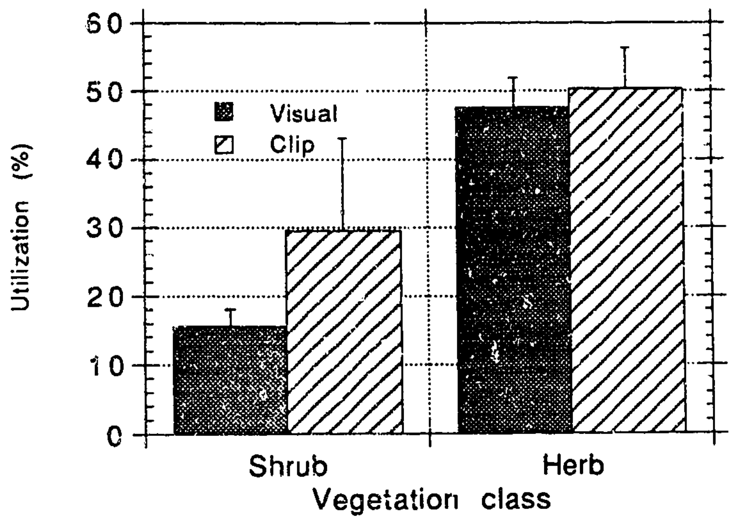

Figure 3.3. A comparison of visual and clipped utilization estimates for moderately grazed sites in first year burned decadent aspen forests. Bars represent 95% confidence intervals.

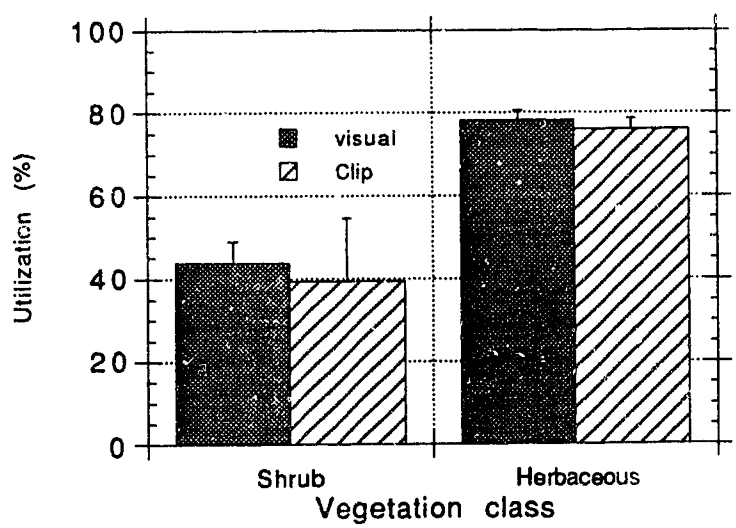

Figure 3.4. A comparison of visual and clipped utilization estimates for heavily grazed sites in first year burned decadent aspen forests. Bars represent 95% confidence intervals.

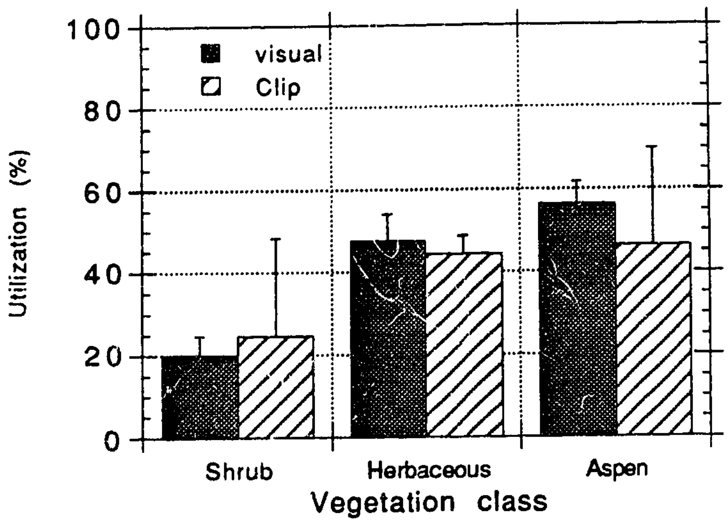

Figure 3.5. A comparison of visual and clipped utilization estimates for moderately grazed sites on two year old burned sapling forests. Bars represent 95% confidence intervals.

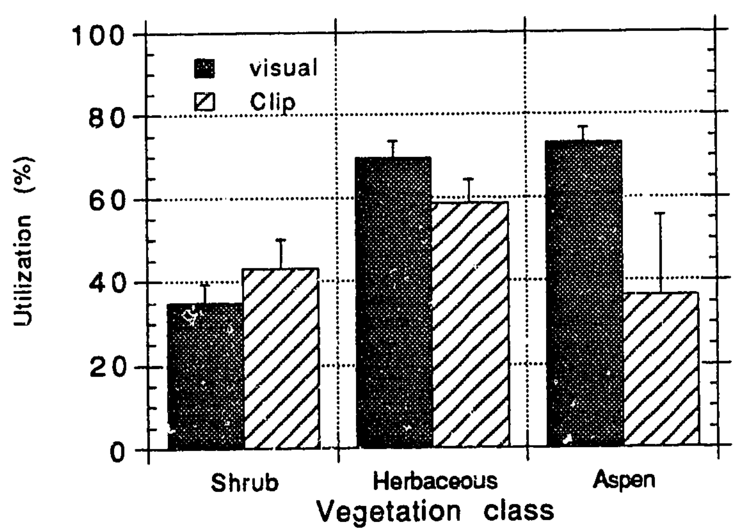

Figure 3.6. A comparison of visual and clipped utilization estimates for heavily grazed sites in two year old burned sapling forests. Bars represent 95% confidence intervals.

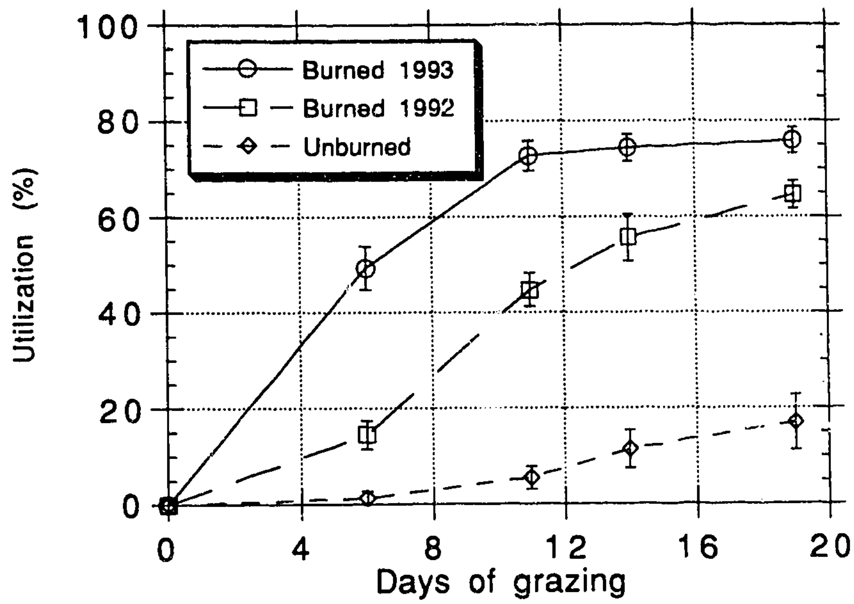

Figure 3.7 Herbaceous forage utilization (%) in first year burned (1993), second year burned (1992) and unburned mature decadent aspen forests in relation to days of grazing. Bars represent 95% confidence interval.

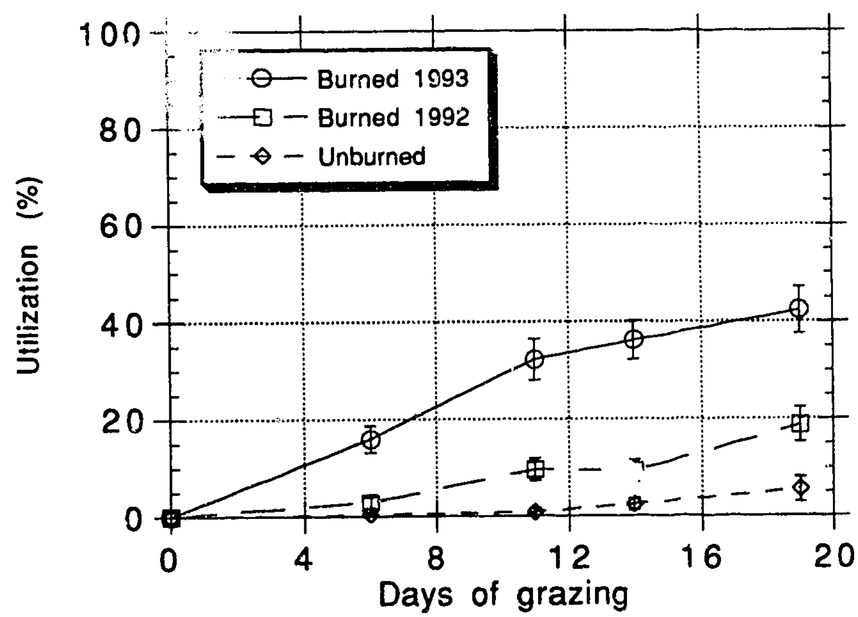

Figure 3.8 Woody forage utilization (%) in first year burned (1993), second year burned (1992) and unburned mature decadent aspen forests in relation to days of grazing. Bars represent 95% confidence interval.

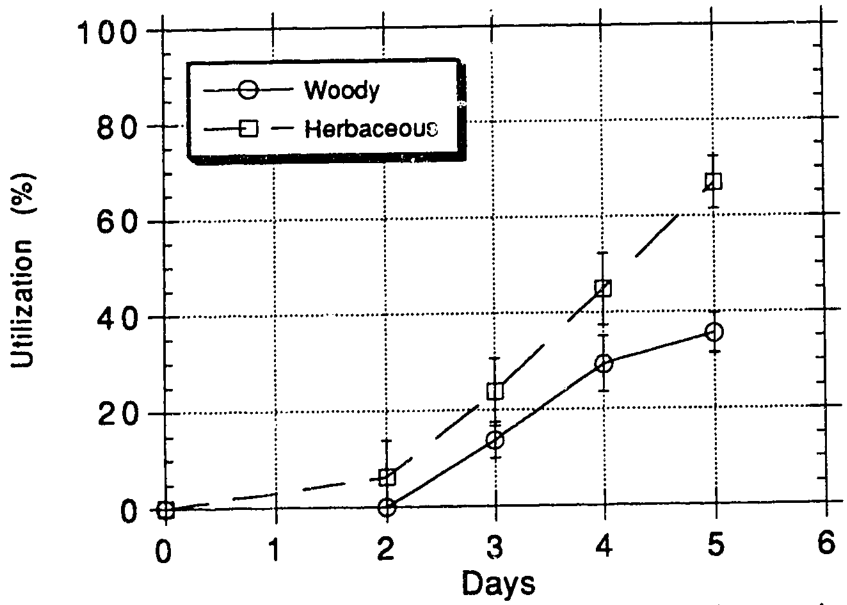

Figure 3.9 Utilization (%) of herbaceous and woody vegetation components in sapling forest over time in 1993, the second year following burning. Bars represent 95% confidence interval.

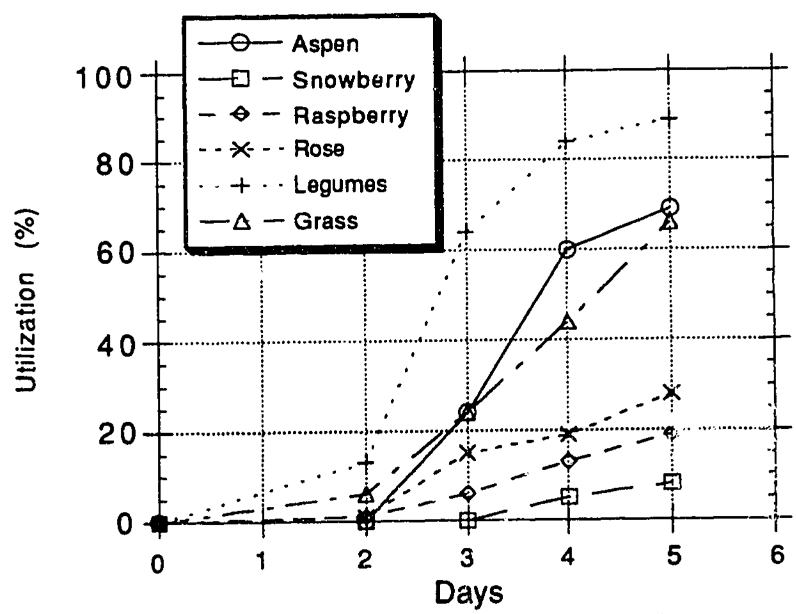

Figure 3.10 Utilization of major vegetation components in sapling forest over time in 1993, the second year following burning.

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IV. A COMPARISON OF THE WOODY PLANT COMMUNITIES AND THE EFFECTS OF GRAZING ON MATURE DECADENT AND HEALTHY SAPLING ASPEN FORESTS FOLLOWING PRESCRIBED BURNING

INTRODUCTION:

Aspen (*Populus tremuloides* Michx.) and brush encroachment onto the productive grasslands of the Alberta Aspen Parkland ecotone has been a serious management problem faced by livestock producers (Jones 1983). The encroachment of aspen and other brush species onto open grassland results in a substantial reduction in forage available to livestock. Aspen and the other woody species of the Aspen Parkland are extremely competitive (Bailey and Gupta 1973). They compete with understory herbaceous forage for light, water, and nutrients (Peterson and Peterson 1992, Jones 1983). This competition reduces herbage yield under aspen and its associated shrub species to as little as 10% of the yield of adjacent grasslands (Bailey and Wroe 1974).

On lands where aspen and other woody species have invaded productive grasslands, prescribed burning has been shown to be an effective means of removing the aspen forest canopy (FitzGerald et al. 1986, Jones and DeByle 1985, FitzGerald and Bailey 1984, Bartos and Mueggler 1979). However, woody plant species of the Aspen Parkland are well adapted to the effects of fire (Peterson and Peterson 1992, Bailey 1988, Jones and DeByle 1985). Following prescribed burning, dominant woody species, aspen, western snowberry (*Symphoricarpos occidentalis* Hook.), wild rose (*Rosa woodsii* Lindl. *and Rosa acicularis* Lindl.), and wild raspberry (*Rubus idaeus* L.) recolonize the area, through vegetative suckering.

In the Aspen Parkland, vigorous suckering of the woody species following burning quickly eliminates any temporary increase in available forage production that results from the removal of the tree canopy (Bailey and Anderson 1979). Not only does the increased suckering compete with and reduce herbage production (Bailey and Gupta 1973), it also creates a serious barrier to cattle movement and grazing (Wright and Bailey 1982, Corns and Schraa 1965).

The extremely competitive nature of the woody species of the Aspen Parkland makes the control of woody sucker regrowth a necessary and important part of post burn management. The control of woody sucker regrowth has been carried out to varying degrees of success using both mechanical means and various selective herbicides (Bowes 1982, 1976, 1975; Bailey 1972). Research by Bailey and others (Bailey et al. 1990, Bailey 1986, FitzGerald and Bailey 1984) has shown that prescribed livestock grazing can also effectively control brush regrowth.

The extensive type of grazing which occurs under traditional continuous grazing systems is not effective in brush control, and can promote the growth and development of woody species over herbaceous species (Mathews 1977). Continuous grazing involves grazing the same area for the entire grazing season with relatively low stock densities (Holecheck 1989). This type of grazing system allows the grazing livestock to be very selective of the forage they consume. Livestock are often able to avoid less palatable woody species by preferentially grazing regrowth of preferred forage species (Holechek 1989, Jones 1983). The avoidance of less palatable woody species, combined with heavy and repeated utilization of the palatable forage species, gives woody species a competitive advantage.

Conversely, a well managed intensive grazing system can be used to control woody species growth. Using high intensity, short duration grazing (Holechek 1989), livestock not only consume preferred forage species but are forced to also consume less palatable forages. With a high intensity, short duration grazing system, utilization rates are high but livestock are removed before there is any significant regrowth thus restricting opportunity for animal selection of regrowth.

The meristematic tissues of most grasses are located close to the ground where grazing will not damage them (Tainton 1981). Conversely, meristematic tissues of woody species are at the tips of stems and branches, susceptible to damage or removal by browsing. This difference in the location of meristematic tissues causes woody species to be more severely affected by livestock defoliation than herbaceous species. The ultimate result is supression of woody species growth (Gruell and Loope 1974, Smith et al. 1972) and the promotion of herbaceous species. In the Aspen Parkland, FitzGerald and Bailey (1984) found that healthy aspen regrowth can be effectively controlled by one year of late season (August) heavy livestock grazing, or by seven years of June grazing (Bailey et al. 1990). Western snowberry can also be controlled to some extent by repeated clipping (Adams 1983), however, snowberry is not readily utilized by grazing cattle. FitzGerald et al. (1986) found some evidence that snowberry utilization may increase following burning.

A study was developed to compare the influence of prescribed burning and controlled livestock grazing on the development of the woody plant community under two different aspen forest types. The two forest types were mature decadent (decadent) and healthy sapling (sapling). The decadent forest type was severly affected by the stresses of droughts and tent caterpillar epidemics during the late 1980's and early 1990's (Chapter 1). The substantial mortality to the aspen forest resulted in a much more open forest canopy with a very productive herbaceous and shrub understory.

The sapling forest was not severely affected by the influences of drought or tent caterpillars.[1] Sapling aspen forests of sucker orgin are much less susceptible to the effects of drought than mature forests because they have high root to photosynthetic area ratios (Peterson and Peterson 1992). The understory plant community of this forest type was not well developed and was unproductive due to competition for light, water, space and nutrients (Woods et al. 1982).

It was hypothesized that these differences in the two forests prior to burning would influence the response of the understory community to burning and prescribed livestock grazing.

OBJECTIVES:

1. To compare the effects of prescribed burning on the density and height of aspen, western snowberry, wild rose and wild raspberry woody sprouts in decadent and sapling aspen forest types.

2. To determine what influences prescribed livestock grazing has on the density and height of woody sprouts in decadent and sapling aspen forest types following prescribed burning.

STUDY AREA:

The study site was located on Kuntz Brothers' Farms, a private cattle ranch 160 kilometers east of Edmonton and approximately ten kilometers south

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[1] Doyle and Norman Kuntz, Personal communication April 1992.

of Minburn, Alberta (52°02"N 111°33"W). The legal land description of the study site was the East 1/2 of Section 36; Township 48, Range 11 West of the 4th meridian, and the North 1/2 of Section 31; Township 48, Range 10 West of the 4th meridian.

Climate:

The climate of the study site is continental, characterized by warm summers and relatively cold winter temperatures (Wyatt et al. 1944). Weather records from the University of Alberta Ranch weather station, (approximately 25 km south of the study site) indicate that the average annual temperature is 1.9° C and average annual precipitation is 432 mm. Seventy five percent of the annual precipitation occurs in the form of rain during the growing season (May - September) and 25% as snow during the dormant season (October -April) (Atmospheric Environment Services 1991). Average frost free period is 100 days with the last spring frost (0°C) usually about May 31, and the first fall frost (0°C) during the first week of September. The start of the growing season usually falls between April 21st and 26th, and the average length of the growing season is between 165 and 170 days (Horton 1991).

On average, potential evapotranspiration exceeds precipitation for every month of the growing season except for the month of June (Horton 1991). The long term precipitation to potential evapotranspiration ratio during the growing season ranges between 0.65 and 1.1.

Geology:

The bedrock geology of the study area is of the Belly River formation (Howitt et al. 1988). This formation is made up of Upper Cretaceous rock (Wyatt et al. 1944) and composed of sandstones, mudstones and siltstones deposited in a non-marine environment (Howitt et al. 1988). The bedrock of the area is overlain with a thick layer of glacial till, which was deposited by the Keewatin ice sheet about 10,000 years ago (Wyatt et al. 1944). The topography of the study site is classified as morainal hummocky (Howitt et al. 1988); it has hummocks with short steep slopes and numerous pothole lakes interspersed between hummocks. The topography is often referred to as Knob and Kettle, a result of the melting of a stagnant ice mass. The Kettles were formed when huge ice blocks underlying morainal material melted. The resultant depressions often develop into small lakes or sloughs.

Soils:

The soils of the study site are dominated by well drained fine loams and are classified as Orthic Black Chernozems (Howitt et al. 1988). These soils occupy the mid and upper slope positions on the landscape. Soils of the lowland depressions, which make up 15 - 20% of the area, tend to be poorly drained and are either classified under the Gleysolic Order or under a gleyed Subgroup of the Chernozemic Order.

Soil parent material ranges between 8 and 30 meters in thickness, and is made up of a calcareous glacial till containing fine loamy to fine clayey particles, with less than 5 percent coarse fragments (Howitt et al. 1988). A typical soil profile on the mid to upper slope position consists of a loamy Orthic Black Chernozemic Ah horizon, 10 - 15 cm thick. This is underlain by a yellow brown, weakly to moderately prismatic B horizon. Unaltered parent material is normally encountered at a depth of 40 - 60 cm. The imperfectly to poorly drained lowlands have Humic Gleysols characterized by an Ah horizon greater than 10 cm and no Bt horizon (Agriculture Canada 1987). The mineral horizons of these soils tend to be strongly gleyed with prominent mottles indicating a high or fluctuating water table.

Vegetation:

The study site was located within the Aspen Parkland vegetation association. This association is a transitional zone between the grassland dominated Mixed Prairie Association to the south and the Boreal Forest Association to the north (Strong and Leggat 1992). The areas of the Aspen Parkland which have not been disturbed by cultivation are characterized by a mosaic of aspen groves and open grasslands. The aspen groves and their associated shrub communities have historically occupied the moister sites while grasslands occupied the drier more exposed sites. Today, because of the elimination of natural pyrogenic and anthropogenic forces (Dormaar and Lutwick 1966; Bird 1961), aspen and shrub communities have invaded onto soils that were historically dominated by grasslands. Aspen and its associated shrub species now occupy between 75 and 85 percent of the land area on the study site. The woody communities are dominated by trembling aspen (*Populus tremuloides* Michx.) western snowberry (*Symphoricarpos occidentalis* Hook.), silver berry (*Elaeagnus commutata* Bernh.), common wild rose (*Rosa acicularis* Lindl. and *Rosa woodsii* Lindl.), wild raspberry (*Rubus idaeus* L.), gooseberry (*Ribes hirtellum* Michx.), saskatoon (*Amelanchier alnifolia* Nutt.), and choke cherry (*Prunus virginiana* L.). The most common understory grasses are smooth brome (*Bromus inermis* Leyss.), blue grasses (*Poa spp.* L.), and reed grasses (*Calamagrostis spp.* Adans.). The open grasslands which occupy south facing slopes and flat areas are dominated by a *Festuca - Stipa* plant community (Looman 1981). On ungrazed sites, plains rough fescue *Festuca halli* ((Vasey) Piper) predominates.

SITE SELECTION:

The study site consisted of a half section (130 ha.) of native rangeland dominated by mature decadent aspen forest (decadent), and an adjacent 25 ha. area dominated by a healthy sapling aspen forest (sapling). The decadent forest was dominated by 30 to 60 year old aspen trees left in a declining and decadent state following the droughts and tent caterpillar epidemics of the late 1980's and early 1990's. The sapling forest was dominated by dense vigorous aspen saplings 3 - 6 m tall. It had developed after mature aspen groves were cleared by bulldozer in 1983. During the tent caterpillar epidemics, the sapling forest type was not seriously defoliated by forest tent caterpillars[2].

METHODS

In the spring of 1992, approximately 1/3 of each forest type (mature decadent and healthy sapling aspen forest) was prescribed burned. Following burning, four groves (sites) within each forest type which met the standards of a selection criteria were randomly selected for sampling.

The selection criteria used to select sites for sampling were:

1. All sites to be sampled must have been burned uniformly.
2. Sites were located on gentle slopes to avoid environmental extremes.
3. Sites were large enough to contain a plot 33 m x 14 m within an area of homogeneous vegetation.

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2 Doyle and Norman Kuntz, Personal communication April 1992.

4. In the decadent aspen forest, sampling sites were located in the portion of the aspen grove that was termed the Small Aspen type by Scheffler (1976). This forest type is the most uniform, and most extensive portion of each grove.

On each site the following treatments were established:

1. burned, ungrazed,
2. burned, moderately grazed (50% removal of herbaceous forage),
3. burned, heavily grazed (70% removal of herbaceous forage).

Cattle grazing of the burned healthy sapling forest type was initiated on 6 July, 1992 and 1 July, 1993. The site was grazed by a herd of 300 cow calf pairs for 5 days. On the decadent forest, cattle grazing began 11 July in both 1992 and 1993; cattle grazed the site for 18 days.

Data Collection:

Within each forest type, 4 groves (sites) were selected. Each site was subdivided into 3 macroplots of 11 by 14 m, with one of the grazing treatments randomly applied to each macroplot. Within each macroplot six 1 m x 1 m permanent microplots were established. Nondestructive sampling was carried out on the microplots at 3 different dates: 1. after grazing in 1992 (mid August 1992), 2. prior to grazing in 1993 (late June 1993), 3. After grazing in 1993 (mid August 1993). At each sampling period the density of stems m^{-2} and the height (cm) of the tallest stem on the microplot was determined for each of the major woody species, (aspen, western snowberry, wild raspberry and wild rose).

Utilization was monitored by visual estimation. When the utilization of herbaceous material was estimated to be 50%, the moderate utilization macro plot was fenced to exclude further grazing . Grazing on the remainder of the field continued until utilization of the herbaceous material was estimated to be 70 percent in the macro plots selected for heavy utilization.

Experimental Design and Data Analysis:

The experimental design was a split plot (Steel and Torrie 1930). Whole plots consisted of 2 forest types (decadent and sapling), and 4 replications (groves) per year per forest type. The subplots consisted of 3 grazing treatments per replication per forest type. On each grazing treatment within each replication 6 permanent micro plots were established. On 3 sampling dates (fall 1992, spring 1993, fall 1993) the density, and height of the dominant woody species was determined.

Sources of variation for analysis of data for ungrazed conditions were forest (f=2), groves within forest (g=4), micro plots within groves (m=6), sampling date (d=3) and the interactions of forest. Whole plots were groves within forest and sampling dates were the split plots.

The sources of variation for analyses of data where the grazing treatments had been introduced were forest (f=2), groves within forest (g=4), grazing treatments within groves (t=3), the interactions of grazing treatment, micro plots within grazing treatment (m=6), date (d=3) and the interactions of micro plots. Whole plots were groves within forest, split plots were the three grazing treatments, and split-split plots were the three sampling dates.

Computations for statistical analysis were made using the above models in the GLM procedure of SAS (SAS Institute, Inc. 1989). Fisher's protected LSD was used to determine differences ($P<0.05$) among means in the presence of a significant F test.

RESULTS:

The densities and heights of woody species without grazing

Within ungrazed sites, density of woody stems decreased over time while average height increased (Table 4.1). In the burned sapling forest, woody stem densities were highest (64 stems m^{-2}) the year of burning, and declined substantially over the winter (Table 4.2). Woody stem densities in the sapling forest did not change between the second and third sampling dates. Within the burned decadent forest, woody stem densities in Fall 1992 were lower than in the sapling forest . In the spring of 1993 woody stem densities in the decadent forest increased significantly and were greater than the density of woody stems in the sapling forest. By the fall of 1993 the density of woody stems was the same in the two forest types.

Over the three sampling dates, without grazing, aspen and western snowberry declined in density while increasing in height (Table 4.3). The average density and height of raspberry and rose did not change significantly over the study period.

The burned sapling forest produced more aspen suckers than the decadent forest (Table 4.4). In the decadent forest, aspen sucker density remained low throughout the study period (Table 4.5). In contrast, within the sapling forest, aspen density was highest shortly after burning and declined over the study period. The height of aspen suckers increased over the study period in both forest types (Table 4.5). During the first growing season following burning, aspen density and height was greater in the sapling forest, however, by the fall of the second growing season, aspen suckers were taller in the decadent forest.

The influence of prescribed cattle grazing on the density and height of woody species

Controlled cattle grazing decreased the density and height of woody stems (Table 4.6). Heavy grazing caused a greater reduction in height than in density of woody stems.

The effects of time since burning and grazing on the density (stems m-2) of woody species are presented in Table 4.7. Western snowberry made up over half of the total density of woody species. Grazing and competition reduced the total density of woody species. (Figure 4.1). Total woody stem density decreased as grazing reduced the density of aspen (Figure 4.2) and snowberry (Figure 4.3). There was no significant difference in the density of aspen, snowberry or total woody species between moderate and heavy grazing treatments (Table 4.7). The density of woody species varied between sampling dates (Figure 4.1). Under ungrazed conditions, woody densities consistently declined over time. With grazing, the response of total woody density over time was more complex. Following the 1992 grazing, woody densities were lower on grazed sites than they were on ungrazed sites. By the second sampling period, however, total woody stem density had increased on the grazed sites such that there was no difference between grazed and ungrazed treatments. By the third sampling date, total woody stem densities on the grazed treatments were again lower than densities on the ungrazed sites.

The heights of the dominant woody species were influenced by a time since burning by grazing treatment interaction (Table 4.8). The height of all woody species was reduced by grazing (Figure 4.4). Height differences between grazing treatments increased as time progressed. Heavy grazing caused the greatest reduction in stem height. On the final sampling date there was a significant difference in stem height between the moderate and heavily grazed sites for all species except raspberry (Table 4.8).

Aspen was the species whose height was most severely affected by the grazing treatments (Figure 4.5). Grazing maintained aspen as a short shrub species whereas on ungrazed sites aspen was well on its way towards a free to grow state.

DISCUSSION:

This study confirmed previous work on how quickly woody species of the Aspen Parkland recolonize burned sites through vegetative suckering (Bailey 1988, FitzGerald and Bailey 1984, Wright and Bailey 1982, Anderson and Bailey 1980). Two months after burning, the woody vegetation on both forest types was well developed.

The density of woody species declined over the study period due to the effects of inter- and intraspecific competition on young woody shoots (Schier et al. 1985a). As the plant community became established following burning, there was intensive competition for light, space, water, and nutrients (Peterson and Peterson 1992, Jones 1983). The effects of competition within young aspen stands has been well documented (Peterson and Peterson 1992, Schier et al. 1985b, Walters et al. 1982, Bella and De Franceschi 1980). Intense intraspecific competition between aspen suckers causes natural thinning of the dense regenerating stand (Peterson and Peterson 1992; Crouch 1983, 1981; Baker 1925; Sampson 1919). Although not as well documented, dense stands of snowberry are also affected by intraspecific competition (Adams 1983). In this study not only intense intraspecific competition occurred, but significant interspecific competition among the major woody species also occurred.

Following burning, the decadent forest produced fewer aspen suckers than the sapling forest . In the sapling forest, aspen suckered prolifically and established itself as the dominant woody species on ungrazed sites. The difference in aspen density between the two forest types influenced the development of woody vegetation components. The sapling forest developed a maximum woody stem density by the end of the first growing season. The next year, competition resulted in reductions in density and aspen height growth. In contrast, woody stem densities did not peak in the decadent forest until the second spring. This is likely due to the lack of aspen competition.

In the sapling forest aspen suckers quickly developed a closed canopy which inhibited the development of new aspen shoots and caused the mortality of some of the smaller existing shoots. Peterson and Peterson (1992) and Schier et al. (1985b) outlined how the least vigorous aspen suckers die during the first 1 or 2 years, leaving one or two dominant suckers in each clump. The competition created by the high aspen density not only affected aspen but also had an effect on all woody species.

The introduction of cattle grazing treatments had a significant influence on woody vegetation. Grazing reduced both aspen and western snowberry stem densities. The young, succulent aspen suckers produced following the burn were highly preferred forage. These young suckers, which had not developed a well lignified stem, were easily broken by livestock grazing and trampling. However, in this study, with grazing occurring in mid to late July, substantial numbers of aspen suckers remained. FitzGerald and Bailey (1984) reported that a single late season (August) heavy grazing treatment effectively eliminated aspen from the plant community, while early season grazing did not effectively control aspen densities. It was hypothesized that late season grazing prevented the development of dormancy characteristics, thus making these suckers susceptible to winter kill. A follow up paper (Bailey et al. 1990) to the one presented by FitzGerald and Bailey (1984), showed that after seven years of early season heavy grazing, aspen was no longer an important part of the plant community. Adams (1983) noted that western snowberry may also be more susceptible to winter kill if late season defoliation occurs.

Although not eliminated from the community, in this study, aspen densities were significantly reduced by grazing; more importantly, grazing controlled aspen sucker height. Cattle grazing maintained aspen suckers at a lower height where the browse was available for both livestock and wildlife. Aspen is a high quality forage (DeByle 1985, Mueggler 1985) which adds to the forage supply and to the diversity of the community. Therefore, as long as aspen suckers are not limiting the forage production or creating a barrier which limits utilization, aspen eradication does not have to be an ultimate goal of cattle ranchers.

Cattle grazing also had some impact on western snowberry density and height. Although western snowberry did not appear to be a preferred forage, cattle did browse significant amounts of western snowberry particularly as grazing intensity increased. Field notes showed that even when utilization was light, some cows preferentially browsed the young western snowberry shoots. Following burning, it appears that western snowberry is more palatable. However, even when western snowberry stems are young, they are extremely tough and rubbery making prehension difficult. Therefore, browsing of western snowberry usually only resulted in the removal of the tips of stems. As western snowberry stems matured, lignification made the stems woody and cattle tended to avoid them.

In previous studies where livestock were used in combination with prescribed burning (Bailey et al. 1990, FitzGerald and Bailey 1984, Bailey 1986), it was suggested that heavy grazing should be used to effectively control aspen encroachment. In this study, control of aspen regeneration in the mature decadent forest was not a serious management problem, and if forest regeneration is desired, some level of protection from grazing would be necessary.

In burned sapling forests, livestock grazing is desirable to prevent development of dense, dog hair aspen stands. The stands not only restrict understory forage production, they also limit habitat value for ungulate species. Moderate or heavy cattle grazing shortly after spring prescribed burning appears to significantly reduce aspen, and to a lesser extent western snowberry density and height. Two years after burning there was no difference between moderate and heavy grazing in their effectiveness to control aspen. Heavy grazing, however, may have had a slightly greater influence on snowberry than moderate grazing. Although grazing did impact snowberry, in this study, like the study carried out by Bailey et al. (1990), it does not appear that prescribed grazing can effectively control western snowberry.

The understory vegetation of forest groves in the Aspen Parkland is extremely diverse (Strong and Leggat 1992). Prescribed burning followed by controlled livestock grazing maintains the diversity of this plant community which is valued both as a forage resource for grazing livestock, and as wildlife habitat. Not only is prescribed burning, used in combination with controlled livestock grazing, a less expensive means of brush control than clearing and breaking, it also maintains other multiple use habitat values of this ecosystem.

Table 4.1 Influence of time since burning on woody vegetation density (stems m^{-2}) and height (cm) in ungrazed sites

Sampling date	Density (stems m^{-2})	Height (cm)
Fall 1992	58.1^{a1}	49.6^{c}
Spring 1993	53.4^{ab}	53.2^{b}
Fall 1993	47.0^{b}	60.1^{a}
SEM	2.2	1.0
P>F	0.015	0.001

1 Means within the same column followed by the same letter are not significantly different (P<0.05)

Table 4.2 Influence of time since burning on density (stems m^{-2}) of woody vegetation in two forest types in ungrazed sites.

Forest type	Fall 1992 (stems m^{-2})	Spring 1993 (stems m^{-2})	Fall 1993 (stems m^{-2})
Decadent	51.7^{bx1}	58.3^{ay}	47.6^{ax}
Sapling	64.4^{ax}	48.5^{by}	46.4^{ay}
SEM[2]		3.2	
P>F[3]		0.014	

1 Means within the same columns followed by the same letter (a,b) and means within the same rows followed by the same letter (x,y) are not significantly different (P<0.05).
2 For all six means.
3 Probability of a significant sampling date by forest type interaction

Table 4.3 Influence of time since burning on density (stems m^{-2}) and height (cm) of four woody species in ungrazed sites

Sample date	Aspen		Snowberry		Raspberry		Rose	
	Density	Height	Density	Height	Density	Height	Density	Height
	stems m^{-2}	(cm)	stems m^{-2}	(cm)	stems m^{-2}	(cm)	stems m^{-2}	(cm)
Fall 1992	12.4^{a1}	64.7^{c}	32.8^{a}	47.9^{b}	8.4	38.0	4.5	47.6^{ab}
Spring 1993	10.4^{ab}	87.1^{b}	31.5^{a}	48.6^{ab}	7.4	32.9	4.1	44.3^{b}
Fall 1993	8.4^{b}	99.8^{a}	26.6^{b}	51.8^{a}	7.7	37.8	4.7	51.0^{a}
SEM	0.94	3.49	1.44	1.12	0.54	1.92	0.33	1.26
P>F	0.02	0.001	0.03	0.06	0.41	0.15	0.49	0.01

1 Means within the same columns followed by the same letter are not significantly different (P<0.05)

Table 4.4 Comparison of density (stems m^{-2}) and height (cm) of four woody species in two burned, ungrazed forest types.

Forest type	Aspen		Snowberry		Raspberry		Rose	
	Density	Height	Density	Height	Density	Height	Density	Height
	stems m^{-2}	(cm)	stems m^{-2}	(cm)	stems m^{2}	(cm)	stems m^{-2}	(cm)
Decadent	1.1	81.5	37.5	52.7	10.1	37.4	3.8	47.1
Sapling	19.4	86.2	23.0	46.2	5.6	35.0	5.0	48.2
SEM	0.72	4.39	8.49	4.47	3.33	5.17	1.02	3.09
P>F	0.001	0.48	0.27	0.34	0.38	0.75	0.44	0.80

Table 4.5 Influence of time since burning on aspen density (stems m^{-2}) and height (cm) in ungrazed sites

Forest type	Sampling date	Density (stems m^{-2})	Height (cm)
Decadent	Fall 1992	1.1[d1]	56[d]
	Spring 1993	1.0[d]	84[bc]
	Fall 1993	1.1[d]	105[a]
Sapling	Fall 1992	23.8[a]	73[c]
	Spring 1993	19.7[b]	91[ab]
	Fall 1993	14.9[c]	95[ab]
SEM		1.33	5.0
P>F[2]		0.02	0.06

1 Means within the same columns followed by the same letter are not significantly different (P<0.05)

2 The probability of a significant 2 way interaction between forest type and sampling date treatment

Table 4.6 Effect of three grazing treatments on density (stems m^{-2}) and height (cm) of woody stems in burned aspen forest.

Grazing treatment	Density (stems m^{-2})	Height (cm)
Control	52.8[a1]	54.3[a]
Moderate	44.2[b]	38.0[b]
Heavy	42.8[b]	33.8[c]
SEM	2.36	1.37
P>F	0.02	0.001

1 Means within the same columns followed by the same letter are not significantly different (P<0.05)

Table 4.7 Influence of time since burning and grazing treatment on density (stems m^{-2}) of woody vegetation.

Species	Grazing treatment	Fall 1992	Spring 1993	Fall 1993
		Density		
		(stems m^{-2})	(stems m^{-2})	(stems m^{-2})
All woody species	Control	58.1^{ax1}	53.4^{ay}	47.0^{az}
	Moderate	45.6^{bx}	49.4^{ay}	37.8^{bz}
	Heavy	41.9^{bx}	49.7^{ay}	36.9^{bz}
Aspen	Control	12.4^{ax}	10.4^{ay}	8.0^{az}
	Moderate	8.6^{bx}	7.5^{bx}	4.9^{by}
	Heavy	7.3^{bx}	6.2^{bx}	4.1^{by}
Snowberry	Control	32.8^{ax}	31.5^{ax}	26.6^{ay}
	Moderate	22.7^{bx}	27.6^{by}	21.7^{bx}
	Heavy	22.7^{bx}	32.1^{ay}	22.7^{bx}
Raspberry	Control	8.4^{ax}	7.4^{ax}	7.7^{ax}
	Moderate	10.9^{bx}	11.9^{bx}	8.1^{ay}
	Heavy	6.9^{ax}	8.2^{ax}	6.3^{ax}
Rose	Control	4.5^{ax}	4.1^{ax}	4.7^{ax}
	Moderate	3.3^{ax}	2.4^{ax}	3.0^{ax}
	Heavy	5.0^{ax}	3.4^{ax}	3.8a^{x}
SEM			0.70	

1 Means within the same woody species cell followed by the same letter (a,b,c) and means within the same rows followed by the same letter (x,y,z) are not significantly different (P<0.05)

Table 4.8 Influence of time since burning and grazing treatment on height (cm) of woody vegetation.

Species	Grazing treatment	Fall 1992	Spring 1993	Fall 1993
		Height		
		(cm)	(cm)	(cm)
All woody species	Control	49.5^{ax}[1]	53.2^{ay}	60.1^{az}
	Moderate	36.0^{bx}	40.0^{by}	38.2^{by}
	Heavy	34.5^{bx}	35.7^{cx}	31.2^{cy}
Aspen	Control	64.7^{ax}	87.1^{ay}	99.8^{az}
	Moderate	33.8^{bx}	51.2^{by}	44.8^{bz}
	Heavy	37.2^{bxy}	41.9^{cx}	35.7^{cy}
Snowberry	Control	47.9^{ax}	48.6^{ax}	51.8^{ax}
	Moderate	45.4^{ax}	43.8^{bx}	46.6^{bx}
	Heavy	36.9^{bx}	40.7^{bx}	37.7^{cx}
Raspberry	Control	38.0^{ax}	32.9^{ay}	37.8^{ax}
	Moderate	29.8^{bx}	25.2^{bx}	26.2^{bx}
	Heavy	28.2^{bx}	24.7^{bxy}	21.9^{by}
Rose	Control	47.6^{axy}	44.3^{ax}	51.0^{ay}
	Moderate	34.9^{bx}	39.1^{bx}	35.3^{bx}
	Heavy	35.6^{bx}	35.3^{bx}	29.4^{cy}
SEM		1.68	1.68	1.7

1 Means within the same woody species cell followed by the same letter (a,b,c) and means within the same rows followed by the same letter (x,y,z) are not significantly different ($P<0.05$)

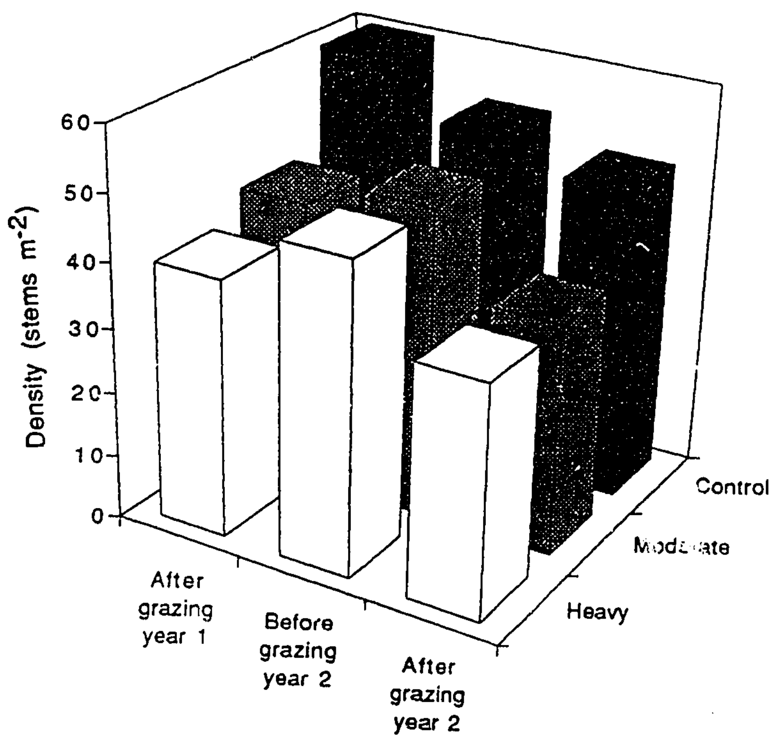

Figure 4.1 The effect of grazing treatment and time since burning on total density of woody species (stems m^{-2}).

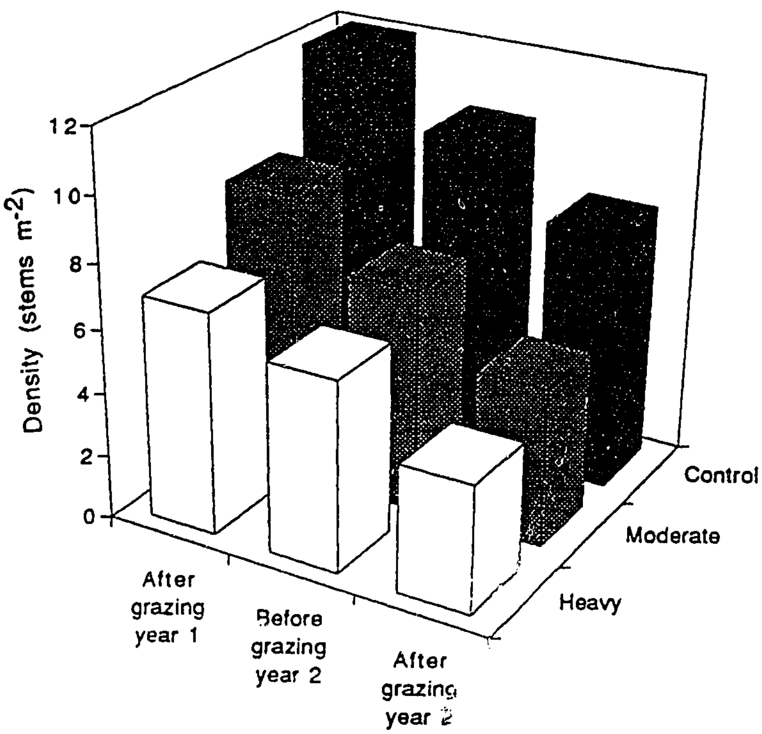

Figure 4.2 The effect of grazing treatment and time since burning on aspen density (stems m^{-2}).

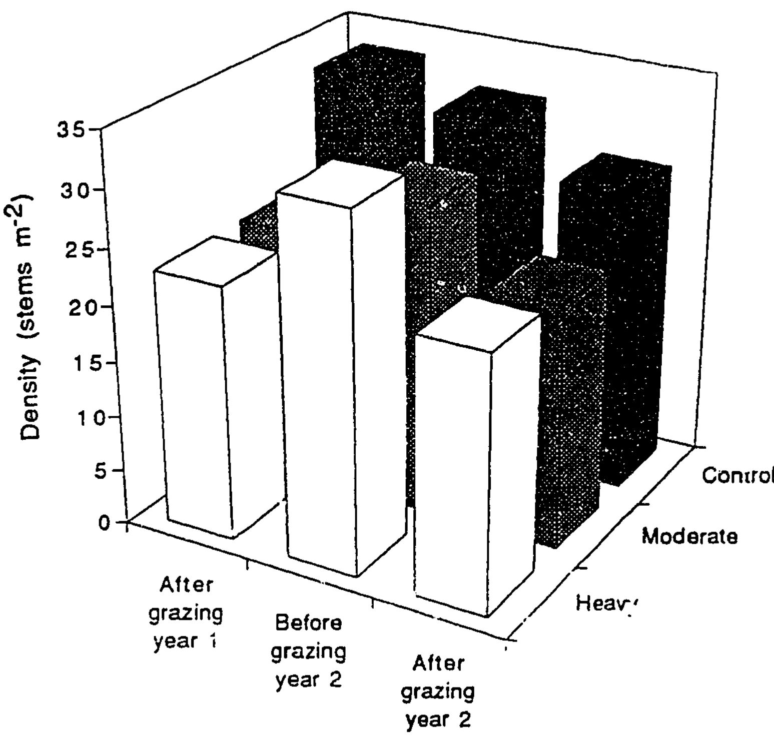

Figure 4.3 The effect of grazing treatment and time since burning on western snowberry density (stems m^{-2}).

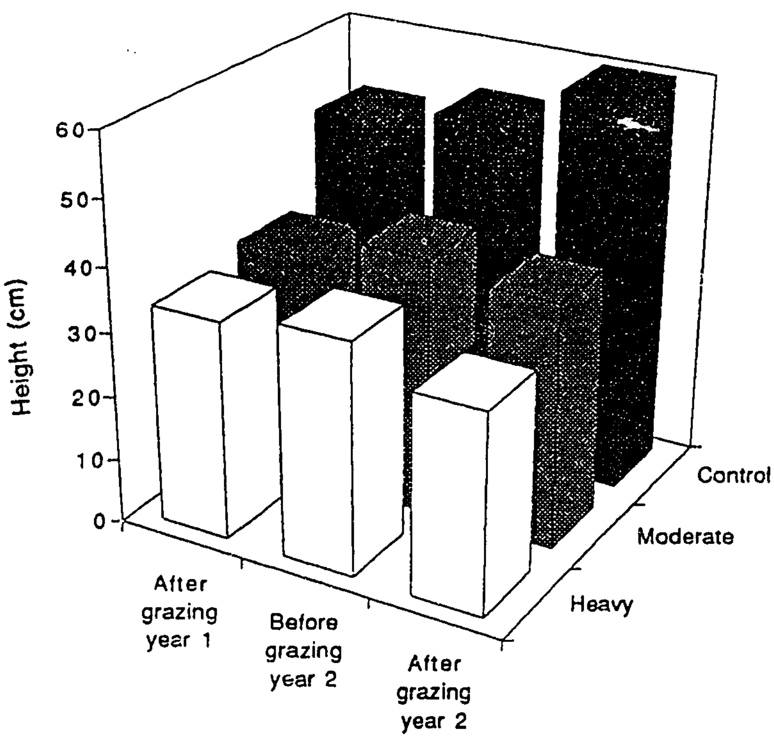

Figure 4.4 The effect of gra· ·nent and time since burning on the average height of woody species

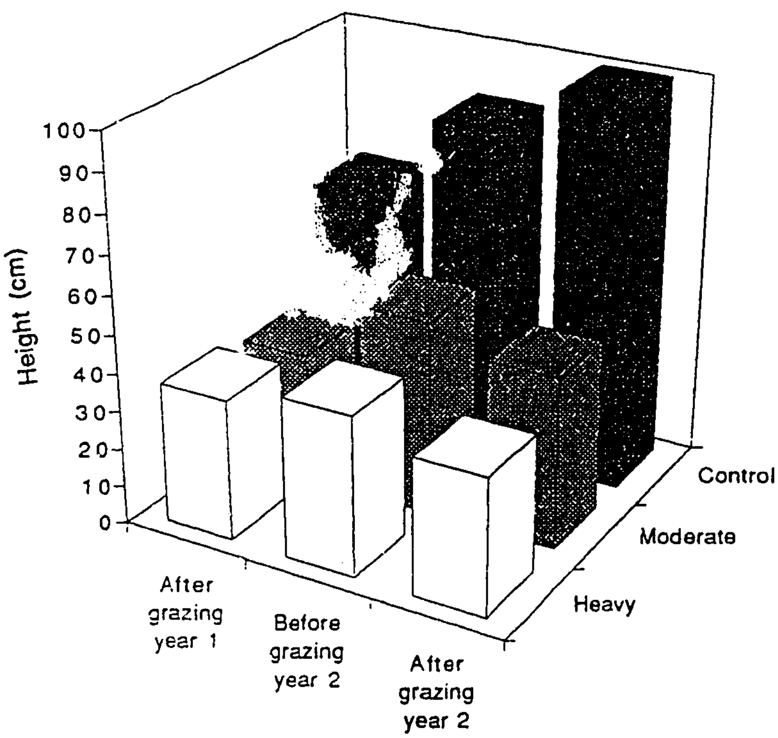

Figure 4.5 The effect of grazing treatment and time since burning on aspen sucker height (cm).

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V. THE EFFECT OF CATTLE GRAZING ON THE REGENERATION OF A HEALTHY SAPLING ASPEN FOREST FOLLOWING PRESCRIBED BURNING

INTRODUCTION:

Trembling aspen (*Populus tremuloides* Michx.) is the most widely distributed North American tree species (Mueggler 1985). It occurs in association with a wide diversity of vegetation types (Peterson and Peterson 1991, Mueggler 1985) and exists either as a seral species, replaced by conifers over time, or as a stable climax species. The diversity which occurs among various aspen associations makes management of this dynamic species a challenge.

Historically, fire played an important role in aspen stand dynamics (Gruell and Loope 1974, Bartos and Mueggler 1981, Bird 1961). However, since the settlement of western North America by European settlers, a policy of fire suppression (Bird 1961,Moss 1934), has removed the important influence of fire on aspen. Aspen is a relatively short-lived tree which normally relies on disturbance for rejuvenation. Without a major disturbance, aspen stands become over mature and tend to deteriorate (Schier 1975). In the western United States the deterioration of mature aspen stands is considered a serious management concern. The aspen forests of that region are highly valued for their multiple-use opportunities. They are important for wildlife habitat, forage production, watershed protection, recreation, esthetics and timber (DeByle 1985). If these important multiple use values are to be maintained, rejuvenation of mature and over mature stands is necessary.

In the Canadian Aspen Parkland, management goals and objectives differ from those in the Western United States (DeByle 1985, Mueggler 1985). The Aspen Parkland vegetation association is an area of transition between the open grassland prairie to the south and the boreal forest to the north (Sanborn and Pawluk 1983, Moss 1934). Historically, the frequent occurrence of fire and heavy browsing pressure by wildlife limited the development of aspen groves to the sites most suitable for tree growth. With European settlement of the Aspen Parkland, and the subsequent introduction of a policy of fire suppression, as well as the eradication of free ranging bison herds, invasion of aspen forests into the productive fescue grasslands of the region has resulted (Scheffler 1976, Bailey and Wroe 1974 Coupland and Maini 1961).

Aspen invasion results in a severe reduction in forage productivity (Bailey and Wroe 1974). Efforts have been made to convert forested sites back to a grassland shrubland community. Prescribed burning used in combination with controlled livestock grazing has been used successfully to achieve this goal (Bailey et al. 1990, Bailey 1986, FitzGerald and Bailey 1984, 1983). Burning top-kills trees and shrubs while controlled livestock grazing is used to control aspen forest regeneration.

In western North America, aspen rarely reproduces from seed; it depends on vegetative suckering from lateral root systems for regeneration (McDonough 1985, Graham et al. 1963, Baker 1918). Vegetative reproduction is normally suppressed by auxin mediated hormonal control from the overstory (Peterson and Peterson 1992, Schier et al. 1985, Schier 1978). Major disturbances such as clearcutting, or burning, disrupt the flow of auxins from the apical meristems to the roots altering the balance of the auxin to cytokinin ratio. This promotes vegetative suckering (Schier et al. 1985, Schier 1978), and a new aspen forest develops on the disturbed site (Bartos et al. 1991, Jones 1975, Baker 1925).

Healthy aspen forests tend to sucker prolifically following burning or clearcutting. Aspen sucker densities ranging from 34,000 - 271,800 stems per hectare have been reported in the first year following a major disturbance (Jones 1975, Jones and Trujillo 1975, Sampson 1919). On sites where aspen sucker densities are high, natural thinning during the first few years is heavy and results in substantial density reduction.(Schier et al. 1985, Smith et al. 1972, Sampson 1919). Competition between suckers is the major factor causing sucker mortality although disease, insects, mammals, and environmental factors also cause substantial sucker mortality (Schier et al. 1985). Bartos et al. (1983) suggested that initially following burning, 10,000 - 20,000 healthy suckers ha^{-1} may be required to ensure successful regeneration of a healthy aspen forest.

Browsing of young aspen suckers reduces growth, vigor and density (DeByle 1985). Sampson (1919) concluded that cattle grazing, which utilized 50-60% of the palatable forage, did not severely damage stands of regenerating aspen suckers whereas both Sampson (1919) and Smith et al. (1972) reported that similar levels of grazing by sheep damaged or killed most aspen suckers. Browsing pressure from high population densities of wildlife can also prevent successful aspen regeneration (Bartos et al. 1994, Mueggler and Bartos 1977, Krebill 1972).

Information is required concerning how aspen suckers respond to ungulate browsing, whether the management goal is rejuvenation of a mature stand, or the control of aspen invasion into grassland.

OBJECTIVES:

1. To determine the response of a healthy sapling aspen forest to prescribed burning.

2. To determine the effect of grazing intensity on density and height of aspen suckers following burning.

3. To determine the kinds and extent of damage by cattle to regenerating aspen suckers following burning.

STUDY AREA:

The study site (52°02"N latitude and 111°33"W longitude) was located on Kuntz Brothers' Farms, a private cattle ranch 160 kilometers east of Edmonton and approximately ten kilometers south of Minburn, Alberta.

Climate:

The climate is continental, characterized by warm summers and relatively cold winter temperatures (Wyatt et al. 1944). Average annual precipitation is 432mm with seventy five percent occurring during the growing season (May - September) as rain and 25% as snow during the dormant season (October-April) (Atmospheric Environment Services 1991). The average annual temperature is 1.9^{0} and the average frost free period is 100 days. The growing season begins between April 21 and 26, and averages between 165 and 170 days in length (Horton 1991).

On average, potential evapotranspiration exceeds precipitation for every month of the growing season except June, and the long term precipitation to potential evapotranspiration ratio during the growing season ranges between 0.65 and 1.1 (Horton 1991).

Geology:

The bedrock geology of the study area is of the Belly River formation (Howitt et al. 1988). This formation is made up of Upper Cretaceous rock (Wyatt et al. 1944), consisting of sandstones, mudstones and siltstones deposited in a non-marine environment (Howitt et al. 1988). The bedrock of the area is overlain with a thick layer of glacial till, which was deposited by the Keewatin ice sheet about 10,000 years ago (Wyatt et al. 1944). The topography of the study site is classified as morainal hummocky (Howitt et al. 1988). It is characterized by hummocks with short steep slopes and numerous pothole lakes or sloughs interspersed between hummocks. The topography is often referred to as Knob and Kettle. The Kettles (depressions) being formed when huge blocks of stagnant ice mixed with morainal material melted.

Soils:

The soils of the study site are dominated by well drained fine loams and are classified as Orthic Black Chernozems (Howitt et al. 1988). These soils occupy the mid and upper slope positions on the landscape. Soils of the lowland depressions, which make up 15 - 20% of the area, tend to be poorly drained and are either classified under the Gleysolic Order or under a gleyed Subgroup of the Chernozemic Order.

Vegetation:

The study site was located within the Aspen Parkland vegetation association. This association is a transitional zone between the grassland dominated Mixed Prairie Association to the south and the Boreal Forest Association to the north (Strong and Leggat 1992). The areas of the Aspen Parkland which have not been disturbed by cultivation are characterized by a mosaic of aspen groves and open grasslands. The aspen groves and their associated shrub communities have historically occupied the moister sites while grasslands occupied the drier more exposed sites. Today, because of the elimination of natural pyrogenic and anthropogenic forces (Dormaar and Lutwick 1966; Bird 1961), aspen and shrub communities have invaded onto soils that were historically dominated by grasslands. Aspen and its associated shrub species now occupy between 75 and 85 percent of the land area on the study site. The woody communities are dominated by trembling aspen (*Populus tremuloides* Michx.) western snowberry (*Symphoricarpos occidentalis* Hook.), wolf willow (*Elaeagnus commutata* Bernh.), common wild rose (*Rosa acicularis* Lindl. and Rosa *woodsii* Lindl.), wild raspberry (*Rubus idaeus* L.), gooseberry (*Ribes hirtellum* Michx.), saskatoon (*Amelanchier alnifolia* Nutt.), and choke cherry (*Prunus virginiana* L.). The most common understory grasses are smooth brome (*Bromus inermis* Leyss.), blue grasses (*Poa spp.* L.), and reed grasses (*Calamagrostis spp.* Adans.). The open grasslands which occupy south facing slopes and flat areas are dominated by a *Festuca - Stipa* plant community (Looman 1981). On ungrazed sites, plains rough fescue *Festuca halli* ((Vasey) Piper) predominates.

SITE SELECTION:

The study site was a 25 ha. area cleared of vigorous, mature aspen forest in the winter of 1983. In 1992, prior to prescribed burning, the area was dominated by groves of dense, vigorous aspen saplings 3-6 m tall.

METHODS:

In the spring of 1992, approximately 1/3 of the sapling aspen forest was prescribed burned. Burning was done on 17 April, 1992. The weather conditions at the time of burning were an air temperature of 19.7°C, 26% relative humidity, and a south east wind of 10 km h^{-1} gusting to 22 km^{h-1}. The high winds were necessary to carry the fire through the low understory fuel load, since much of the fuel was leaf litter.

Fire severity over most of the area was moderate with some localized areas only experiencing a light burn (Brown and DeByle 1987). Most of the leaf litter and fine woody material was consumed, shrubs were killed and most of their canopy consumed. Aspen saplings were extremely sensitive to fire, and mortality on moderately burned sites was nearly 100%. Following burning, four groves (sites) which met the standards of a selection criterion were randomly selected.

The selection criteria used to select sites for sampling was:

1. All sites to be sampled must have been burned uniformly.
2. Sites were located on gentle slopes to avoid environmental extremes.
3. Sites were large enough to contain a plot 33m long and 14m wide within an area of homogeneous vegetation.

On each site the following grazing treatments were established:

1. burned, ungrazed,
2. burned, moderately grazed (50% removal of herbaceous forage),
3. burned, heavily grazed (70% removal of herbaceous forage).

Cattle grazing of the burned sapling type was initiated on 6 July, 1992 and 1 July, 1993. The site which was approximately 25 hectares in size was grazed by a herd of 300 cow calf pairs for 5 days. The stocking rate was 2 AUM/ha^{-1}.

Data Collection:

On each forest type, the four groves (sites) were selected to provide four replications. Each site was subdivided into three macro plots of 11m by 14m. One grazing treatment was randomly applied to each macro plot. Within each macro plot six 1m by 1m permanent micro plots were established.

On 19 June, 1992 the 5 tallest suckers on each micro plot were individually marked, and the height of each recorded. Sampling dates were spring 1992 (late June), after grazing 1992 (mid July), spring 1993 (late June), after grazing 1993 (mid July). On all sampling dates, aspen sucker densities (suckers m^{-2}) and the height of the tallest sucker (cm) was recorded for each micro plot. The height, and whether or not mortality had occurred, was recorded for each of the marked aspen suckers. After the 1992 grazing, browsing damage (whether or not stems had been browsed; heavy browsing involved apical browsing and substantial stripping of foliage), trampling damage (scaring of the stem) and breakage that had occurred to marked suckers was noted. Where mortality had occurred, the probable cause of mortality was also recorded. In the spring of 1993, along with total aspen sucker densities, the density of both new aspen suckers and one year old suckers were recorded separately.

Experimental Design and Data Analysis:

The experimental design used was a split plot (Steel and Torrie 1980). Whole plots consisted of four groves of aspen saplings (sites), and three grazing treatments per site. The split plot consisted of four sampling dates. From each grazing treatment (macro plot), six permanent micro plots were sampled.

Changes in the density and height of aspen suckers under the three grazing treatments over time were analyzed using repeated measures analysis. Sources of variation for analysis of aspen density and height were: sites (s=4), grazing treatments within site (t=3), micro plots within grazing treatment (m=6), and date as the repeated measure (d=4).

Analysis of the data collected from the individually marked suckers (height, browsing damage, trampling damage, breakage, and mortality) was analyzed as a completely randomized block. Sources of variation were: sites (s=4), grazing treatments within site (t=3), and micro plots within sites (m=6). Damage was recorded as a percentage of the marked suckers. An arcsine transformation was applied to the data. Since the transformation did not affect the analysis results, the actual means are presented for ease of interpretation.

RESULTS:

Aspen suckering was prolific after burning. Two months after burning, aspen sucker densities averaged 15.8 stems m^{-2} (Figure 5.1). Average aspen sucker density peaked at the end of the first growing season after the spring burn, and then declined over time. Grazing also influenced aspen sucker density (Figure 5.1) in that densities decreased when a grazing treatment was introduced. There did not, however, appear to be any difference between the effects of moderate and heavy grazing on aspen sucker density. The main effects of time and grazing treatment explained the variation in aspen sucker densities. There was no significant grazing treatment by time interaction.

Grazing treatments affected the age of the aspen suckers (Table 5.1). In the second spring following burning (June 1993), ungrazed sites were dominated by one year old aspen suckers, whereas the moderate and heavily grazed sites were dominated by new aspen suckers and the total aspen sucker density was lower. Similar numbers of new aspen suckers were produced under all grazing treatments.

Heights of the tallest aspen suckers were influenced by a significant sampling date-by-grazing treatment interaction (Table 5.2). On ungrazed sites, height of the tallest aspen suckers consistently increased over time. Grazing treatments restricted height growth of the tallest aspen suckers, with heavy grazing being more effective than moderate grazing. However, when the average aspen sucker heights were analyzed (Table 5.3), the effect of moderate grazing was the same as heavy grazing.

As grazing intensity increased, the level of browsing also increased (Table 5.4). Ninety five percent of the aspen suckers were browsed under heavy grazing. The percentage of aspen suckers which had basal scarring, caused by trampling, or broken stems were similar for both moderate and heavy grazing treatments (Table 5.4). Approximately 40% of the suckers which were present at the start of the study were broken after the first grazing. Trampling caused damage in the form of a basal scar on approximately 25% of the aspen suckers. Basal scars ranged in size from minor abrasions to almost complete girdling of the sucker.

Following the first grazing treatment, 100 percent of the aspen sucker mortality which had occurred on the ungrazed controls, was due to unknown causes (Table 5.5). On the grazed sites most aspen sucker mortality was due to breakage. Slightly greater than 50% of the suckers which had been broken were either consumed or removed from the site. Less than 10% of sucker mortality was directly attributed to livestock trampling (Table 5.5). However, trampling was only recorded as the cause of mortality where it could be positively identified as the cause.

By the second spring following burning (July 1993), total aspen sucker mortality was 25, 70 and 89% for the ungrazed, moderately grazed and heavily grazed sites, respectively (Table 5.6). Mortality during the first winter tended to be greater on the heavily grazed sites than it was on the moderately grazed sites.

DISCUSSION:

Over time, aspen sucker densities declined on all sites, including those which had not been grazed. Later developing aspen suckers were suppressed by the dominant suckers. The larger suckers out competed the smaller suckers for light, water and nutrients (Peterson and Peterson 1992, Jones 1983), causing high levels of mortality. On the ungrazed sites, personal observations indicated that small mammal damage and disease were also responsible for substantial sucker mortality. The ungrazed sites became refuges for very high densities of rodents and lagomorphs after grazing removed most of the cover from grazed sites. These small mammals consumed a high percentage of the new suckers which developed. Rodent damage to young aspen suckers has been reported to be a major cause of aspen sucker mortality (DeByle 1985, Lucas 1969).

Disease caused substantial mortality to the aspen suckers. In June 1993 the ungrazed sites were infected by the fungus *Venturia macularis* causing an epidemic of aspen leaf and twig blight disease (Hiratsuka 1987, Anderson and Anderson 1980). This disease infects young shoots, causing disfiguration and reducing growth. On ungrazed sites, leaf and twig blight infected between 70 and 85% of the aspen suckers, and a significant number of those infected died. On grazed sites, however, leaf and twig blight infection was not as serious and less than 25% of the aspen suckers were infected.

Cattle grazing effectively reduced aspen sucker densities. By the fall of the second year following burning, aspen sucker density on grazed sites was approximately 55% of ungrazed sites. However, even after two years of grazing, aspen sucker densities were still greater than 80,000 suckers/ha^{-1}. Normally such aspen sucker density would be considered sufficient for successful regeneration of a new aspen forest (Bartos et al. 1983). However, in this study, even though aspen sucker density was still high after two years grazing, it was the author's opinion that if the grazing treatments were continued, the prognosis for successful aspen forest regeneration would be poor.

This opinion is supported by an earlier study by FitzGerald and Bailey (1984) which reported that after two years of heavy, early season grazing, aspen sucker density remained high. A follow up paper, by Bailey et al. (1990), however, reported that after seven years of heavy, early season grazing, aspen had been virtually removed from the plant community.

Grazing not only reduced the density of aspen suckers, it also changed the age dynamics of the stands. Grazed sites were dominated by aspen suckers which developed during the second spring or during the fall of the first year after grazing had occurred. Only 10-30 percent of the suckers which were present prior to the first grazing remained after the first winter.

Grazing induced mortality was similar for both moderate and heavy grazing treatments. However, it appeared that the suckers on the heavily grazed sites were more susceptible to mortality during winter than were moderately grazed suckers. FitzGerald and Bailey (1984) found that heavy grazing late in the growing season was effective in eliminating aspen suckers after only one year. They hypothesized that late season browsing prevented development of winter dormancy in browsed stems leaving them susceptible to winter kill. In the present study, although late season grazing was not used, high percentages of the heavily browsed suckers not directly killed by browsing were stressed severely enough that they did not survive the winter. Winter survival appeared to be related to the severity of browsing in the previous growing season. Several studies have reported that sucker mortality increased with the severity of browsing damage (Bailey and Arthur 1985, Krebill 1972, Smith et al. 1972, Sampson 1919)

Grazing maintained aspen suckers at a lower height, within the reach of browsing cattle. Repeated browsing of these suckers wi" continue to stress the young trees and will make them susceptible to disease and other secondary causes of mortality (Krebill 1972, Patton and Jones 1977). When aspen suckers are protected from browsing or are browsed only lightly, they normally attain a height where their crowns are out of the reach of browsing ungulates (2.5 - 3.0m) within 3 - 7 years (Crouch 1983, Patton and Jones 1977, Patton and Avant 1970). However, repeated heavy browsing can prevent aspen suckers from reaching a height taller than 1m (Krebill 1972) and can lead to a gradual depletion of non structural carbohydrates in the roots (Schier 1976), which can weaken the sucker and reduce its chances of survival (DeByle 1985).

First year aspen suckers whose stems had not begun to lignify were palatable forage (Chapter 3). These young shoots were susceptible to damage or breakage from the time of emergence until their stems lignified. It is during this period that aspen suckers are extremely prone to browsing induced mortality (Bailey and Arthur 1985, DeByle 1985, Smith et al. 1972).

The severe impact that cattle grazing had on regenerating aspen was due in part to the high stocking densities used in this study. Three hundred cow calf pairs grazed the 25 ha site for 5 days. These high stocking rates likely increased the damage which occurred to the aspen suckers. Damage to aspen suckers on sites where ungulates congregate in high densities is usually severe, and often prevents the successful regeneration of the aspen forest (Crouch 1983, Meuggler and Bartos 1977, Sampson 1919). However, in the present study it is believed that damage to the succulent unlignified suckers which dominated the site in the first year following burning, would have been severe even if the stocking rates were lower because these tender shoots were a preferred forage. Once these aspen suckers developed a lignified stem they appeared to become more resistant to browse induced mortality.

The current study shows that grazing management can play an important role in aspen forest regeneration following prescribed burning. On sites where aspen control is desired, heavy stocking rates and moderate to heavy grazing intensities initiated in the first year, before aspen sucker stems have started to lignify, will work effectively to control aspen sucker densities and maintain those that remain at a height where their forage production is usable. By deferring grazing until aspen sucker stems have become lignified and / or by controlling livestock densities and promoting good animal distribution, successful aspen regeneration should be possible following the burning of healthy aspen stands.

In the above study the goal had been to control aspen regeneration following a prescribed burn. An intensive grazing system was established, in which a large number of animals were concentrated on a relatively small land base. Under these situations as long as the grazing treatments were continued aspen regeneration could be effectively controlled. However, even after two years of the grazing treatments, there was evidence that if the grazing treatments were either discontinued or if a less intensive form of grazing management was used aspen would have likely regenerated successfully.

Tables 5.1 The effect of grazing treatment on sucker density of different aged suckers in June 1993, the second spring following burning.

Grazing Treatments	Suckers which developed during the first year	Suckers which developed in the spring of the second year
	(stems m^{-2})	(stems m^{-2})
Control	18.2^{ay1}	5.3^{az}
Moderate	9.3^{by}	4.8^{ay}
Heavy	6.5^{by}	5.0^{ay}
SEM	1.83	1.83
P>F^{2}	0.05	

1 Means within the same columns followed by the same letter (a,b,c) and means within the same rows followed by the same letter (y,z) are not significantly different (P<0.05).
2 Probability of a grazing treatment by sucker age interaction

Table 5.2 Changes in height of the tallest aspen suckers over time under three grazing treatments.

Sampling date	Control	SEM	Moderate	SEM	Heavy	SEM
	(cm)		(cm)		(cm)	
June 1992	29.2^{cx1}	2.90	26.6^{cx}	2.90	33.3^{bx}	2.90
August 1992	72.9^{bx}	2.90	35.1^{cy}	3.10	31.9^{by}	2.96
June 1993	90.6^{ax}	2.90	61^{ay}	2.90	48.6^{az}	2.90
August 1993	95.1^{ax}	2.90	49.4^{by}	2.90	36.3^{bz}	2.90
P>F^{2}	0.0001					

1 Means within the same columns followed by the same letter (a,b,c) and means within the same rows followed by the same letter (x,y,z) are not significantly different (P<0.05).
2 Probability of a significant sampling date by grazing treatment interaction

Table 5.3 The effect of grazing treatment on average aspen sucker height on three different sampling dates.

Grazing Treatment	June 1992	August 1992	June 1993
	(cm)	(cm)	(cm)
Control	22[a1]	57[a]	71[a]
Moderate	20[a]	30[b]	38[b]
Heavy	24[a]	30[b]	38[b]
SEM	2.1	2.2	2.8
P>F	0.55	0.0002	0.0002

1 Means within the same columns followed by the same letter (a,b,c) are not significantly different (P<0.05).

Table 5.4 Cattle damage (%) of three month old aspen suckers caused by three grazing treatments, following burning.

Grazing Treatment	Browsed suckers	Heavily browsed suckers	Basal scarring	Broken stem
	(%)	(%)	(%)	(%)
Control	0[c]	0[c]	0[b]	0[b]
Moderate	81[b]	27[b]	28[a]	38[a]
Heavy	95[a]	44[a]	23[a]	40[a]
SEM	3.5	5.1	5.0	5.4
P>F	0.0001	0.0001	0.0004	0.0001

1 Means within the same columns followed by the same letter (a,b,c) are not significantly different (P<0.05).

Table 5.5 Causes of aspen sucker mortality under different grazing treatments after 1992 grazing.

Grazing Treatment	Broken	Removed	Trampled	Unknown
	(%)	(%)	(%)	(%)
Control	0^{b}	0^{b}	0^{a}	100^{a}
Moderate	70^{a}	42^{a}	7^{a}	30^{b}
Heavy	61^{a}	32^{a}	7.5^{a}	39^{b}
SEM	7.5	7.5	4.8	7.5
P>F	0.001	0.047	0.76	0.001

1 Means within the same columns followed by the same letter (a,b,c) are not significantly different (P<0.05).

Table 5.6 The effect of grazing treatment on aspen sucker mortality.

Grazing Treatment	Suckers which died after 1st grazing	Suckers which died during 1st winter	Total mortality after 1st winter
	(%)	(%)	(%)
Control	5^{b}	20^{b}	25^{c}
Moderate	40^{a}	29^{ab}	70^{b}
Heavy	47^{a}	42^{a}	89^{a}
SEM	5.1	5.4	4.7
P>F	0.0001	0.016	0.0001

1 Means within the same columns followed by the same letter (a,b,c) are not significantly different (P<0.05).

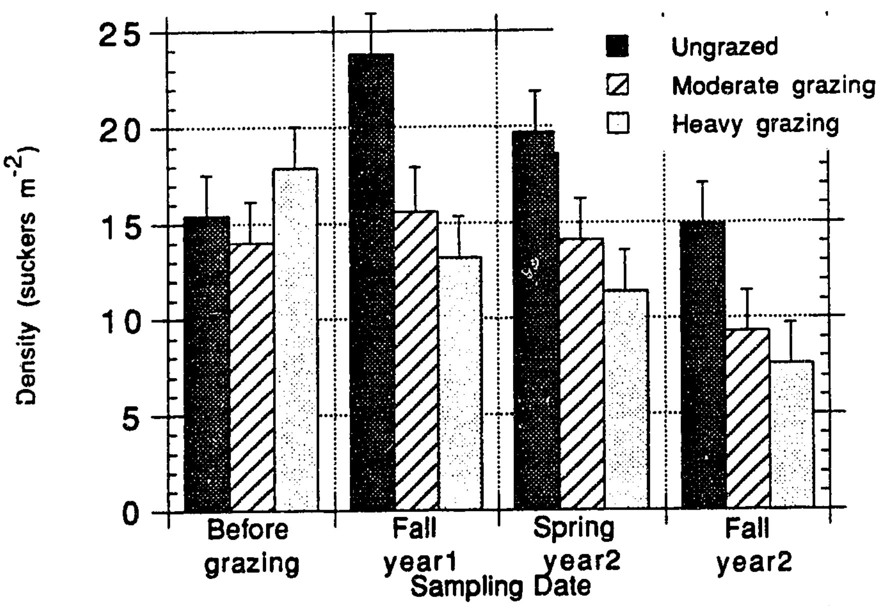

Figure 5.1 The effect of grazing treatment on aspen sucker density over time. Bars represent standard errors of the mean.

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VI. SHOOT PRODUCTION FROM EXCISED ASPEN ROOTS OF MATURE DECADENT, AND HEALTHY SAPLING ASPEN FORESTS GROWN UNDER ETIOLATED CONDITIONS

INTRODUCTION:

In western North America, aspen (*Populus tremuloides* Michx.), rarely reproduces by seed. Instead it regenerates by adventitious root suckers which originate along lateral roots (Peterson and Peterson 1992, Schier et al. 1985, Schier 1976). Most root suckers develop from newly initiated meristems, or preexisting suppressed shoot primordia (Schier 1973). The development of new suckers is influenced by hormonal control, soil temperature, and root carbohydrate reserves (Schier et al. 1985).

Apical dominance, mediated by auxin hormones, is one of the major factors controlling aspen suckering (Schier 1976). Auxins produced by meristematic tissues in the tree top, are translocated to the root system where they suppress sucker development (Schier 1985, Schier et al. 1985, Steneker 1974). Auxins are relatively unstable hormones that are rapidly inactivated (Eliasson 1971), therefore, if the influence of apical dominance is to be maintained, the supply of auxin to the root must be continuous. Cytokinins are growth promoting hormones produced in the root meristems, which promote aspen sucker development (Schier et al. 1985). The ratio of cytokinins to auxins in the roots influences aspen sucker development. When the ratio of cytokinins to auxins is high, sucker development is promoted, whereas when this ratio is low, sucker development is suppressed. Normally, auxins are present in roots in sufficient quantities to suppress shoot development. However, cutting or killing the above ground stems interrupts the movement of auxins into the roots, increasing the cytokinin to auxin ratio, promoting aspen shoot development.

Soil temperature is also important in controlling aspen suckering (Zasada and Schier 1973, Maini and Horton 1966). Low soil temperatures inhibit sucker formation, while high soil temperatures stimulate sucker formation and promote sucker growth. High soil temperatures can also promote the degradation of auxins in the roots effectively altering the cytokinin to auxin ratio such that sucker formation is favored (Schier 1985; 1976).

Once aspen shoot development has been initiated, root carbohydrate reserves supply the energy necessary for bud development and shoot out growth (Schier et al. 1985, Schier and Zasada 1973, Zahner and DeByle 1965). Root carbohydrate reserves supply the energy requirements for the developing sucker until it emerges from the soil surface and develops a photosynthetic system capable of supplying it's energy needs. Young aspen suckers are heavily dependent on the parent root system even after their leaves begin to photosynthesize (Baring 1988, Zahner and DeByle 1965). Repeated destruction of new aspen suckers by browsing, cutting, burning, or herbicides may result in the exhaustion of root carbohydrate reserves (Schier et al. 1985), reducing the ability of the parent root system to produce more suckers (Schier et al. 1985, Sampson 1919, Baker 1918).

Most aspen suckers develop from lateral roots growing within 12 cm of the soil surface (Peterson and Peterson 1992, Schier and Campbell 1978). High fire intensities kill near surface roots forcing an increase in the depth of the parent roots from which suckers are initiated (Schier et al. 1985, Schier and Campbell 1978). Parent roots that produce suckers range in diameter from 0.1 cm - 9 cm, with the vast majority of suckers being produced by roots smaller than 3 cm in diameter (Peterson and Peterson 1992, Schier et al. 1985, Schier and Campbell 1978). It does not appear that either distance from the parent tree, or root age regulate suckering (Schier et al. 1985).

There are large differences among aspen clones in their ability to sucker (Schier et al. 1985, Schier and Zasada 1973, Farmer 1962). Genotype plays an important role in suckering ability, however, non genetic factors such as clone history, stem age, clone age from seed, site, and health of the clone also have an important influence (Schier 1976). When aspen stands become overmature, there is a tendency for them to deteriorate. Deteriorating mature aspen clones tend to produce fewer suckers after a disturbance than do healthy clones (Mueggler 1989).

Etiolated growth is the process whereby plants are grown in the absence of light (Salisbury and Ross 1978). This technique can be used to estimate plant vigor (Edwards 1965). When excised roots are grown under etiolated conditions, the only source of energy available to produce and support the growth of new shoots are the energy reserves of the root. Research has shown that etiolated regrowth is not necessarily well correlated with the TNC (total nonstructural) reserves of the roots (McKenzie et al. 1988, Richards and Caldwell 1985). Stout (1984) postulated that the poor correlation between TNC and etiolated growth was because etiolated growth reflected all stored food reserves which included carbohydrates, fats and proteins.

In the Aspen Parkland of Central Alberta, drought and forest tent caterpillar (*Malacosoma disstria* Hubner.) epidemics during the late 1980's and early 1990's have resulted in substantial deterioration of aspen groves (Chapter 1). Unlike the deteriorating aspen groves of the Western United States (Schier 1975), the Aspen Parkland groves are not over mature; most groves are dominated by trees between 30 and 60 years of age. A study comparing the suckering ability of these deteriorating aspen groves with adjacent stands of healthy sapling aspen showed that the deteriorating groves produce fewer suckers than the healthy sapling forest (Chapter 4). It was hypothesized that one of the factors affecting the ability of the deteriorating groves to produce aspen suckers was the repeated defoliations by forest tent caterpillars. Aspen trees were forced to expend substantial amounts of their energy reserves to refoliate following defoliation, stressing the energy reserves of the clones thus reducing suckering ability.

In a previous paper (Chapter 4), it was found that under natural conditions the sapling forest type suckered prolifically following burning, producing 24 suckers m^{-2}, while the decadent forest only produced 1 sucker m^{-2}. A study was designed to compare how roots from these two forest types sprouted under etiolated conditions, and to determine some of the factors which may influence the suckering ability of the two forest types.

OBJECTIVES:

1. To compare the ability of excised roots from mature decadent and healthy sapling aspen forest to produce aspen suckers under etiolated conditions.
2. To compare the total non structural carbohydrate reserves of excised roots from the mature decadent and healthy sapling aspen forests.
3. To determine if burning and one season of heavy livestock grazing had an effect on total nonstructural carbohydrates or the ability of excised aspen roots to sucker.

STUDY AREA:

The study site (52°02"N latitude and 111°33"W longitude) was located on Kuntz Brothers' Farms, a private cattle ranch 160 kilometers east of Edmonton and approximately ten kilometers south of Minburn, Alberta.

Climate:

The climate is continental, characterized by warm summers and relatively cold winter temperatures (Wyatt et al. 1944). Average annual precipitation is 432mm with seventy five percent occurring during the growing season (May - September) as rain and 25% as snow during the dormant season (October-April) (Atmospheric Environment Services 1991). The average annual temperature is 1.9^{0} and the average frost free period is 100 days. The growing season begins between April 21 and 26, and averages between 165 and 170 days in length (Horton 1991).

On average, potential evapotranspiration exceeds precipitation for every month of the growing season except June, and the long term precipitation to potential evapotranspiration ratio during the growing season ranges between 0.65 and 1.1 (Horton 1991).

Geology:

The bedrock geology of the study area is of the Belly River formation (Howitt et al. 1988). This formation is made up of Upper Cretaceous rock (Wyatt et al. 1944), consisting of sandstones, mudstones and siltstones deposited in a non-marine environment (Howitt et al. 1988). The bedrock of the area is overlain with a thick layer of glacial till, which was deposited by the Keewatin ice sheet about 10,000 years ago (Wyatt et al. 1944). The topography of the study site is classified as morainal hummocky (Howitt et al. 1988). It is characterized by hummocks with short steep slopes and numerous pothole lakes or sloughs interspersed between hummocks. The topography is often referred to as Knob and Kettle. The Kettles (depressions) being formed when huge blocks of stagnant ice mixed with morainal material melted.

Soils:

The soils of the study site are dominated by well drained fine loams and are classified as Orthic Black Chernozems (Howitt et al. 1988). These soils occupy the mid and upper slope positions on the landscape. Soils of the lowland depressions, which make up 15 - 20% of the area, tend to be poorly drained and are either classified under the Gleysolic Order or under a gleyed Subgroup of the Chernozemic Order.

Vegetation:

The study site was located within the Aspen Parkland vegetation association. This association is a transitional zone between the grassland dominated Mixed Prairie Association to the south and the Boreal Forest Association to the north (Strong and Leggat 1992). The areas of the Aspen Parkland which have not been disturbed by cultivation are characterized by a mosaic of aspen groves and open grasslands. The aspen groves and their associated shrub communities have historically occupied the moister sites while grasslands occupied the drier more exposed sites. Today, because of the elimination of natural pyrogenic and anthropogenic forces (Dormaar and Lutwick 1966; Bird 1961), aspen and shrub communities have invaded onto soils that were historically dominated by grasslands. Aspen and its associated shrub species now occupy between 75 and 85 percent of the land area on the study site. The woody communities are dominated by trembling aspen (*Populus tremuloides* Michx.) western snowberry (*Symphoricarpos occidentalis* Hook.), wolf willow (*Elaeagnus commutata* Bernh.), common wild rose (*Rosa acicularis* Lindl. and Rosa *woodsii* Lindl.), wild raspberry (*Rubus idaeus* L.), gooseberry (*Ribes hirtellum* Michx.), saskatoon (*Amelanchier alnifolia* Nutt.), and choke cherry (*Prunus virginiana* L.). The most common understory grasses are smooth brome (*Bromus inermis* Leyss.), blue grasses (*Poa spp.* L.), and reed grasses (*Calamagrostis spp.* Adans.). The open grasslands which occupy south facing slopes and flat areas are dominated by a *Festuca - Stipa* plant community (Looman 1981). On ungrazed sites, plains rough fescue *Festuca halli* ((Vasey) Piper) predominates.

SITE SELECTION:

The study site consisted of a half section (130 ha.) of native rangeland dominated by mature decadent aspen forest (decadent), and an adjacent 25 hectare field which was dominated by a healthy sapling aspen forest (sapling). The decadent forest was dominated by 30 to 60 year old aspen trees which were left in a declining and decadent state following the droughts and tent caterpillar epidemics of the late 1980's and early 1990's. The sapling forest, located adjacent to the declining decadent forest, was dominated by dense vigorous aspen saplings 3 - 6 m tall. It developed after mature aspen groves were cleared by bulldozer in 1983. During the tent caterpillar epidemics, the sapling forest type was not seriously defoliated by forest tent caterpillars[1].

METHODS:

Etiolated growth study:

The study involved two aspen forest types (mature decadent and healthy sapling), and two treatments for each forest type (burned & grazed, and control). The burned and grazed treatment involved prescribed burning the forests in the

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[1] Doyle and Norman Kuntz, Personal communication April 1992.

spring of 1992 (20 April) and heavily grazing (70 percent utilization of the herbaceous forage) the aspen regeneration in early July, 1992. The control treatment was a forest undisturbed by these treatments. On 17 April, 1993, prior to the breaking of winter dormancy, four aspen groves were randomly selected from each forest type by treatment combination. From each grove, 15 lateral roots that appeared to be alive, healthy, undamaged, and growing at a depth $<$ 25 cm from the soil surface were randomly selected and excised from the ground. From each root a 50 cm undamaged segment with a diameter between 0.5 and 3.0 cm was collected. Roots were kept moist and were stored in a cold room (4°C) overnight. The following day the roots were washed free of soil and both ends trimmed to a length of approximately 35 cm. Each root segment was weighed to determine fresh weight, actual length was measured and the diameter of each segment was measured at the ends and the centre to estimate the average diameter.

Root segments were soaked in a 5% bleach solution for 5 minutes to reduce pathogen activity, then rinsed in sterile water, and the ends of each segment sealed with molten paraffin. The root segments were planted at a 1.5 cm depth in trays of moistened vermiculite. All trays were treated with a 0.025% solution of Oxine Benzoate to reduce dampening off of the shoots. Trays were covered with lids to control evaporation and placed in a darkened growth chamber. Roots were grown under a 16 hour, 25°C day and an 8 hour, 16°C night cycle with a relative humidity of 90%. Trays were inspected bi-weekly under low intensity light to determine growth and moisture status. By Day 23, aspen shoots had become tall enough for covers to be removed. On Day 54, the shoots from each root were harvested, and shoot density per root was determined. The aspen shoots from each root were dried (70°C) for 48 hours and dry weight determined.

Following harvest, the roots were again planted in trays of moistened vermiculite and were grown out once again following the same procedure. By Day 87 of the study, many shoots had begun to brown off and die; the shoots from each root were harvested, the density of shoots/root, and the dry weight of the shoots produced by each root were determined.

Total nonstructural carbohydrate analysis:

At the beginning of the study, a 5 cm sample was taken from each root. Root samples were oven dried (70°C), for 96 hours. The 15 root samples from each grove were grouped and ground to 40-mesh size in a Wiley mill. The ground samples were well mixed and four 200 mg sub-samples were taken. Soluble carbohydrates were determined from the 200 mg sub-samples by hydrolysing glucosans and sucrose sugars in 0.2N H_2SO_4 (Suzuki 1971). Sugar concentrations were determined by a phenol sulfuric colorimetric method using a glucose standard (Dubois et al. 1956). Carbohydrate content was expressed as a percent of dry matter.

Experimental Design and Data Analysis:

The experimental design used was a completely randomized design (Steel and Torrie 1980). There were two forest types (mature decadent and healthy sapling), There were two treatments, (burned & grazed, and control) and four groves (sites) per treatment per forest type. Fifteen roots were collected from each grove.

Sources of variation for analysis of data from the etiolated growth study were: forest (f=2), treatment (t=2), forest by treatment interaction, and sites within forest by treatment (s=4). In the analyses, root volume, which was calculated from individual root length and diameter was used as a covariate to adjust roots to a common volume of 72.5 cm^3. Volume was selected as a covariate because it took into account variations which occurred between individual roots in both length and diameter.

Sources of variation for analysis of data from the total non structural carbohydrate analyses were: forest (f=2), treatment (t=2), the forest by treatment interaction, sites within forest by treatment (s=4), and roots within site by forest by treatment (r=15). Linear correlations between total non structural carbohydrate content and shoot density/root or total shoot weight /root were calculated using a Pearson correlation.

Computations for statistical analysis were made using the above models in the GLM procedure of SAS (SAS Institute, Inc. 1989). In the presence of a significant F test, Fisher's protected LSD was used to determine differences ($P<0.05$) among means.

RESULTS:

Etiolated Growth Study:

Roots used in this study averaged 35.3 cm in length, 1.5 cm in diameter and 72.5 cm^3 in volume. Root length, diameter, and volume did not differ significantly ($P<0.05$) between forest type, treatment or forest type by treatment interaction. However, root weight was affected by a forest type by treatment interaction (Table 6.1). The heaviest roots were from the control treatment of the sapling forest (67.9 g), while the lightest roots came from the grazed and burned treatment of the sapling forest (33.9 g). In the decadent forest there was no difference in root weight between treatments.

Root length, root diameter and root volume were analyzed for their suitability as covariates to standardize roots. Root volume was the most suitable covariate as it adjusted values to account for variations between roots in both diameter and length. When volume was used as a covariate, it primarily adjusted for within site variations in root volume introduced during root collection. The covariate adjusted all roots to a common volume of 72.5 cm^3.

The sapling forest produced more aspen shoots per root than the decadent forest (Table 6.2). Total shoot production was 24.7 and 15.8 shoots per standardized root (72.5 cm^3) for the sapling and decadent forest types, respectively. The total weight of shoots produced by roots from the sapling forest was not significantly greater than the weight of shoots produced by roots from the decadent forest (Table 6.3). The average individual shoot weight was 0.019 and 0.016 g for the decadent and sapling forest, respectively, a non significant difference ($p<0.05$).

Burning the aspen forest, followed by heavy grazing of the aspen regeneration the year before root collection resulted in fewer shoots being produced per root, as compared to the control (Table 6.4). The burned and grazed treatment produced 43% as many shoots per root as the controls on the first harvest date, and less than 10 percent on the second harvest date. The total weight of shoots per root followed the same pattern as shoot density with the heaviest shoot production coming from the control treatment (Table 6.5). The average individual shoot weight was similar for the two treatments and averaged 0.018 and 0.016 g/shoot for the control and burned and grazed treatments, respectively.

Both forest types responded similarly to the two treatments, therefore there was no significant forest type by treatment interaction for shoot density per root (Figure 6.1) or for total shoot weight per root (Figure 6.2).

Total nonstructural carbohydrates (TNC):

The mean TNC was not significantly different between the two forest types (Table 6.6). However, burning and grazing treatment did reduce TNC (Table 6.7). Total nonstructural carbohydrates averaged 26.1 and 19.7% for the control and burned and grazed treatments, respectively. There was no significant forest type by treatment interaction (Figure 6.3).

Root total nonstructural carbohydrate (TNC) content was linearly correlated with the density of shoots produced per root R=0.76 (Y= -22.4 + 1.86x) (Figure 6.4) and with the total weight of shoots produced per root R=0.62 (Y=-0.37 + 0.030x) (Figure 6.5). The forest by treatment combinations which had the lowest total soluble carbohydrates also produced the lowest density and weight of shoots per root. There was considerable variation between sites, within each forest by treatment combination, in the relationship of TNC with either shoot density or shoot weight (Figure 6.4 & 6.5). When the mean values for each forest by treatment combination were analyzed, the correlations between TNC and shoot density per root or total shoot weight per root improved to 0.98 and 0.97, respectively.

DISCUSSION:

Differences between the mature decadent and the healthy sapling forest:

This study presents evidence that low root energy reserves may have limited aspen suckering in the mature decadent forest. It was found, however, that TNC reserve variance insufficiently explained the suckering differences which occurred between the forest types under natural conditions.

When roots were being collected, it was noted that in the decadent forest there was a high percentage of dead and decaying roots. Schier (1975) hypothesized that when stems in deteriorating clones weaken and die, the root systems also die back because the reduced crown area cannot channel sufficient photosynthate to the roots. In the current study, it was noted that in the decadent forest most of the dead and decaying roots were close to the soil surface, while healthy roots were normally found at depths below 15 cm from the soil surface. Conversely, in the sapling forest, healthy roots were common very close to the soil surface. Schier and Zasada (1973) stated that because sucker growth in darkness is affected by root carbohydrate concentration, the number of suckers appearing above the soil surface should be positively correlated with the level of TNC reserves. Schier and Zasada's ideas can be carried further to assume that suckers developing from deeper roots place a greater demand on energy reserves than suckers from shallow roots. Therefore, the effect of low carbohydrate reserves on suckering would be expressed more strongly on sites where the parent roots were eeper.

The effects of burning and grazing:

On both forest types, one season of heavy grazing following prescribed burning greatly reduced the ability of aspen roots to sucker compared to roots from untreated groves. Burning and grazing not only reduced the density of new suckers but also reduced the biomass produced by each root.

On the burned and grazed treatment, the removal of apical dominance by burning, in 1992, would have stimulated aspen suckering (Schier 1985, Schier et al. 1985, Steneker 1974). New aspen suckers are totally dependent on the TNC reserves of the parent roots until they develop a self supporting photosynthetic system (Schier and Zasada 1973, Zahner and Debyle 1965). This would reduce the energy reserves of the parent roots (Gardner et al. 1985).

When grazing was applied the new suckers were heavily browsed, before the TNC reserves had been replenished. Browsing caused significant sucker mortality and stimulated new sucker development which further depleted the carbohydrate reserves of the parent roots. There was no opportunity for these roots to replenish depleted carbohydrate reserves before they were collected and grown out in the dark.

In field studies, repeated destruction of new aspen suckers by browsing, cutting, burning, or herbicide spraying, can drastically reduce the ability of the parent root system to produce more suckers (Bailey et al. 1990, Schier et al. 1985, Sampson 1919, Baker 1918). It is widely accepted that this reduction in the ability of aspen to sucker is caused by the exhaustion of root carbohydrate reserves (Schier et al. 1985). When roots which had received the burned and grazed treatment were excised and grown out in the dark, TNC was the only source of energy available (Schier and Zasada 1973), it would appear that because their TNC reserves had been depleted they did not sprout as vigorously as roots from untreated sites.

The relationship between total nonstructural carbohydrates and aspen sucker production:

Within each forest by treatment combination there was substantial variation in the relationship of TNC content with both the average density of shoots produced/root and the total weight of shoots produced/root. This variation caused shoot density/root and total shoot weight/root to be poorly correlated with TNC within each forest by treatment combination. However, when all the forest by treatment combinations were analyzed together, the density of shoots produced/root and the total weight of shoots produced/root were positively correlated with the percentage of TNC available. The strongest association between TNC and either shoot density/root or total shoot weight/root was developed by correlating the mean TNC with the mean shoot density/root or mean total shoot weight/root of each forest by treatment combination. This correlation emphasized how conditions which caused TNC reserves to decrease reduced the ability of aspen forests to regenerate through vegetative suckering.

In a similar study, Schier and Zasada (1973) studied the role of carbohydrate reserves in the development of root suckers in aspen clones and found no correlation between TNC and shoot density. However, they postulated that with TNC concentrations above or below the range they looked at, TNC may significantly affect sucker production. Schier and Zasada (1973) did find that individual shoot weight was a function of TNC levels and the number of suckers produced. As the density of shoots produced increased, the total amount of dry weight produced also increased but individual shoot weight decreased. In the current study, individual shoot weight was not well correlated with either TNC or density of shoots produced and average individual shoot weight was similar between the two treatments. However, at both harvest dates, many shoots that were produced by roots with lower TNC contents (roots from the burned and grazed treatment), were beginning to brown off and die while shoots on the roots with higher TNC levels remained healthy. It is likely that the shoots on the higher TNC roots would have continued to grow after shoots on the lower TNC roots had died.

During root collection, it was noted that a significant number of roots appeared to be unhealthy or dead on the burned and grazed sapling treatments, while all roots on the control sapling treatments appeared healthy. FitzGerald and Bailey (1984) reported that after one year of heavy late season grazing, aspen reproduction by vegetative suckering was virtually eliminated.

They hypothesized that late season grazing prevented the roots from developing winter dormancy characteristics and caused them to be susceptible to winter kill. In the present study, the burning and grazing treatment may have stressed these roots to cause their deterioration over winter.

At the time of collection, roots of similar volumes from the different forest by treatment combinations had large differences in average root weight. Root weight was heaviest from the control sapling forest. These roots also produced the greatest number of shoots under etiolated conditions and had the highest root TNC content. Surprisingly the burned and grazed sapling forest had the lightest roots. After this forest had been burned, it suckered prolifically. It was hypothesized that some of the weight loss which occurred in the roots was related to the high energy output made towards producing suckers. Another factor which may have contributed to lower root weights was that burning removed the forest canopy, causing the site to become drier. The aspen roots collected were growing close to the soil surface and may have also lost moisture. Root weights from the decadent forest did not vary significantly between treatments and their weights were between the weights of roots from the control sapling and the burned and grazed sapling forest. Roots from the grazed and burned treatment on the decadent forest did not produce many new suckers, and they tended to be deeper and therefore less prone to desiccation prior to being collected.

This study has shown that some of the differences between a healthy sapling and a decadent aspen forest in their ability to sucker may be due to differences in root TNC levels between the two forest types. However, other factors related to deterioration of the root system (Schier 1975) and the depth of healthy roots may be more important. Heavy grazing following prescribed burning appears to be effective in lowering aspen root TNC reserves, thus lowering the ability of the roots to produce new suckers (FitzGerald and Hoddinott 1983)

Table 6.1 The effect of forest type and grazing treatment on weight (g) of excised root segments.

Treatment	Decadent	Sapling
	(grams)	(grams)
Control	45.6[ay]	67.9[ax]
Burned & grazed	45.9[ax]	33.9[bx]
SEM		5.74
P>F[2]		0.01

1 Means within the same columns followed by the same letter (a,b) and means within the same rows followed by the same letter (x,y) are not significantly different according to Pdiff (P<0.05).
2 Probability of a significant sampling date by forest type interaction.

Table 6.2 Shoot density (shoots root $^{-1}$) produced by excised aspen roots from the decadent and sapling forest, adjusted to a common volume (72.5 cm^3) using volume as a covariate.

	Shoot density		
Forest type	Harvest date 1	Harvest date 2	Total
	(shoots root^{-1})	(shoots root^{-1})	(shoots root^{-1})
Decadent	14.6	1.2	15.8
Sapling	22.2	2.5	24.7
SEM	2.37	0.51	2.62
P>F	0.045	0.10	0.035

Table 6.3 Weight (g $root^{-1}$) of aspen shoots produced by excised aspen roots from the decadent and sapling forest, adjusted to a common volume (72.5 cm^3) using volume as a covariate.

Forest type	Shoot weight		
	Harvest date 1	Harvest date 2	Total
	(g $root^{-1}$)	(g $root^{-1}$)	(g $root^{-1}$)
Decadent	0.23	0.02	0.25
Sapling	0.32	0.06	0.38
SEM	0.056	0.011	0.058
P>F	0.27	0.10	0.14

Table 6.4 The effect of treatment on shoot density (shoots $root^{-1}$) production by excised aspen roots adjusted to a common volume (72.5 cm^3) using volume as a covariate.

Treatment	Shoot density		
	Harvest date 1	Harvest date 2	Total
	(shoots $root^{-1}$)	(shoots $root^{-1}$)	(shoots $root^{-1}$)
Control	25.7	3.3	29.0
Burned & grazed	11.1	0.3	11.5
SEM	2.35	0.50	2.6
P>F	0.001	0.001	0.0005

Table 6.5 The effect of treatment on shoot weight (g root^{-1}) production by excised aspen roots adjusted to a common volume (72.5 cm^3) using volume as a covariate.

Treatment	Shoot weight: Harvest date 1 shoot weights	Shoot weight: Harvest date 2 shoot weight	Shoot weight: Total shoot weight
	(g root^{-1})	(g root^{-1})	(g root^{-1})
Control	0.41	0.07	0.49
Burned & grazed	0.13	0.01	0.15
SEM	0.055	0.011	0.057
P>F	0.004	0.003	0.001

Table 6.6 Differences in total soluble carbohydrates of excised aspen roots between the mature decadent and healthy sapling aspen forests.

Forest type	TNC
	(%)
Decadent	21.6
Sapling	24.2
SEM	1.32
P>F	0.20

Table 6.7 Differences in total soluble carbohydrates of excised aspen roots between control and burned and grazed treatments

Treatment	TNC
	(%)
Control	26.1
Burned & grazed	19.7
SEM	1.32
P>F	0.005

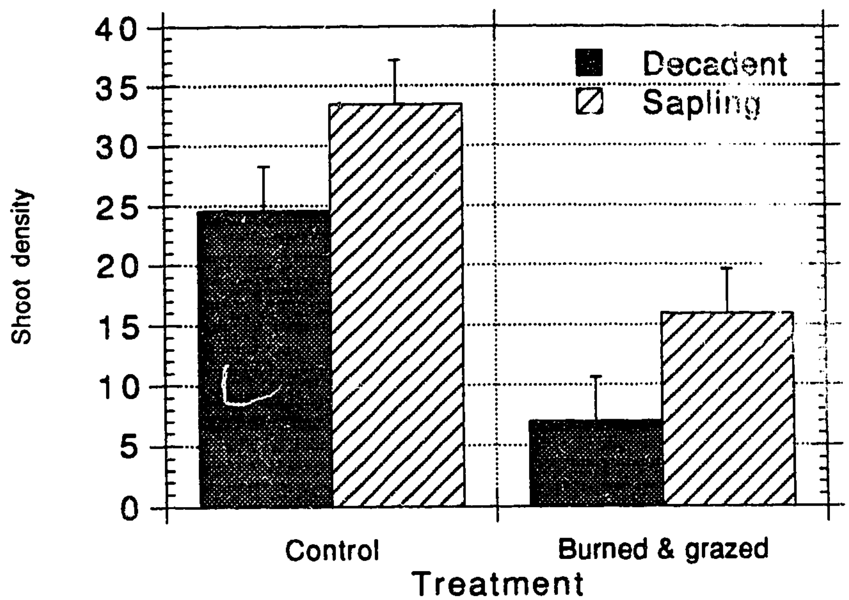

Figure 6.1. Density of aspen shoots (shoots root^{-1}) produced by roots adjusted to a common volume (72.5 cm^3) using volume as a covariate. Bars indicate standard errors of the means.

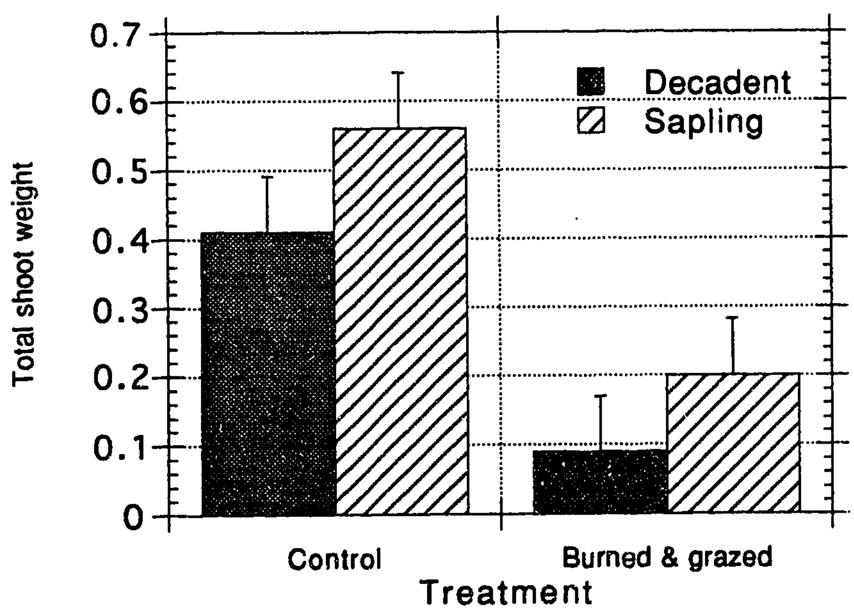

Figure 6.2. Weight of aspen shoots (shoots root^{-1}) produced by roots adjusted to a common volume (72.5 cm^3) using volume as a covariate. Bars indicate standard errors of the means.

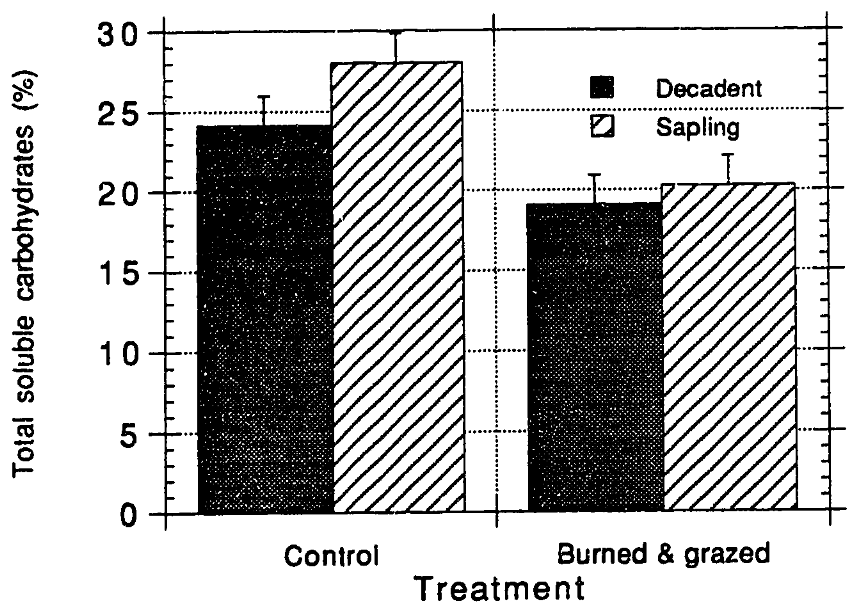

Figure 6.3. The effect of forest type and treatment on total soluble carbohydrates of aspen roots. Bars indicate standard error of the means.

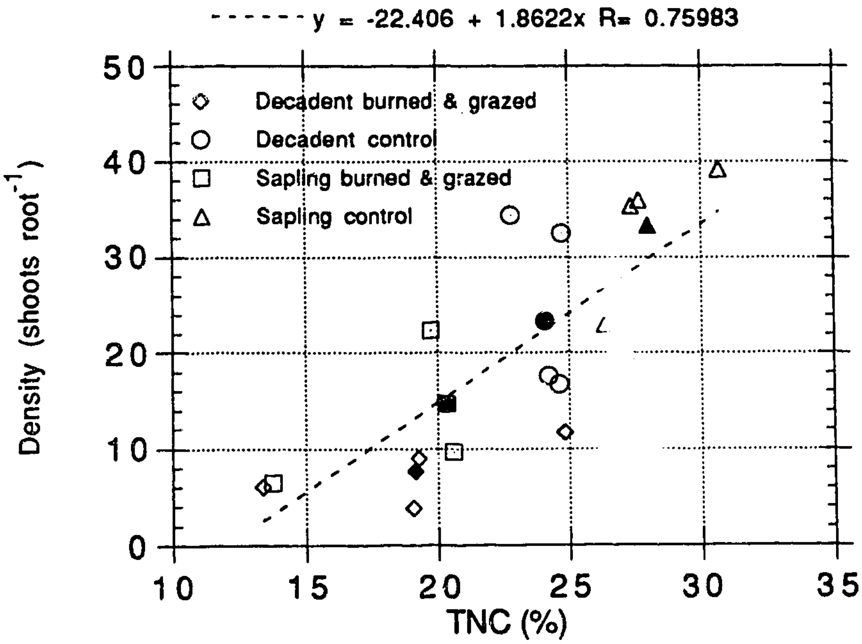

Figure 6.4. Correlation of average TNC with average density of shoots produced per root for each of the 4 sites within each forest by treatment combination. The solid points represent the mean values for each forest by treatment combination.

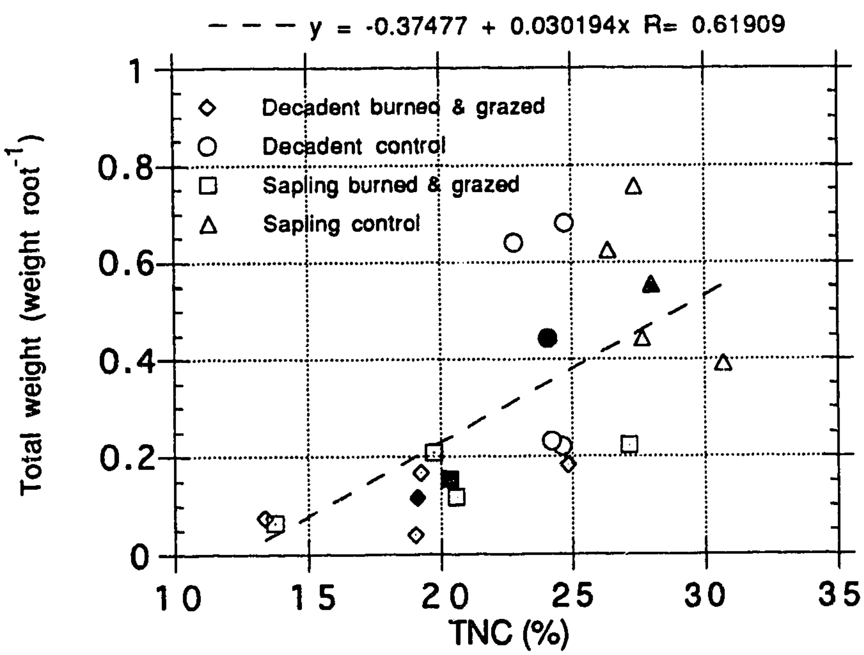

Figure 6.5. Correlation of average TNC with average total weight of shoots produced per root for each of the 4 sites within each forest by treatment combination. The solid points represent the mean values for each forest by treatment combination.

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VII. GENERAL DISCUSSION:

The differences in plant communities between mature decadent and healthy sapling aspen forest types following burning were related to differences in the ability of aspen to sucker. In the sapling forest, aspen suckered vigorously following burning and quickly became the dominant vegetation. Without grazing, the high density stands of aspen suckers out competed the other vegetation for light, water and nutrients, and prevented the herbaceous vegetation from becoming productive.

In the decadent aspen forest, the open forest canopy caused by tree mortality allowed for a productive understory in which herbaceous species were an important component prior to burning. After burning all vegetation types except aspen responded quickly to recolonize the burn. Very few aspen suckers were produced by the decadent forest.

The low density of aspen suckers produced by the decadent forest in relation to the sapling forest was related to the condition of the two forests prior to burning. The decadent forest type although not overly mature was in a declining state. Environmental stresses caused by years of drought, tent caterpillar epidemics, and the fact that many of these aspen forest groves were growing on sites marginal for tree growth, has resulted in substantial mortality to this forest type. Damage not only occurred to the forest canopy, but also to the roots in that nonstructural carbohydrate reserves stored in the roots were depleted to refoliate following the repeated defoliations by tent caterpillars. More importantly, it would appear that the stresses which caused mortality to a large portion of the aspen canopy also resulted in substantial mortality of the shallow lateral roots which normally produce new aspen suckers. In healthy aspen forests the majority of aspen suckers are produced by lateral roots within the first 10cm of the soil surface. However, in the decadent forest, because of high levels of mortality to the shallow roots, many of the aspen suckers produced had developed from lateral roots deeper than 15cm. Suckers produced by deep lateral roots require greater contributions from root carbohydrate reserves to reach the soil surface than suckers produced by shallow roots. The combined effect of lower root nonstructural carbohydrate reserves and high levels of mortality to shallow lateral roots resulted in the decadent forest only being able to produce a small number of new aspen suckers after burning.

Livestock grazing influenced plant community development. In the sapling forest, cattle were effective in decreasing the height and density of aspen suckers. The control of aspen suckers caused by cattle grazing reduced aspen competition and allowed the herbaceous vegetation to become better established. In the decadent forest, the herbaceous vegetation was well established and because there was no serious aspen competition, herbaceous species were productive both with and without grazing.

Young aspen suckers whose stems had not begun to lignify were found to be a very palatable forage. Cattle readily utilized aspen under both moderate and heavy grazing intensities. Young aspen suckers were very susceptible to grazing induced mortality when they were grazed before their stems had lignified. During this period, young suckers were fragile and easily broken at the base when they were browsed or trampled. Cattle also utilized aspen after the stems had begun to lignify, however, it appeared that these more mature suckers were less likely to be broken off at the base when they were browsed. This observation requires further study as it could have important implications for the successful rgeneration of aspen on grazed cutblocks.

Management Implications:

The mature decadent aspen forests which dominate most of the Aspen Parkland of Central Alberta support a more productive understory than they did as healthy aspen forests in the early 1980's. In this study, the deadfall barrier which prevented livestock from utilizing the increased production was effectively removed by prescribed burning. Livestock actively selected the most recently burned sites over older burns, and only lightly utilized the unburned sites.

The understory of the healthy sapling forest was not productive prior to burning, however burning removed the dense foliar canopy allowing the understory to develop. Under ungrazed conditions, aspen suckers quickly became the dominant vegetation type and effectively inhibited the development of the herbaceous vegetation component through competition for light, water and nutrients. Grazing was effective in controlling aspen on the sapling forest. Both moderate and heavy grazing intensities appeared to be equally effective in controlling aspen regeneration. Grazing during early July did not remove aspen from the plant community, but it did control aspen density and height such that a more productive herbaceous understory was able to develop. Grazing also maintained aspen suckers at a height where they were well within the reach of browsing animals, enabling animals to utilize the trees as a valuable forage resource.

Aspen regeneration, a serious livestock management concern on healthy aspen forests, was not a problem on the decadent forest type. The sparse aspen reproduction which occurred was not dense enough to compete with the herbaceous vegetation component which remained productive following burning. In the decadent forest type some form of proactive management may be required for successful regeneration of a healthy aspen forest. In the decadent forest type it appears that total protection of the young saplings from browsing animals may be required during the first few years if the successful regeneration of a healthy aspen forest is the management goal. Conversely, successful aspen regeneration in the sapling forest should be possible following burning by deferring grazing until aspen sucker stems have become lignified, as well as controlling livestock densities and promoting good animal distribution.

Conclusions:

In healthy aspen groves aspen suckers vigorously following burning. The dense stand of suckers which develops appears to limit herbaceous forage production. repeated moderate to heavy grazing of these stands appears to control aspen suckers and improve herbaceous forage production.

In mature decadent aspen groves, forage productivity is very high, however, forage availability is limited by deadfall barriers. Burning increases forage availability by removing the deadfall barriers. The decadent condition of these aspen groves limits their ability to sucker. Aspen reinvasion is therefore not a serious management concern. In fact, concentrated livestock grazing immediately after burning could effectively eliminate aspen from these marginal sites.