UNIVERSITY OF ALBERTA

Seasonal Herbage Dynamics and Utilization by Yearlings on a Native Aspen Parkland Riparian Landscape in Central Alberta

by

Stephen Appiah Asamoah ©

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DEDICATION

This thesis is dedicated to my parents

STEPHEN ENOCH ASAMOAH and SELINA OSEI AMPONSAA

for their relentless efforts in my education.

ABSTRACT

Initial and season-long herbage yields and quality, as well as herbage utilization patterns by cattle, were evaluated across a native Aspen Parkland landscape from May to September 2000. Grass was the principal herbage, with season-long yield nearly three times greater on riparian meadows than upland grasslands. Overall, both grass dry matter and crude protein yields remained consistently greater on riparian meadows from May through September. Whereas "absolute" herbage utilization was greatest on riparian meadows, "relative" utilization remained similar across topographic positions. Frequency of cattle utilization of plant communities was consistently greatest on riparian meadows from June to August. While upland grasslands were least selected in June, forested sites were avoided in August. Collectively, these results indicate that riparian meadows provide abundant, high quality season-long foraging opportunities, and together with an understanding of utilization patterns, sustainable livestock grazing strategies can be developed for native Aspen Parkland landscapes.

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CHAPTER 1

INTRODUCTION

1.1. Importance of Riparian Areas

Riparian area management has gained worldwide attention in recent years because of accelerated wetland loss associated with a variety of anthropogenic disturbances (Platts 1990). Livestock grazing, cultivation and forestry, individually or in combination, influence the ecological characteristics of riparian areas, adjacent uplands and aquatic bodies, even in the short-term (Clarke et al. 1947, Coupland 1950, Walker and Coupland 1970, Willms and Jefferson 1993, Svejcar 1997). In addition, natural local variations in microclimate and edaphic conditions within various ecological zones influence riparian characteristics (Platts 1990). These disturbances significantly influence the production of riparian plant communities along with their species composition, structure and diversity (Walker and Coupland 1970, Willms and Jefferson 1993).

Healthy and functioning riparian areas produce lush vegetation that provides abundant forage for livestock (Buckhouse and Elmore 1991, Elmore 1992, Svejcar 1997). In the prairies, forage utilization by cattle across the landscape has been reported to be controlled by water availability (Willms 1990) and forage availability (Willms 1988). Livestock grazing in turn has been reported to influence forage quality (Philips et al. 1999). Topographic lowlands and associated riparian meadows have higher grazing capacities, and cattle congregate on such areas relative to adjacent uplands (Reid and Pickford 1946, Pickford and Reid 1948, Roath and Krueger 1982, Willms 1988, Stuth 1993). With the strategic use of these productive areas, livestock producers may be able to obtain greater gains per unit area compared to all other topographic positions on the landscape (Willms 1988).

Water within or adjacent to riparian areas is typically a source of drinking water for livestock. Close proximity to drinking water probably gives the added advantage of preventing energy losses associated with cattle movement along slopes and over long distances in search of water (Reid and Pickford 1946, Roath and Krueger 1982). Forested riparian areas also provide thermal cover for grazing livestock, particularly in rangelands dominated by open grasslands.

A large variety of wildlife, including both large and small mammals, birds, reptiles, amphibians, fish, and both aquatic and terrestrial invertebrates, either in whole or in part, depend on riparian areas for meeting their habitat requirements (Thomas et al. 1979, Kauffman and Krueger 1984, Weller 1996). Migratory waterfowl use riparian areas as nesting sites, as well as stopover sites for replenishing energy reserves in the course of migration (NAWMP 1986). Additionally, other riparian-dependent resident and locally migrant wildlife use these areas for feeding, watering, thermal protection, and escape from predators (Weller 1996).

Hydrologically, riparian areas influence the water quality and seasonal pattern of water flow within watersheds. Vegetation within these zones maintains water quality by removing suspended particles and settling sediments as water moves through them (Prichard et al. 1998). Riparian areas in healthy condition can help reduce non-point source pollution that might otherwise end up in streams and rivers

(Lowrance et al. 1984). They also help with aquifer recharge, rebuilding of floodplains and reduction of stream-bank erosion, by acting as a sponge to hold water and slowly release it (Elmore and Beschta 1987, Prichard et al. 1993, Prichard et al. 1994). In doing so, they store water and reduce the risk of either excessive flooding or late summer drought (Prichard et al. 1994). Enhanced water availability, in turn, may increase riparian vegetation growth relative to that on adjacent uplands (Bork et al. 2001) and maintain more favorable forage quality (Philips et al. 1999).

In summary, riparian areas constitute unique ecosystems with a diversity of components that functionally interact to provide a wide array of products and services. The ability of these ecosystems to remain healthy depends heavily on the functional stability of important ecological processes such as nutrient cycling, energy transfer, and maintenance of hydrological condition. Any form of disturbance that exceeds the inherent tolerance of riparian ecosystem processes has the potential to cause detrimental effects to their long-term sustainability and utility.

1.2. Research Problem

The Aspen Parkland ecoregion of Alberta (Strong 1992) is an important cattle production zone in the Western Canadian Prairies (Baron and Knowles 1984, McCartney 1993). Within the Parkland, as well as the neighboring ecoregions to the north (Boreal Mixedwood) and south (Mixed Grass and Fescue Prairie), riparian meadows provide important forage sources in the landscape (McCartney 1993). Given that cattle tend to avoid excessive slopes (Mueggler 1965), and that they may preferentially graze riparian meadows over adjacent uplands at certain periods during the growing season (Willms 1988), these meadows may be susceptible to overuse.

Livestock grazing can promote riparian habitat quality or destroy it, depending on the nature of grazing activities. In order to maintain riparian zones in the Aspen Parkland, management strategies will have to evolve to meet the inherent limitations of riparian vegetation to livestock grazing. Relatively little baseline information exists, however, on the natural growth cycle of riparian meadow vegetation, particularly in relation to that of adjacent upland grasslands within the Aspen Parkland. Information on season-long changes in herbage yield and quality will play an important role in developing these grazing strategies. Furthermore, information is limited on the natural foraging behavior of cattle across Aspen Parkland landscapes, including their preference for lowland meadows, upland grasslands, and north-facing forested sites. Meadow, upland and forest vegetation are highly interspersed across the Parkland's typical "knob and kettle" topography, making physical separation impractical for ranchers. As a result, the development of effective grazing systems and other management practices to ensure the conservation of riparian vegetation will require a detailed understanding of the basic foraging opportunities available, along with an understanding of the inherent behavioral responses of cattle to the spatially mixed plant communities common in these environments.

Specific questions of relevance to ranchers include knowing at which point during the year cattle prefer to utilize riparian meadows relative to other topographic positions. Furthermore, it is essential to know how these preferences relate to the progressive phenological changes in herbage yield and quality that occur naturally within these plant communities. Landscape ecologists are also interested in understanding how cattle grazing may influence internal characteristics of riparian vegetation (compared to those at other locations within the landscape), including plant species composition, structure and diversity, as well as soil physical properties. Answers to these questions and others would provide better insight into what specific range management strategies, including the timing of grazing, that could be employed to maintain and/or enhance the sustainability of riparian zones, as well as that of the adjacent uplands. Ideally, these strategies would simultaneously maintain optimum cattle production in the Aspen Parkland as well.

1.3. Research Objectives

The objectives of the research reported in this thesis were as follows:

- To quantify changes in riparian meadow herbage dry matter yield and quality (crude protein, crude protein yield and neutral detergent fibre), and contrast this pattern with that of adjacent upland grasslands,

- To document the inherent patterns of herbage utilization by cattle across different topographic positions in the Aspen Parkland, including riparian meadows, adjacent south-facing upland grasslands, and north-facing forests,

- To identify the implications of the above information on the development of grazing strategies that may optimize the use of forage resources in the Aspen

Parkland while maintaining the long-term sustainability of plant communities across various topographic positions.

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CHAPTER 2

LITERATURE REVIEW

2.1. Riparian Ecosystems: Morphological Characteristics

Several people have defined riparian areas in North America, including Miller (1976), Prichard et al. (1993), Nener et al. (1996), Ehrhart and Hansen (1997) and Campbell (1999). Perhaps the most insightful are the definitions of Hennan (1996), Svejcar (1997) and Moen (1998), which describe riparian areas as transition zones between uplands and aquatic systems within the landscape catena, resulting in characteristics of both terrestrial and aquatic ecosystems. Vascular plants adapted to these areas have the tendency to be submerged during at least part of the growing season, usually spring. Although the occurrence of drought is typically infrequent, moisture deficits may still occur late in the growing season.

Riparian areas vary in size relative to the entire landscape (Pickford and Reid 1948). Although riparian areas constitute about 2% of the total range landscape, they are disproportionately more important for forage production than adjacent upland grasslands (Adams and Fitch 1995).

Two broad categories of riparian zones have been described on the basis of the net velocity of water movement within the adjacent aquatic system. Lotic riparian zones are typically associated with aquatic systems that flow, or have a net positive velocity of water movement. These include riparian zones associated with rivers, streams and springs. Depending on the morphology, geology, and edaphic characteristics within the watershed, as well as rainfall intensity, lotic riparian plant communities may be susceptible to disturbance caused by water erosion. In contrast, lentic riparian zones are located at the peripheries of standing water bodies such as lakes, ponds and reservoirs that have a zero net velocity of water movement. Plant communities in lentic riparian zones may be susceptible to extremes of hydrologic regimes such as flooding and drought (Platts 1990).

2.2. Riparian Ecosystems: Ecological Characteristics

Riparian zones are dynamic, disturbance-driven ecosystems that are continually reshaped over time (Platts 1990). Hygrophilic plants, including sedges, grasses, rushes and willows are typical of riparian areas. However, anthropogenic disturbances such as livestock grazing and cultivation may render riparian ecosystems susceptible to invasion by non-native species such as Kentucky blue grass (*Poa pratensis* L) and dandelion (*Taraxacum officinale* Weber).

Riparian plant communities are structurally diverse (Grazing and Pasture Technology Program 2001). Malanson (1993) related the high structural diversity to three major ecological hypotheses, including:

i. The individualistic hypothesis of plant associations, which uses water gradients to describe plant community composition and distribution across the landscape (Leonard et al. 1992).

ii. The intermediate disturbance hypothesis, which uses the gradient, frequency and intensity of disturbance characterized by flooding regimes, to dictate plant community composition and distribution (Connell and Slatyer 1977),

iii. The competition hypothesis of niche differentiation, which stipulates that the level of competition within and between species may have effects on plant community composition and distribution.

Riparian ecosystems function as corridors and conduits for organisms, material and bioenergetic movements across the landscape gradient (Forman and Gordon 1986). According to Malanson (1993), riparian width is a function of water availability, with wider riparian areas being more structurally heterogeneous and complex. Functional interactions involving organisms, materials and bioenergetic movements between riparian areas and the adjacent uplands or aquatic systems are controlled, to a great extent, by the width of the riparian zone, as width determines the effectiveness of both barrier and buffer functions (Malanson 1993, Grazing and Pasture Technology Program 2001).

Riparian vegetation plays a significant role in controlling material and energy transfer and dissipation from uplands into aquatic systems, as well as reducing stream velocity and stabilizing banks (Kauffman and Krueger 1984). Riparian vegetation also contribute to the maintenance of stable water flows and water quality, the latter by filtering off nutrients, pollutants and sediments from above and below-ground sources (Preston et al. 1998, Lowrance et al. 1984a, 1984b, 1984c), including those contained in water from uplands before entry into the aquatic system (Malanson 1993). In discussing the ramifications of maintaining healthy riparian areas in watersheds where adjacent uplands are farmed, Lowrance et al. (1984) pointed out that these areas can reduce non-point source pollution that might otherwise end up in streams and rivers.

Riparian function is effectively enhanced under conditions of ample vegetation cover, greater riparian width, and low levels of anthropogenic disturbance (Platts 1990, Grazing and Pasture Technology Program 2001).

2.3. Riparian Ecosystems: Production Characteristics

Extensive research has been done to quantify herbage yields in various ecosystems around the world (Heady and Child 1994). Herbage productivity is known to be greatly dependent on the level of soil water (Walker and Coupland 1970, Irving 1992, Martin and Chambers 2001, Stringham et al. 2001). As a result, riparian zones having significant soil moisture show different phenological changes in herbage yield and quality compared to other topographic positions within the landscape (Mueggler and Stewart 1981, Mueggler 1983). However, within boreal regions, excessive flooding in closed basin lentic riparian areas may limit herbage production (Bork et al. 2001).

In northeastern Oregon, Pickford and Reid (1948) estimated that one acre of riparian meadow was equivalent to 10 – 15 acres of forested range in terms of grazing capacity. In their analysis they showed that although mountain meadows comprised just 1 – 2% of the total land area, they provided 20% of the summer forage used by livestock. They also indicated that this amount would vary depending on the condition of the meadows in relation to adjacent uplands, as well as the system of grazing being utilized. A similar observation has been made for riparian zones supporting livestock production in the interior of British Columbia, Canada (Van Ryswyk et al. 1995).

On rangelands in Alberta, it has generally been well established that positive relationships exist between herbage yield and precipitation (for example, Smoliak 1956, Johnston et al. 1969, Smoliak 1986, Bork et al. 2001). In the Fescue Prairie, Willms (1988) reported a differential pattern of herbage productivity across various topographic positions, and concluded that sub-irrigated lowlands were important sources of abundant, high quality forage for cattle. Forage production on uplands was half that of sub-irrigated lowlands (Willms 1988). Riparian meadows also respond positively to fertilization and provide predictable livestock forage and wildlife management alternatives (Corns 1974, Reece et al. 1994).

Herbage quality characteristics such as crude protein normally decline from early to late season on both uplands (Clarke and Tisdale 1945, Johnston and Bezeau 1962, Fisher et al. 1996, Donkor 2001) and riparian meadows (Corns and Schraa 1962, Corns 1974). A decline in herbage quality is typically accompanied by increasing herbage yields (Huston and Pinchak 1993). Although riparian meadows are considered to be relatively tolerant of livestock grazing, a high frequency of defoliation can adversely affect their herbage regrowth potential (Corns 1974). Frequent defoliation, however, is associated with greater quality regrowth (Corns 1974). As a result, grazed riparian areas are generally greater in forage quality compared to ungrazed areas (e.g., Philips et al. 1999).

2.4. Riparian Ecosystems: Livestock and Wildlife Utilization

The importance of riparian zones for livestock production, environmental stewardship, and fish and wildlife habitat conservation on rangelands has been widely discussed (for example, Holochek et al. 1998, Vallentine 2001). As these zones are micro-climatically, edaphically, hydrologically, and functionally different from other topographic positions on the landscape, they need to be given special consideration in the design of any livestock grazing program (Platts 1990, Holochek et al. 1998, Grazing and Pasture Technology Program 2001).

Irving et al. (1995) observed that distance from water source greatly influenced herbage utilization patterns by cattle within the Mixed Prairie – Aspen Parkland transition of central Alberta. Furthermore, different species and age groups of livestock may graze rangelands in different ways and therefore exert variable impacts on the landscape (Platts 1990, Holochek et al. 1998). For example, cattle have been reported to exert more trampling effects on riparian zones than sheep and goats (Holochek et al. 1998). Cattle congregate on lowlands relative to adjacent uplands (Willms 1988, Stuth 1993, Philips et al. 1999, Vallentine 2001), potentially due to the inhibitory effect of steep slopes (Mueggler 1965), or variation in forage type, palatability, abundance, and quality (Vallentine 2001). Working in the Fescue Prairie of Alberta, Willms (1988) found that the greatest relative use of lowlands occurred during spring and early summer, but declined later in the growing season. Marlow and Pogacnik (1986) observed that abundant early season precipitation on a foothill rangeland facilitated greater herbage growth on uplands, with cattle subsequently attracted to these topographic positions earlier in the season relative to riparian meadows. The opposite pattern occurred when there was low early season precipitation, and cattle utilized riparian meadow herbage prior to switching onto uplands later in the season.

Riparian areas also serve as critical habitats for wildlife (Platts 1990). Some wildlife species are completely dependent on riparian zones for survival, while many others use these zones as transient habitats, either spatially or seasonally. Thomas et al. (1979) estimated that about 80% of the terrestrial wildlife species known to occur in southeastern Oregon were either directly dependent on riparian areas, or used these areas proportionately more than other habitats. Kauffman and Krueger (1984) also indicated that a large proportion of rangeland avifauna depend on riparian habitats for at least part of the year, and these habitats also serve as important stopover sites for migrating waterfowl. Wildlife dependence on riparian zones is increasingly becoming an issue of concern because of the numerous problems associated with over-utilization by cattle (Platts 1990). Concentrated cattle grazing significantly influences plant community composition (Kauffman et al. 1983, Kauffman and Krueger 1984), as well as vegetation structure and diversity (Bai et al. 2001), and accordingly, wildlife and their habitats (Schulz and Leininger 1990, Eccard et al. 2000).

2.5. Riparian Ecosystems: Management Options

Various livestock grazing strategies have been developed for maintaining and enhancing the productivity and conservation of riparian zones (Platts 1990, Holochek et al. 1998, Grazing and Pasture Technology Program 2001). Some grazing systems have been criticized on grounds that they focus on maintaining upland productivity to the detriment of riparian zones, or they are too expensive to maintain (Fitch and Adams 1998). Platts (1990) indicated that the level of acceptable herbage removal (i.e., safe use level) by the grazing animal is important in determining grazing guidelines other than the conventional "take half and leave half" (moderate grazing) principle. In order to take advantage of regrowth later in the year, Platts (1990) recommended grazing riparian zones early in the growing season using an appropriate timing and duration of use to ensure vigorous regrowth.

Although various livestock grazing strategies have evolved over the years through grazing trials on both native rangelands and tame pastures (Stoddart et al. 1975, Popolizio et al. 1994), Platts (1990) has indicated that no single grazing strategy can suffice for all resources or land types because of inherent variability in landscape, vegetation, climatic, and edaphic characteristics. These variations may produce differential patterns of herbage productivity and quality, which may in turn, control the grazing behavior of livestock on the range (Stoddart et al. 1975, Gillen et al. 1985, Walker et al. 1989, Coughenour 1991, Kie and Boroski 1996, Bailey et al. 1996, Clary and Leininger 2000, Laca 1998, Willms and Rode 1998, Vallentine 2001). Stoddart et al. (1975) indicated that no rangeland of appreciable size can be utilized uniformly: areas that normally experience heavy use are around water holes, salting grounds, road clearances, level valley floors and more accessible ridge-tops. Studies in various ecosystems have reported that cattle distribution on the range is influenced by herbage type (Smith et al. 1992, Vallentine 2001), yield (Bryant 1982, Willms 1988, Vallentine 2001), quality (Cook 1966, Kie and Boroski 1996, Vallentine 2001), topography (Mueggler 1965, Pinchak et al. 1991, Hart et al 1991), and water availability (Willms 1990, Irving et al. 1995). In addition, the timing, frequency and intensity of defoliation influence the herbage productivity and quality of riparian meadows (Corns 1974) as well as upland grasslands (Donkor 2001).

Options for rehabilitating riparian zones have included complete livestock exclusion, rotational grazing schemes, or changes in the season, type or class of animal, as well as techniques that improve livestock distribution (Holochek et al. 1998). With the rising awareness of the tremendous importance of riparian zones as critical waterfowl habitats, exclusion of livestock grazing has been advocated in order to protect such sites (NAWMP 1986). This recommendation appears to be based on the assumption that grazing is incompatible with the conservation of riparian zones. However, several research studies have reported that herbage productivity and soil properties on riparian zones can be maintained under appropriate livestock grazing strategies (Kauffman and Krueger 1984, Elmore 1992, Kie and Boroski 1996). Of more importance may be the maintenance of adequate herbage stubble height (for example, 10 cm or more), capable of sustaining plant vigor, stabilizing stream-banks, and enhancing cattle grazing efficiency (Clary and Leininger 2000).

Table 2.1 contains a listing of some livestock grazing strategies and their qualitative ratings with respect to their individual capabilities for keeping riparian zones in excellent condition (Platts 1990).

2.6. Riparian Grazing Management in the Aspen Parkland

The Aspen Parkland ecoregion is an important livestock and cereal crop production zone in Alberta (McCartney 1993), and therefore, is of significant economic importance to the province (Lagroix-Mclean and Naeth 1997). The ecoregion is characterized by typical "knob and kettle" topography, which results in numerous patches of riparian meadows, lowlands and sloughs, interspersed in a matrix of grasslands and forests. Thus, topography exerts a significant effect on soils (Acton 1965), along with the identity and distribution of the resulting vegetation types.

Many of the native Aspen Parkland rangelands have been converted into tame pastures for the purpose of sustaining the increasing demand for livestock forage in the province (McCartney 1993). However, the remaining native rangelands (~5%) support a considerable proportion of the beef industry in the province (Bailey et al. 1987). Previous livestock grazing strategies in the region appeared to be less sensitive to the fragility of riparian meadows, resulting in an appreciable loss of riparian zones and important waterfowl habitats (Adams and Fitch 1995). Thus, under habitat conservation initiatives from Ducks Unlimited Canada (an environmental, non-governmental organization), livestock grazing is frequently deferred until mid July within areas containing critical waterfowl habitats, or altogether rested to enable waterfowl to successfully complete their annual breeding cycle (NAWMP 1986, NAWMP 1994). During grazing deferment and rest periods, livestock producers resort to alternative foraging sources (e.g., tame upland pastures).

Table 2.1: Qualitative Ratings for Improvement of Grazing Strategies of Stream-Riparian Habitats.

STRATEGY	LEVEL TO WHICH RIPARIAN VEGETATION IS COMMONLY USED	CONTROL OF ANIMAL DISTRIBUTION (ALLOTMENT)	STREAM-BANK STABILITY	BRUSHY SPECIES CONDITION	SEASONAL PLANT REGROWTH	STREAM-RIPARIAN REHABILITATIVE POTENTIAL	RATING
Continuous season-long (cattle)	Heavy	Poor	Poor	Poor	Poor	Poor	1[a]
Holding (sheep or cattle)	Heavy	Excellent	Poor	Poor		Poor	1
Short-duration high intensity (cattle)	Heavy	Excellent	Poor	Poor	Poor	Poor	1
Three herd - four pasture (cattle)	Heavy to moderate	Good	Poor	Poor	Poor	Poor	2
Holistic (cattle or sheep)	Heavy to light	Good	Poor to good	Poor	Good	Poor to excellent	2-9
Deferred (cattle)	Moderate to heavy	Fair	Poor	Poor	Fair	Fair	3
Seasonal suitability (cattle)	Heavy	Good	Poor	Poor	Fair	Fair	3
Deferred rotation (cattle)	Heavy to moderate	Good	Fair	Fair	Fair	Fair	4
Stuttered deferred rotation (cattle)	Heavy to moderate	Good	Fair	Fair	Fair	Fair	4
Winter (sheep or cattle)	Moderate to heavy	Fair	Good	Fair	Fair to good	Good	5
Rest-rotation (cattle)	Heavy to moderate	Good	Fair to good	Fair	Fair to good	Fair	5
Double rest-rotation (cattle)	Moderate	Good	Good	Fair	Good	Good	6
Seasonal riparian preference (cattle or sheep)	Moderate to light	Good	Good	Good	Fair	Fair	6
Riparian pasture (cattle or sheep)	As prescribed	Good	Good	Good	Good	Good	8
Corridor fencing (cattle or sheep)	None	Excellent	Good to excellent	Excellent	Good to excellent	Excellent	9
Rest-rotation with seasonal preference (sheep)	Light	Good	Good to excellent	Good to excellent	Good	Excellent	9
Rest or closure (cattle or sheep)	None	Excellent	Excellent	Excellent	Excellent	Excellent	10

Source: Adapted from Platts 1990

[a]Rating scale based on 1 (poorly compatible) to 10 (highly compatible) with fishery needs

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CHAPTER 3

SEASONAL HERBAGE YIELD AND QUALITY OF RIPARIAN MEADOWS AND UPLAND GRASSLANDS IN THE ASPEN PARKLAND

3.1. Introduction

Livestock and diversified wildlife production, along with annual cropping, are important agricultural land use activities in the Aspen Parkland ecoregion of central Alberta. Thus, the region is of significant economic importance to the province of Alberta (Lagroix-Mclean and Naeth 1997). Many native rangelands in the Aspen Parkland have been seeded into tame pastures for the purpose of sustaining the increasing demand for livestock forage in the province (McCartney 1993). Current advocates exist to conserve the remnants of intact native rangelands, as well as integrate wildlife habitat and general landscape-level conservation and management into agricultural land use activities within the Aspen Parkland (NAWMP 1986, NAWMP 1994).

In the Canadian prairies, herbage production has been significantly correlated with available soil water (Smoliak 1956, Smoliak 1986, Irving 1992), and differential patterns of herbage productivity have been typically associated with various topographic positions (Willms 1988, Bork et al. 2001). Willms (1998) found that herbage production in the Fescue Prairie was greatest on lowlands, with uplands producing 50% less than sub-irrigated lowlands. Although riparian zones constitute as little as 2 % of the total landscape (Adams and Fitch 1995), they are an abundant source of high quality forage for livestock (Willms 1988, Van Ryswyk et al. 1995). It has been reported from other areas in North America, that riparian meadows show a unique phenological pattern in growing season herbage yield and quality compared to adjacent uplands (Mueggler and Stewart 1981, Mueggler 1983, Vallentine 2001).

Cattle have also shown a preference for utilizing forage on lowland positions relative to adjacent uplands (Willms 1988, Stuth 1993, Philips et al. 1999, Vallentine 2001), potentially due to the inhibitory effect of steep slopes (Mueggler 1965), or variation in forage type, palatability, abundance, and quality (Vallentine 2001). Willms (1988) found that the greatest relative use of lowlands occurred during spring and early summer, with depletion later in the growing season forcing cattle to switch to uplands.

Although riparian vegetation is often considered relatively resistant to grazing, Corns (1974) found that a high frequency of defoliation can adversely affect the herbage regrowth potential of riparian meadows. However, more frequent defoliation was associated with greater quality regrowth (Corns 1974). Herbage quality (e.g., crude protein) generally declines from early to late season on both uplands (Clarke and Tisdale 1945, Johnston and Bezeau 1962, Fisher et al. 1996, Donkor 2001) and riparian meadows (Corns and Schraa 1962, Corns 1974). On temperate rangelands, the seasonal decline in herbage quality (crude protein) brought on by an increase in structural carbohydrates (crude fibre) with advancing maturity, is typically accompanied by increasing herbage yields (Huston and Pinchak 1993).

Though numerous studies have examined changes in herbage yield and quality on tame or introduced herbage types, limited information exists on the comparative season-long changes in herbage yield and quality of different native rangeland plant communities in the Aspen Parkland, including any variation among different topographic positions. Such information is relevant for understanding the inherent season-long grazing opportunities available to cattle, and also for identifying appropriate management strategies (for example, times of defoliation) in order to maintain long-term herbage productivity, quality, and condition within rangelands of the Aspen Parkland. It is also important for facilitating the successful integration of wildlife habitat conservation with livestock grazing activities.

The research reported here quantifies the different spatial (landscape) patterns, as well as the temporal (growing season) dynamics of herbage yield and quality within lowland riparian meadow and upland grassland plant communities and discusses implications for sustainable livestock production on a native Aspen Parkland rangeland in Central Alberta.

3.2. Materials and Methods

3.2.1. Study Area

The study was conducted at the University of Alberta Beef Cattle Research Ranch (53°01'N, 111°34'W), located near Kinsella in the County of Beaver, about 150 km southeast of Edmonton, Alberta. The ranch, which is partitioned into fenced paddocks, is 3,100 ha in size, and is situated within the Aspen Parkland Ecoregion of western Canada (Strong 1992). In its continental setting, the ranch experiences cold winters and warm summers that peak in January and July, respectively. Growing season average monthly temperatures are shown in Appendix I. Average annual

(January to December) and growing season (May to August) precipitation are 412 and 259 mm, respectively (Environment Canada 1960-2000). Appendix II shows the average monthly growing season rainfall patterns for the ranch.

The ranch is located on a geological formation characterized by calcareous parent material developed from glacial debris deposited over underlying marine shales during the last glaciation, ending about 10,000 years ago (Gravenor 1959). The landform is hummocky moraine, and there are typically strong effects of topography and aspect on soils and vegetation across the landscape (Ellis 1932, Moss and Campbell 1947, Acton 1965). According to Wheeler (1976), zonal soils on well-drained upland topographic positions include Orthic Black Chernozems, while poorly drained lowlands and riparian meadows are characterized by Gleysols. Eluviated Black Chernozems occur on mid to lower slope positions, with Luvisolic soils on forested north-facing slopes and Dark Brown Chernozems on more xeric and steeply sloped upland sites with grassland vegetation.

Vegetation includes native and tame grasslands, interspersed with deciduous shrub and forest communities (Wheeler 1976). The distribution of plant communities across the landscape is strongly influenced by topography and aspect (Wheeler 1976, Scheffler 1976), as well as anthropogenic disturbances such as livestock grazing (Bailey et al 1990, Fitzgerald and Bailey 1984) and burning (Bailey et al 1990, Anderson and Bailey 1980, Bailey and Anderson 1979).

The native grassland vegetation has been described as the *Festuca scabrella* Association (Moss and Campbell 1947) or Fescue Prairie Association (Coupland

1961). According to Wheeler (1976) and Scheffler (1976), the range type common on well-drained xeric uplands, the *Stipa-Agropyron* faciation, is comprised of western porcupine grass (*Stipa curtiseta* A.S. Hitch.), northern wheatgrass (*Agropyron dasystachyum* Scribn.), and western wheatgrass (*Agropyron smithii* Rydb.). *Festuca-Stipa* grasslands, dominated by plains rough fescue (*Festuca hallii* (Vasey) Piper) and western porcupine grass, along with northern and western wheatgrasses, occupy non-forested uplands on deep moist soils. Depressional vegetation in lowlands includes hygric sedges (*Carex spp.*), slough grass (*Beckmannia syzigachne* Steud.), tall mannagrass (*Glyceria grandis* S. Wats.) and alkali cordgrass (*Puccinellia nuttalliana* Schult.), with an occasional overstorey of willows (*Salix spp.*). Trembling aspen (*Populus tremuloides* Michx.) forest is common on north-facing slopes, while buckbrush (*Symphoricarpos occidentalis* Hook.), snowberry (*Symphoricarpos albus* Blake), rose (*Rosa spp.* L.), Saskatoon (*Amelanchier alnifolia* Nutt.), silverberry (*Elaeagnus commutata* Bernh.) and shrubby cinquefoil (*Potentilla fruticosa* L.) occur in association with aspen forests, or as shrublands on deep, moist soils on depressional fringes.

Common upland forbs and shrubs include common yarrow (*Achillea millefolium* L.), silver sage (*Artemisia cana* Pursh), prairie sagewort (*Artemisia ludoviciana* Nutt.), and pasture sagewort (*Artemisia frigida* Willd.). Forbs are widespread within more mesic sites on both north and south aspects. These include smooth aster (*Aster laevis* L.), old man's whiskers (*Geum triflorum* Pursh), sticky purple geranium (*Geranium viscosissimum* Fisch. & Mey.), and northern bedstraw

(*Galium boreale* L.). Common herbaceous invaders include Kentucky bluegrass (*Poa pratensis* L.), smooth brome grass (*Bromus inermis* Leyss.), and dandelion (*Taraxacum officinale* Weber).

The ranch is partitioned into fenced paddocks for livestock grazing. This study utilized an area of the ranch known as the "wagon wheel" grazing system, which includes ten paddocks with a central water source used annually for rotational grazing of 150 yearling heifers. In this study, three of the ten paddocks were selected on the basis of their uniformity in size (15 ha each), as well as the availability of suitable riparian meadows (minimum of two per paddock) in close proximity to adjacent upland native grasslands and aspen forests, for testing the study hypotheses. Within the paddocks, riparian meadows constituted 0.6 ± 0.1 ha of the land base, while upland grassland and forest communities were 7.8 ± 1.2 and 6.6 ± 0.9 ha, respectively. Sedges (*Carex spp.*) dominated the meadows, with shrubby willows (*Salix spp.*) occupying their fringes. A list of herbaceous plant species within upland grassland, riparian meadow, and forest communities is shown in Appendix III. Prior to beginning field sampling in May 2000, the meadows had traces of standing water in them, likely originating from spring melt water accumulation. However, all the water had disappeared by the first date of sampling (May 22).

3.2.2. Study Design

The study was set up as a repeated measure (Zar 1999) at each of six locations, comparing plant communities within spatially paired riparian meadow and upland grassland topographic positions. Locations were further stratified with two in each of the three paddocks. The main treatment was topographic position (riparian meadow vs. upland grassland), with repeated sampling of herbage occurring within each plant community (N=12) at each of six successive dates of initial defoliation (sampling) scheduled as follows: May 22, June 04, June 18, July 03, July 30, and September 02, 2000. Dates of defoliation were selected to facilitate the documentation of biologically important phenological changes within the plant communities, and also to investigate responses due to differential dates of initial deferment of livestock grazing.

3.2.3. Vegetation Sampling

3.2.3.1. Herbage Yield

Twelve 1.5 x 1.5 m exclosure range cages were randomly set up in each plant community soon after snow melt on May 10, 2000. Beginning on May 22, all aboveground herbage was clipped within 0.32 m^2 (40 cm x 80 cm) quadrats from two randomly selected range cages within each plant community. Duplicate clip sub-samples were taken to help overcome localized variability in herbage yield. This procedure was repeated using "unsampled" range cages on each of the subsequent five scheduled initial clipping dates for the study. Additionally, herbage regrowth was clipped in all previously clipped quadrats on September 14, 2000. Each clip sample was sorted into grass and forb components, oven-dried at 30°C for 72 hours, and weighed to determine both initial and regrowth dry matter (DM) yields of each component.

3.2.3.2. Herbage Quality

Oven-dried samples of both grass and forb components were each ground separately through a 1 mm screen using a Wiley Mill to facilitate laboratory determination of percent crude protein (CP) and neutral detergent fibre (NDF). Crude protein (i.e., nitrogen content of the sample multiplied by 6.25) was analyzed by the Dumas method using the LECO FP-428 analyzer (Sweeney and Rexroad 1987, Jacob et al. 1995, Simonne et al. 1995, Lee et al. 1996). Crude protein yield (CPY) was calculated as the CP fraction of grass DM yield in g/m^2, using the relationship: (CP/100)*DM. The ANKOM filter bag technique (Komarek 1993, Safigueroa et al. 1999) was used to analyze NDF.

3.2.3.3. Soil Moisture

Soil moisture was sampled on the first five successive dates of vegetation sampling. A two-centimeter diameter soil corer was used to take quadruplicate sub-samples of soil to a 15 cm depth from four random locations within each plant community during each of the five sampling dates: May 22, June 04, June 18, July 03, and July 30. Moist sample weights of cores were immediately recorded in the field. Cores were subsequently oven-dried at 30°C for 72 hours, and re-weighed to determine gravimetric soil moisture by subtracting the oven-dried weights from the moist weights. Sub-sampling moisture values were pooled to the community level in each topographic position, and are provided in Fig. 3.1.

3.2.4. Data Analyses

It was hypothesized that riparian meadows and upland grasslands did not differ significantly in terms of initial, regrowth or total accumulated herbage community DM yield, and quality (CP, CPY and NDF) at all sampling dates throughout the growing season.

The statistical procedure PROC GLM of SAS (SAS Institute Inc. 1999) was used to perform data analyses. Prior to testing the study hypotheses, normality tests were performed on the raw field data: box-plot output showed the data to be normally distributed. In addition, preliminary statistical tests were run to assess the possible effects of the three paddocks on the response variables, as varying historical grazing or land management activities among them could have resulted in different riparian zones within paddocks being non-independent. However, analysis consistently showed that the paddocks had no effect, either alone or in combination with other treatment variables, on each of the dependent variables examined. As a result, each paired riparian meadow - upland grassland combination was considered an independent block in subsequent analysis.

Repeated measure ANOVA was used to examine the effects of variable sampling dates on individual response variables from the plant communities. Statistical tests of hypotheses examined the effects of topographic position (riparian meadow vs. upland grassland), date of sampling (six initial defoliation dates), and the interaction of these factors, on the response variables of herbage yield and quality.

Specific variables examined included initial grass and forb DM yield, as well as total accumulated (initial plus regrowth) DM yield of grasses and forbs. Both initial and total were analyzed, as both are commercially important production variables. Initial growth levels are indicative of opportunities for early season grazing, while total accumulated yield is indicative of the maximum potential season-long grazing opportunities under each defoliation regime. The herbage quality variables analyzed included CP (%), NDF (%), and the CPY (in g/m^2) of initial grass, regrowth grass, and initial forb. In addition, the CPY of total accumulated (initial + regrowth) grass was determined. Mean comparisons were conducted for all significant treatment effects using the Tukey test procedure (Zar 1999). Treatment effects were considered to be statistically significant at $p<0.05$.

3.3. Results and Discussion

3.3.1. Herbage DM Yield

Topographic position, date of defoliation and their interaction had significant effects ($p<0.01$) on initial grass yield (Table 3.1). Initial grass DM yields on upland grasslands ranged from 60 g/m^2 in the early season (May 22) to 200 g/m^2 in the late season (September 02), while those of riparian meadows ranged 151 g/m^2 to 552 g/m^2 over the same period (Fig. 3.2A). The observed production patterns agree with those of Willms (1988) for the Fescue Prairie and Bork et al. (2001) for the Boreal Mixed-Wood, that upland grasslands are considerably lower in season-long herbage production than riparian meadows.

Initial grass yield was about 60% less on upland grasslands than on riparian meadows in May, with this deficit increasing to 72% by July, thereafter declining to 64% in September. These changes account for the significant date of defoliation by topographic position interaction on initial grass yield (Fig. 3.2A). These results indicate that riparian areas may actually increase in importance for producing forage through until late July.

On average, the proportional yield difference between uplands and riparian meadows was 66% for the entire growing season. This value contrasts with that of Willms (1988) who found a difference of 50% in the Fescue Prairie. The results of this study therefore show a greater discrepancy between upland grasslands and riparian meadows in the Aspen Parkland, as compared to those of the Fescue Prairie. Nevertheless, the results from both regions corroborate one other on the importance of lowlands and riparian meadows for herbage production and the provision of greater foraging opportunities for cattle.

The yield difference between upland grasslands and riparian meadows may be attributed to disproportionate levels of soil moisture, which were significantly greater ($p<0.001$) within riparian meadows throughout the study period (Fig. 3.1). Though both topographic positions received the same amount of rainfall during 2000, the meadows may have received and stored additional water that drained into them from adjacent uplands, and may also have benefited from greater snow accumulation. Bork et al. (2001) found that lowlands are more likely to respond to precipitation occurring during the previous dormant season (from snow and runoff) while uplands rely heavily on growing season rainfall.

It is interesting to note that the date of initial grass peak production coincided with July in riparian meadows, but extended into September on uplands (Fig. 3.2A). This observation suggests that despite their low early season production, upland grasslands may still be an important forage source late in the growing season, as was also reported by Willms (1988) for the Fescue Prairie.

Total season-long accumulated grass DM yield was significantly different between the two topographic positions ($p<0.001$), but unlike initial yield, was not significantly different over time (Table 3.1). Mean accumulated grass yield was consistently greater on riparian meadows (575.7 g/m^2) than upland grasslands (197.4 g/m^2) throughout the growing season regardless of initial clipping date (Fig. 3.2B). This finding further reinforces that riparian meadows are more important (on a per unit area basis) for providing season-long forage to ranchers operating in the Aspen Parkland. The fact that there was no significant temporal change in accumulated grass yield in either topographic position (Fig. 3.2B) suggests that in the absence of severe moisture stress and under one-time initial defoliation, grass regrowth appears to compensate for earlier defoliation, irrespective of the timing of initial defoliation. The favorable grass regrowth may be partly due to the high rainfall in July 2000 (Appendix II), which could have maximized the regrowth potential of grass in all the plant communities. However, it is also possible that repeated early season defoliation, particularly if accompanied by drought, could alter range condition and the future production potential of these plant communities.

Initial and total accumulated forb yields were each similar between the two topographic positions examined. Like grass, initial forb yield increased significantly ($p<0.01$) with later dates of defoliation (Table 3.1) with mean initial forb DM yields ranging from 20.8 g/m^2 in May to a peak of 81.4 g/m^2 in September. In contrast, total accumulated forb yields remained relatively uniform at all sampling dates (Table 3.1), averaging 59.1 g/m^2. These results suggest that unlike grasses, forb yields on native Aspen Parkland rangelands are independent of topographic position, although there may be differences in forb species composition among plant communities in different topographic positions (Appendix III). Overall, forb production was only 30% and 10.3% of grass production on upland grasslands and riparian meadows, respectively. This implies that grass (and grass-like) plants provide the most abundant source of forage within this region, especially within riparian meadows.

3.3.2. Herbage Quality

3.3.2.1. Crude Protein and Crude Protein Yield

Initial grass CP and CPY were significantly different ($p<0.001$) between the two topographic positions examined, and also interacted significantly ($p<0.05$) with date of defoliation (Table 3.2). Overall, riparian meadow initial grass CP was greater than that of the upland grasslands from May to September (Fig. 3.3A). This observation agrees with those of Mueggler (1983) and Willms (1988), who also reported a similar difference in forage quality between uplands and lowlands. However, a unique result of the present study is the simultaneous documentation of the sequential season-long decline in grass CP in both riparian meadows and upland grasslands, which better describes the differential season-long changes in the quality of forage available on native Aspen Parkland rangeland. Upland initial grass CP levels declined steadily from 13.6% to 7.2%, while those of the meadows also declined from 16.9% to 8.5% from May to September (Fig 3.3A), representing a temporal decline of approximately 46% on uplands and 50% on meadows.

The CP content of upland grass was greater than the average requirement for both yearling heifers and lactating cows from May to mid June, while that of riparian meadows extended into early July (Fig. 3.3A). This suggests that riparian meadows may be more important as sources of quality forage in sustaining cow-calf production in the Aspen Parkland.

It is worth noting that the CP content of initial upland and meadow grass samples collected on July 30 were similar (~ 9 %). Although the reason for this similarity is unknown, it may be associated with the abnormally high July 2000 precipitation (Appendix II), which probably alleviated soil moisture stress on uplands and enhanced grass growth, allowing forage quality to remain similar to that of riparian meadows (Fig. 3.3A).

Similar to CP, the pattern observed for initial grass CPY was greatest on the meadows (Fig. 3.3B). In contrast to CP, however, CPY increased temporally with progressively later dates of initial defoliation (Fig. 3.3B). Season-long initial grass

CPY of upland grasslands ranged from 8.2 g/m^2 in May to 14.6 g/m^2 in September. On riparian meadows, these values varied from 25.7 g/m^2 in May, to a peak of 55 g/m^2 in late July, and then declined to 46.9 g/m^2 at the end of the growing season in September (Fig. 3.3B). The temporal increase in riparian meadow grass CPY from May until late July indicates that the large increase in grass DM yield was able to more than offset any reduction in CP concentration. The decline in CPY after late July may be attributed to grass maturation and the onset of dormancy, which together with a declining CP content, probably resulted in the reduced meadow grass CPY. These results further indicate that although riparian meadows may constitute a small proportion of the entire landscape, they do provide a disproportionately large amount of the high quality, season-long foraging opportunities for livestock, which may explain why cattle congregate and consume greater herbage from lowland meadows than upland grasslands (Willms 1988, Stuth 1993, Chapter 4 - this volume). It is also apparent that maximum foraging opportunities under a one-time grazing regime may only be attained if livestock grazing is carried out near the date of peak phytomass production in late July.

Regrowth grass CP was similar between the two topographic positions, but changed significantly ($p<0.001$) with initial date of initial defoliation (Table 3.2). As expected, the CP of regrowth grass was lowest for grass initially defoliated early in the season, and greatest for that of regrowth following late season defoliation. Regrowth grass CP ranged from 8.4% for regrowth after May 22nd clipping to 10.5% for that after July 30th. The temporal increase is likely due to the fact that regrowth following later defoliations remained in a younger stage of vegetative growth (Philips et al. 1999).

Regrowth grass CPY varied significantly ($p<0.05$) between topographic positions, date of initial defoliation, and their interaction (Table 3.2). Early to late season regrowth grass CPY ranged from 13.5 g/m^2 to 2.5 g/m^2 on upland grasslands, and 33.8 g/m^2 to 4 g/m^2 on riparian meadows (Fig.3.4A). Following initial clipping, regrowth grass CPY declined on both topographic positions, with greater declines evident on riparian meadows than upland grasslands (Fig. 3.4A).

Total accumulated grass CPY varied significantly ($p<0.05$) across both topographic positions and dates of initial defoliation (Table 3.2), being greatest on the meadows - ranging from 61 g/m^2 in May to 47 g/m^2 in September, and lowest on uplands - ranging from just 22 g/m^2 to 15 g/m^2 over the same period (Fig. 3.4B). These results indicate that riparian meadows provide the greatest quantities of high quality grass all season-long, with no seasonal differences in total CPY provided that the initial date of defoliation occurs prior to August (Fig. 3.4B). Accordingly, deferring livestock grazing until July 15, as practiced on some riparian meadows under waterfowl conservation agreements with Ducks Unlimited Canada (NAWMP 1986), may still sustain total CPY on such meadows, provided grazing is carried out before August when CPY declines (Fig. 3.4B).

Initial forb CP and CPY were similar between the two topographic positions examined. However, initial forb CP and CPY varied significantly by date of defoliation ($p<0.01$) (Table 3.2). As expected, average forb CP declined from 17.9 %

to 11.1 % from May to September, while forb CPY followed a reverse pattern, actually increasing from 2.5 g/m^2 to 7.5 g/m^2 over the same period. Although season-long forb CP seemed to be comparatively greater than that of grass, forb CPY was far less than grass CPY as a result of the very low levels of forb production.

3.3.2.2 Neutral Detergent Fibre

Topographic position had no significant effect on the NDF content of initial grass, regrowth grass, or initial forb samples. However, each of these variables responded significantly to the date of defoliation ($p<0.05$) (Table 3.2). These results suggest that NDF is less sensitive to landscape variation than CP or CPY. Mean initial grass and forb NDF content showed temporal increases from May to September (Table 3.3). This observation corroborates the results of Donkor (2001) who reported a similar trend for boreal grasslands. The temporal increase in NDF is probably indicative of increased fibre content due to plant maturation and the onset of lignification in both plant community types.

Regrowth grass NDF displayed a non-linear temporal trend (Table 3.3). Regrowth grass NDF declined from 66.7% following May 22 initial defoliation to 62.7% with July 02 defoliation, and then rose up to 66.4% when defoliated on July 30. The general decline in regrowth grass NDF from May to July was probably the result of the longer recovery time following early defoliation in may and greater phenological changes towards senescence. However, the increase in regrowth grass NDF after late July was unexpected, as NDF generally shows a continuous decline trend because of reduced fibre in the regrowth of later defoliated plants. Although the reason for this situation is unclear, it may be linked to the interplaying roles of two hydrologic extremes, including the below normal rainfall June 2000 and above normal rainfall July 2000 (Appendix II).

3.4 Summaries and Conclusions

This research documented the simultaneous dynamics of herbage yield and quality in riparian meadow and upland grassland plant communities on a native Aspen Parkland rangeland in central Alberta from May to September 2000. This information provides a better understanding of the sequential season-long grazing opportunities available to livestock, with changes in native range herbage productivity and quality for both riparian meadow and upland grassland communities. Furthermore, this study evaluated the entire plant community, rather than a few select, often tame forages as have been done elsewhere (e.g., Corns 1962, Corns 1974, Philips et al. 1999, Donkor 2000).

Results of the study showed riparian meadows as the more productive topographic position, as well as the one with the greatest quality of herbage throughout the growing season. This may have resulted from increased soil moisture availability in the landscape, which probably ensured vigorous continuous growth of herbage. Whereas initial grass DM yield in each topographic position increased from May to September, total accumulated grass yield in each topographic position remained relatively constant over the same period. This suggests that in the absence of severe moisture stress and under one-time initial defoliation, grass regrowth appears to compensate for earlier defoliation, irrespective of the timing of initial defoliation. The favorable grass regrowth may be partly due to the high rainfall in July (Appendix II), which could have maximized the regrowth potential of grass within the plant communities investigated. Based on the results of this research, it appears livestock grazing can be carried out on native rangeland meadows at any time during the growing season, provided ample time is allowed for plant recovery following initial defoliation. However, some (unaddressed) critical issues to consider may be the frequency, intensity and duration of grazing, as these may significantly influence plant stubble height, regrowth potential, vigor, and ultimately, riparian condition and ecological site potential.

Grass CP was generally greater on riparian meadows. Initial grass CP declined temporally, probably as a result of plant maturation and senescence later in the growing season. The CP content of upland grass was greater than the average requirement for both yearling heifers and lactating cows from May to mid June, while that of riparian meadows extended into early July. Thus, riparian meadows may be more important as sources of high quality forage in sustaining cow-calf production in the Aspen Parkland.

Initial grass CPY was greatest on riparian meadows and increased temporally from May to late July. The temporal increase probably indicates that the large increase in grass yield was able to more than offset any temporal reduction in CP concentration. Riparian meadows also provided the greatest quantities of accumulated (initial + regrowth) grass CPY all season-long, with no apparent seasonal difference prior to early August. This suggests that it is possible to maintain livestock production on riparian meadows provided grazing is carried out before August and a sufficient rest period is allowed to sustain plant regrowth and vigor. In addition, results of this research indicate that deferring livestock grazing until mid July (Ducks Unlimited Canada's Conservation Agreements) for the purpose of conserving critical waterfowl riparian habitats, may not necessarily lead to over-maturation of riparian herbage and a loss of livestock foraging opportunity. However, it must also be recognized that the window of initial grazing opportunity after the deferment period may not last long enough before grass CPY begins to decline in August.

Table 3.1: Effects of topographic position (P), date of defoliation (D), and their interaction on initial and total accumulated grass and forb DM yield within a native Aspen Parkland rangeland in central Alberta during 2000.

			Initial Yield		Total Accumulated Yield (Initial + Regrowth)	
Herbage Component	Source	DF	Mean Square	F value[a]	Mean Square	F value[a]
Grass	Topographic Position (P)	1	229624.6	**33.0****	527572.2	**54.5*****
	Block (B)	5	10703.9	1.5	22535.2	2.3
	Error 1 (B x P)	5	6966.8		9673.7	
	Date of Defoliation (D)	5	31331.1	**28.4*****	437.1	0.3
	D x P	5	9842	**8.9*****	1132.9	0.8
	D x B	25	1480.2	1.3	1606	1.1
	Error 2 (D x B x P)	25	1101.6		1453.8	
	Total	71				
Forb	Topographic Position (P)	1	443.8	0.6	352.2	0.2
	Block (B)	5	277.1	0.4	507.8	0.3
	Error 1 (B x P)	5	764.7	1.3	1613.4	3
	Date of Defoliation (D)	5	1332.4	**5.7****	1242.7	2.3
	D x P	5	79.7	0.3	313.4	0.6
	D x B	25	216.8	0.9	337.4	0.6
	Error 2 (D x B x P)	25	235.6		539	
	Total	71				

[a] - *, **, and *** indicate significant effects at p<0.05, p<0.01, and p<0.001 respectively.

Table 3.2: Effects of topographic position (P), date of defoliation (D), and their interaction on grass and forb CP, CPY and NDF within a native Aspen Parkland rangeland in central Alberta during 2000.

			Crude Protein (CP)		Crude Protein Yield (CPY)		Neutral Detergent Fibre (NDF)	
Herbage Component	Source	DF	Mean Square	F value[a]	Mean Square	F value[a]	Mean Square	F value[a]
Initial Grass	Topographic Position (P)	1	84.2	**68.4*** **	15776.8	**33.4** **	21.1	0.7
	Block (B)	5	4.0	3.3	725.9	1.5	33.4	1.1
	Error 1 (B x P)	5	1.2		473		31	
	Date of Defoliation (D)	5	91.6	**52.8*** **	431.2	**10.5*** **	212.5	**19.7*** **
	D x P	5	5.6	**3.2* **	151	**3.7* **	22.2	2.1
	D x B	25	2.4	1.4	67.5	1.7	12.2	1.1
	Error 2 (D x B x P)	25	1.7		41		10.8	
Initial Forb	Topographic Position (P)	1	5.9	0.7	66.4	0.8	17.3	1
	Block (B)	5	4.6	0.5	26	0.3	28.6	1.7
	Error 1 (B x P)	5	9.1		85.5		16.7	
	Date of Defoliation (D)	5	89.7	**23.2*** **	101.7	**4.2** **	290.5	**17.4*** **
	D x P	5	13.1	**3.4* **	11.7	0.5	17.7	1.1
	D x B	25	4.1	1.1	21.2	0.9	10.9	0.7
	Error 2 (D x B x P)	25	3.9		24.4		16.7	
Regrowth Grass	Topographic Position (P)	1	5.4	4.5	2302.4	**206*** **	0.1	0.0
	Block (B)	5	0.3	0.2	121.5	**10.9* **	4.7	0.2
	Error 1 (B x P)	5	1.2		11.2		24.7	
	Date of Defoliation (D)	4	75.1	**90.0*** **	765.9	**18.8*** **	37.3	**4.0* **
	D x P	4	2.2	2.6	178.3	**4.4* **	3.9	0.4
	D x B	20	1.0	1.2	55.3	1.4	4.8	0.5
	Error 2 (D x B x P)	20	0.8		40.7		9.2	
Total Accumulated Grass	Topographic Position (P)	1			28699.2	**57.3*** **		
	Block (B)	5			1264.8	2.5		
	Error 1 (B x P)	5			501.1			
	Date of Defoliation (D)	5			265.2	**3.5* **		
	D x P	5			74.5	1		
	D x B	25			105.1	1.4		
	Error 2 (D x B x P)	25			75.6			

[a] - *, **, and *** indicate significant effects at p<0.05, p<0.01, and p<0.001 respectively.

Table 3.3: Mean initial grass, regrowth grass, and initial forb NDF in upland grassland and riparian meadow topographic positions, under different initial defoliation dates on a native Aspen Parkland rangeland sampled in central Alberta during 2000. As there were no significant topographic position effects, mean comparisons are with respect to temporal variations in the grand means of the individual variables ($p<0.05$).

Initial Defoliation Date	Initial grass NDF (%)			Regrowth grass NDF (%)			Initial forb NDF (%)		
	Upland	Meadows	Grand mean (temporal)	Upland	Meadows	Grand mean (temporal)	Upland	Meadows	Grand mean (temporal)
May 22	58.3	63.8	**61.1a**	68.1	66.7	**67.4a**	39.4	39.3	**39.3a**
Jun 04	58.2	61.1	**59.6a**	65.2	66.5	**65.9ab**	40.3	34.3	**37.3a**
Jun 18	64.9	62.7	**63.8ab**	65.4	65.5	**65.5ab**	41.7	40.6	**41.1ab**
Jul 03	65.2	65.8	**65.5ab**	62.2	63.2	**62.7b**	42.4	46.6	**44.5abc**
Jul 30	69.5	69.8	**69.6b**	66.8	66.1	**66.4a**	45.5	49.0	**47.3bc**
Sep. 02	69.9	69.4	**69.6b**	-	-	-	51.1	52.3	**51.7c**
Grand mean (position)	64.3	65.4	64.9	65.5	65.6	65.6	43.4	43.7	43.5
Standard Error	2.1	1.5	1.7	1.0	0.6	0.8	1.8	2.7	2.2

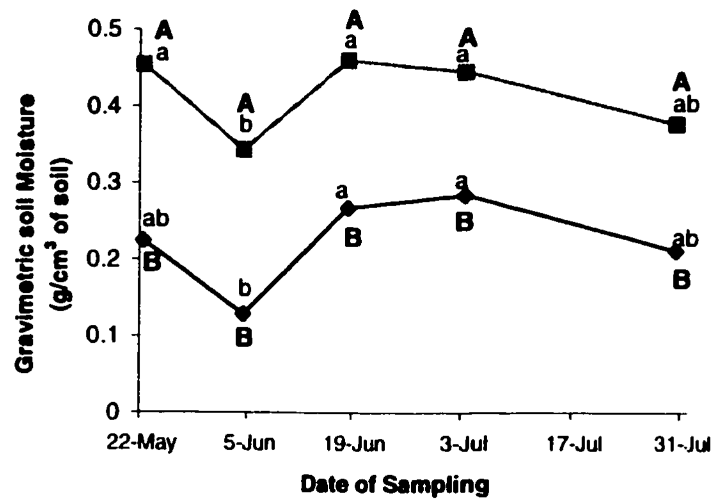


Fig. 3.1: Seasonal variation in gravimetric soil moisture in two topographic positions [upland grassland (♦) and riparian meadow (■)] at Kinsella Ranch during 2000. Within a date of sampling, position means with different uppercase letters differ significantly ($p<0.001$). Within a position, means of different dates of sampling with different lowercase letters differ significantly ($p<0.05$).

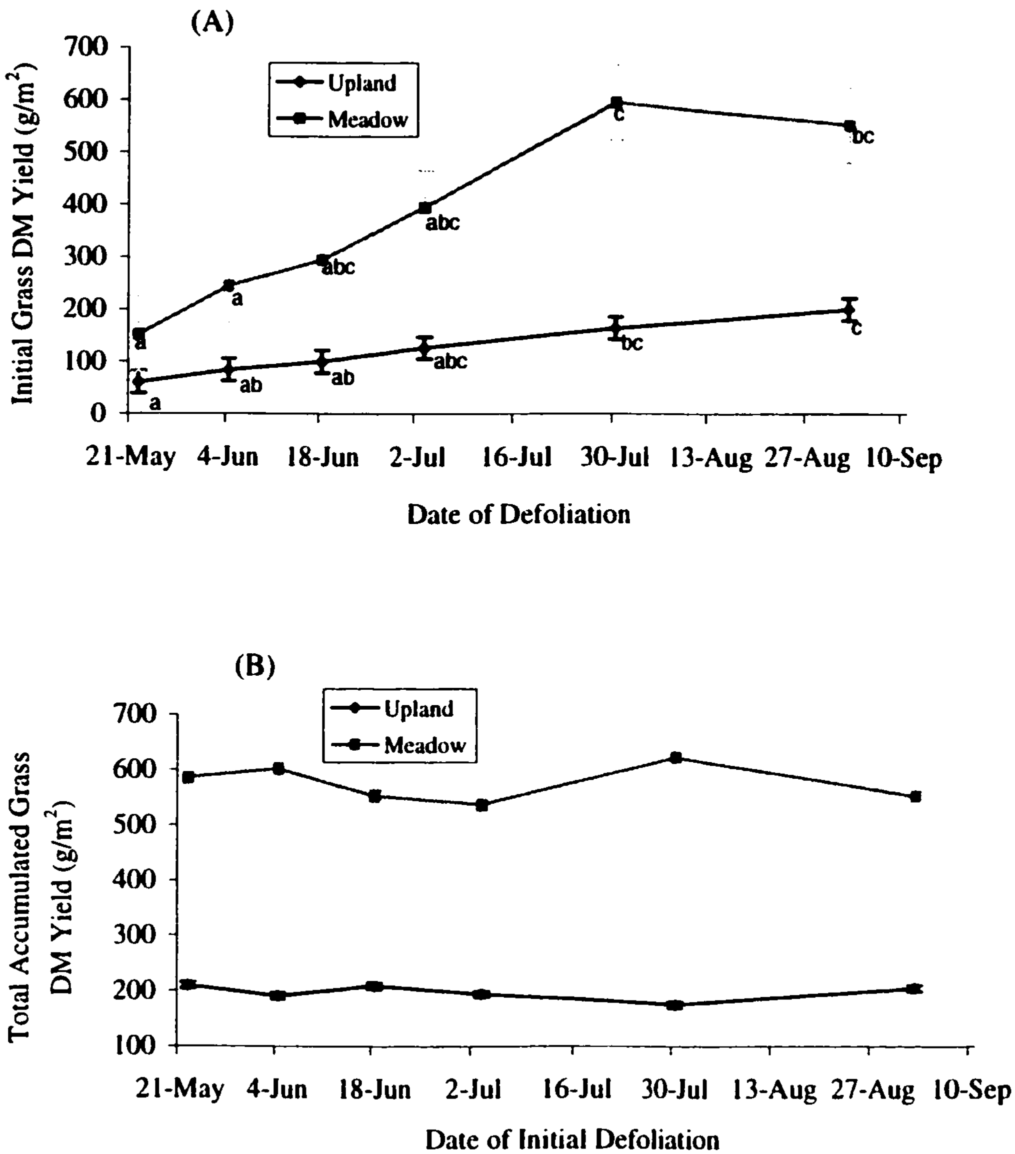
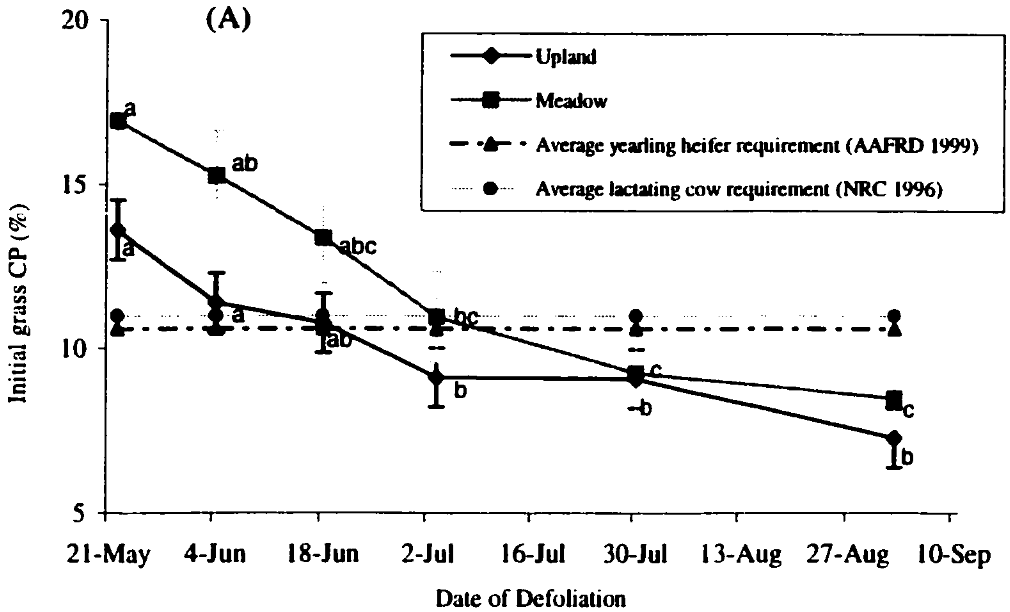


Fig. 3.2: Seasonal dynamics of mean (± s.e.) initial grass (A) and total accumulated (initial + regrowth) grass (B) dry matter (DM) yield in upland grassland and riparian meadow topographic positions on a native Aspen Parkland rangeland sampled in central Alberta during 2000. Within response variables and main treatment (topographic position) effects, means with different lowercase letters differ significantly ($p<0.05$).



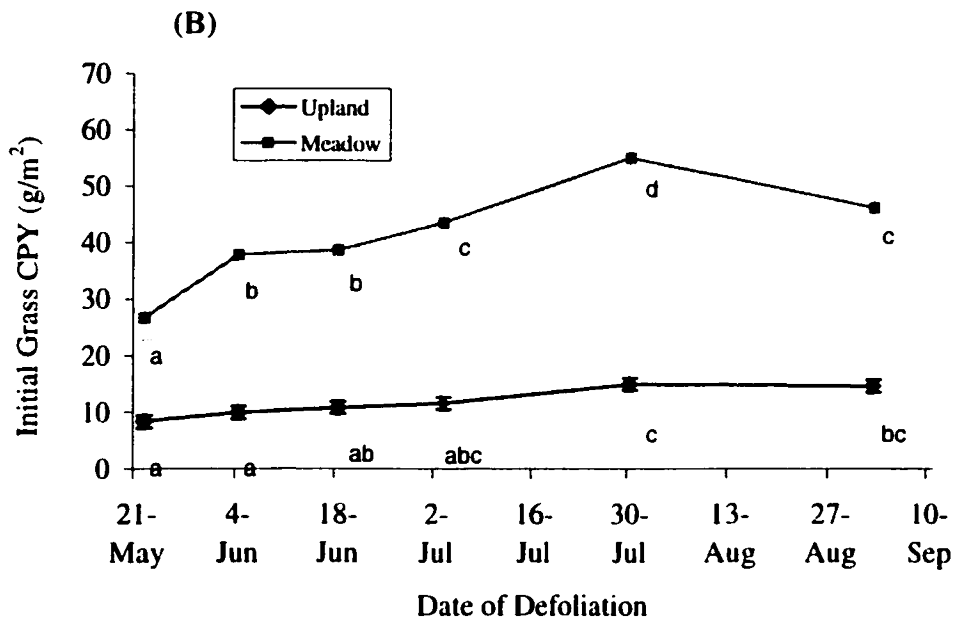
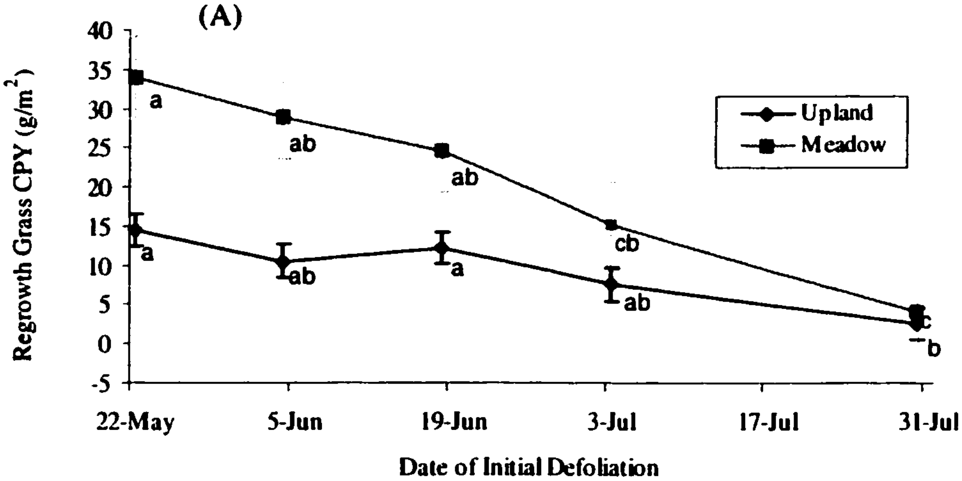


Fig. 3.3: Seasonal dynamics of mean (± s.e.) initial grass (A) crude protein (CP) and (B) crude protein yield (CPY) in upland grassland and riparian meadow topographic positions on a native Aspen Parkland rangeland in central Alberta during 2000. Within response variables and main treatment (topographic position) effects, means with different lowercase letters differ significantly ($p<0.05$).



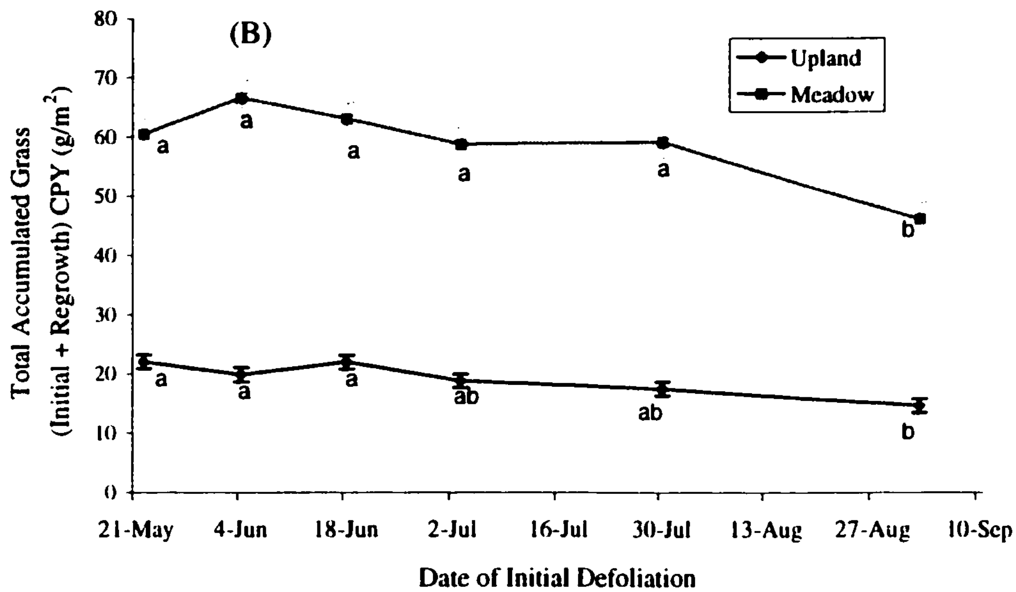


Fig. 3.4: Seasonal variation in mean (± s.e.) regrowth grass (A) and total accumulated (initial + regrowth) grass (B) crude protein yield (CPY) in upland grassland and riparian meadow topographic positions under different initial defoliation dates on a native Aspen Parkland rangeland in central Alberta during 2000. Within response variables and main treatment (topographic position) effects, means with different lowercase letters differ significantly ($p<0.05$).

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CHAPTER 4

HERBAGE UTILIZATION PATTERNS BY YEARLING CATTLE IN DIFFERENT TOPOGRAPHIC POSITIONS OF THE ASPEN PARKLAND

4.1. Introduction

Livestock grazing strategies have evolved over the years through grazing trials on both native rangelands and tame pastures (Stoddart et al. 1975, Popolizio et al. 1994). No one grazing strategy, however, can suffice for all resources or land types because of inherent variability in landscape, vegetation, climatic, and edaphic characteristics (Platts 1990). These variations may produce differential patterns of herbage productivity and quality, which may in turn, dictate the grazing behavior of livestock on the range (Stoddart et al. 1975, Gillen et al. 1985, Laca 1988, Walker et al. 1989, Coughenour 1991, Bailey et al. 1996, Kie and Boroski 1996, Willms and Rode 1998, Clary and Leininger 2000, Dockrill 2001).

Studies in various ecosystems have reported that cattle distribution on rangelands is influenced by herbage type (Smith et al. 1992, Vallentine 2001), availability (Bryant 1982, Willms 1988, Vallentine 2001), and quality (Cook 1966, Kie and Boroski 1996, Vallentine 2001), as well as topography (Mueggler 1965, Hart et al 1991, Pinchak et al. 1991) and water availability (Willms 1990). In addition, different species and age groups of livestock graze rangeland herbage, especially those in riparian zones, in different ways and exert variable impacts on the landscape (Platts 1990, Holochek et al. 1998). For example, cattle have been found to congregate on lowlands relative to adjacent uplands (Willms 1988, Stuth 1993, Philips et al. 1999), potentially due to the inhibitory effect of steep slopes (Mueggler 1965), and they have been found to exert more trampling effects on riparian zones than either sheep or goats (Holochek et al. 1998).

According to Irving et al. (1995), distance from water source greatly influenced herbage utilization patterns by cattle in the Mixed Prairie-Aspen Parkland transition in central Alberta. Working in the Fescue Prairie, Willms (1988) found that the greatest relative use of lowlands occurred during spring and early summer, but declined later in the growing season. Marlow and Pogacnik (1986) observed that abundant early season (spring) precipitation on a foothill rangeland facilitated greater growth of upland herbage, which attracted cattle to utilize these topographic positions earlier in the season compared to riparian meadows. The opposite pattern occurred when there was low spring precipitation, with cattle utilizing riparian meadows prior to switching onto uplands later in the season. Available literature indicates that the primary attractants to grazing animals within riparian zones include high forage availability, quality, palatability, and succulence (Skovlin 1984, Dockrill 2001, Vallentine 2001).

Riparian areas also serve as critical habitats for wildlife (Platts 1990). Wildlife dependence on riparian zones is increasingly becoming an issue of critical concern because of the numerous problems associated with over-utilization by cattle (Platts 1990, Holochek et al. 1998, Vallentine 2001). Some wildlife species are completely dependent on riparian zones for survival, while many others use these zones as transient habitats, either spatially or seasonally (Thomas et al. 1979, Kauffman and Krueger 1984). Concentrated cattle grazing on rangelands significantly affects plant community composition (Kauffman et al. 1983, Kauffman and Krueger 1984), as well as vegetation structure and diversity (Bai et al. 2001), which in turn, affect wildlife and their habitats (Schulz and Leininger 1990, Eccard et al. 2000). The timing, frequency and intensity of defoliation significantly influence herbage production and quality on both lowland meadows (Corns 1974) and upland grasslands (Donkor 2001). However, grazed riparian areas have been found to be greater in forage quality compared with that of ungrazed areas (Philips et al. 1999).

In summary, riparian zones are critically important for forage production (Willms 1988, Van Ryswyk et al. 1995), as well as water yield, wildlife habitat, and esthetics (Skovlin 1984, Elmore and Beschta 1987). Despite their importance, riparian zones have often been overlooked over the years because of their small size relative to the entire range landscape (Gillen et al. 1985), and have often been overgrazed (Holochek et al. 1998). With the increasing awareness of the tremendous importance of riparian zones as critical waterfowl habitats, exclusion of livestock grazing has been advocated in order to protect such sites (NAWMP 1986). This recommendation appears to be based on the assumption that grazing is incompatible with the conservation of riparian zones. However, several research studies have reported that herbage productivity and soil properties within riparian zones can be improved under appropriate livestock grazing strategies (Kauffman and Krueger 1984, Elmore 1992, Kie and Boroski 1996). For example, maintaining adequate herbage stubble height (10 cm or more) is important for sustaining plant vigor, stabilizing stream-banks, and enhancing cattle grazing efficiency (Clary and Leininger 2000).

The Aspen Parkland is an important livestock production zone in western Canada (McCartney 1993). According to Bailey (1987), native rangelands in the region significantly support the beef industry in Alberta. Topography exerts a significant effect on soils (Acton 1965) and resulting vegetation distribution across landscapes in the region. The Aspen Parkland's typical "knob and kettle" topography creates an abundance of sloughs and riparian zones in depressional areas that are important livestock foraging sites, as well as critical habitats for waterfowl and other wildlife. Under conservation initiatives from Ducks Unlimited (an environmental non-governmental organization in North America), livestock grazing is frequently deferred on waterfowl nesting sites until mid July each year to enable waterfowl to successfully complete their annual breeding cycle (NAWMP 1986). The successful implementation of this initiative, especially on private lands, requires extensive cooperation from private landowners. Ranchers are faced with the challenge of balancing riparian conservation with obtaining livestock gains from utilizing the abundant, high quality herbage found in these areas. Thus, it becomes evident that in order to develop sustainable livestock grazing strategies for complex landscapes containing riparian zones, it is important to understand the inherent livestock grazing behavior and pattern of occupancy within various plant communities during various stages of the growing season. This information is prerequisite to developing innovative and effective livestock grazing strategies that make optimum bio-economic use of total seasonal herbage production while conserving riparian habitats in the Aspen Parkland. Such information will also be critical in providing advice on the appropriate ecosystem or "key area" based grazing strategies (Stoddart 1975) required to maintain overall rangeland productivity. Grazing strategies are often site-specific, and must conform to the ecological needs of each specific land area (Platts 1990).

The research reported here documents early and late season herbage utilization patterns by yearling heifers across three topographic positions on a native rangeland in the Aspen Parkland ecoregion of central Alberta, and provides information needed to develop appropriate livestock grazing strategies for maintaining native rangeland productivity and long-term sustainability in the region. This study was done concurrently with the one reported earlier in Chapter 3.

4.2 Materials and Methods

4.2.1. Study Area

The study was conducted at the University of Alberta Beef Cattle Research Ranch (53°01'N, 111°34'W), located near Kinsella in the County of Beaver, about 150 km southeast of Edmonton, Alberta. The ranch, which is partitioned into fenced paddocks, is 3,100 ha in size, and is situated within the Aspen Parkland Ecoregion of western Canada (Strong 1992). In its continental setting, the ranch experiences cold winters and warm summers that peak in January and July, respectively. Growing season average monthly temperatures are shown in Appendix I. Average annual (January to December) and growing season (May to August) precipitation are 412 and 259 mm, respectively (Environment Canada 1960-2000). Appendix II shows the average monthly growing season rainfall patterns for the ranch.

The ranch is located on a geological formation characterized by calcareous parent material developed from glacial debris deposited over underlying marine shales during the last glaciation, ending about 10,000 years ago (Gravenor 1959). The landform is hummocky moraine, and there are typically strong effects of topography and aspect on soils and vegetation across the landscape (Ellis 1932, Moss and Campbell 1947, Acton 1965). According to Wheeler (1976), zonal soils on well-drained upland topographic positions include Orthic Black Chernozems, while poorly drained lowlands and riparian meadows are characterized by Gleysols. Eluviated Black Chernozems occur on mid to lower slope positions, with Luvisolic soils on forested north-facing slopes and Dark Brown Chernozems on more xeric and steeply sloped upland sites with grassland vegetation.

Vegetation includes native and tame grasslands, interspersed with deciduous shrub and forest communities (Wheeler 1976). The distribution of plant communities across the landscape is strongly influenced by topography and aspect (Wheeler 1976, Scheffler 1976), as well as anthropogenic disturbances such as livestock grazing (Bailey et al 1990, Fitzgerald and Bailey 1984) and burning (Bailey et al 1990, Anderson and Bailey 1980, Bailey and Anderson 1979).

The native grassland vegetation has been described as the *Festuca scabrella* Association (Moss and Campbell 1947) or Fescue Prairie Association (Coupland 1961). According to Wheeler (1976) and Scheffler (1976), the range type common on well-drained xeric uplands, the *Stipa-Agropyron* faciation, is comprised of western porcupine grass (*Stipa curtiseta* A.S. Hitch.), northern wheatgrass (*Agropyron* *dasystachyum* Scribn.), and western wheatgrass (*Agropyron smithii* Rydb.). *Festuca-Stipa* grasslands, dominated by plains rough fescue (*Festuca hallii* (Vasey) Piper) and western porcupine grass, along with northern and western wheatgrasses, occupy non-forested uplands on deep moist soils. Depressional vegetation in lowlands includes hygric sedges (*Carex spp.*), slough grass (*Beckmannia syzigachne* Steud.), tall mannagrass (*Glyceria grandis* S. Wats.) and alkali cordgrass (*Puccinellia nuttalliana* Schult.), with an occasional overstory of willows (*Salix spp.*). Trembling aspen (*Populus tremuloides* Michx.) forest is common on north-facing slopes, while buckbrush (*Symphoricarpos occidentalis* Hook.), snowberry (*Symphoricarpos albus* Blake), rose (*Rosa spp.* L.), Saskatoon (*Amelanchier alnifolia* Nutt.), silverberry (*Elaeagnus commutata* Bernh.) and shrubby cinquefoil (*Potentilla fruticosa* L.) occur in association with aspen forests, or as shrublands on deep, moist soils on depressional fringes.

Common upland forbs and shrubs include common yarrow (*Achillea millefolium* L.), silver sage (*Artemisia cana* Pursh), prairie sagewort (*Artemisia ludoviciana* Nutt.), and pasture sagewort (*Artemisia frigida* Willd.). Forbs are widespread within more mesic sites on both north and south aspects. These include smooth aster (*Aster laevis* L.), old man's whiskers (*Geum triflorum* Pursh), sticky purple geranium (*Geranium viscosissimum* Fisch. & Mey.), and northern bedstraw (*Galium boreale* L.). Common herbaceous invaders include Kentucky bluegrass (*Poa pratensis* L.), smooth brome grass (*Bromus inermis* Leyss.), and dandelion (*Taraxacum officinale* Weber).

The ranch is partitioned into fenced paddocks for livestock grazing. This study utilized an area of the ranch known as the "wagon wheel" grazing system, which includes ten paddocks with a central water source used annually for rotational grazing of 150 yearling heifers. In this study, three of the ten paddocks were selected on the basis of their uniformity in size (15 ha each), as well as the availability of suitable riparian meadows (minimum of two per paddock) in close proximity to adjacent upland native grasslands and aspen forests, for testing the study hypotheses. Within the paddocks, riparian meadows constituted 0.6 ± 0.1 ha of the land base, while upland grassland and forest communities were 7.8 ± 1.2 and 6.6 ± 0.9 ha, respectively. Sedges (*Carex spp.*) dominated the meadows, with shrubby willows (*Salix spp.*) occupying their fringes. A list of herbaceous plant species within upland grassland, riparian meadow, and forest communities is shown in Appendix III. Prior to beginning field sampling in May 2000, the meadows had traces of standing water in them, likely originating from spring melt water accumulation. However, all the water had disappeared by the first date of sampling (May 22).

4.2.2. Study Design

Herbage yield and utilization by cattle were tested with a split-plot design (Zar 1999), using the three grazing paddocks. In each paddock, two replicate "blocks" of three plant communities (r=2) were examined. Each block consisted of three adjacent and sequential topographic positions (a=3) across the landscape catena, including a south-facing upland grassland, lowland riparian meadow, and north-facing aspen forest community. Grazing was implemented in two separate rotations over the same paddocks in order to make early and late-season observations. Dates of grazing and sampling in the 1st rotation (early season) were June 01-04, June 17-20, and July 01-04 (b_1=3), while those in the 2nd rotation (late season) were July 16-18, July 29-31, and August 12-14 (b_2=3). Duplicate sub-sampling was conducted in each plant community within a block (n=2), bringing the total sub-sample size (**N=a** x **b**$_i$ x **n** x **r**) in each rotation to 36.

The same design implemented above was used in studying daily patterns of cattle utilization of herbage among the three plant communities. Within each plant community, Frequencies of herbage use by cattle (f_i) were repeatedly measured at the end of each day of grazing during each grazing period. Grazing periods in the 1st and 2nd rotation were four and three days, respectively. Thus, the total sub-sample sizes (**N=a** x **b**$_i$ x **n** x **r** x **f**$_i$) in the frequency data were 144 and 108 in the 1st and 2nd rotation, respectively.

4.2.3. Herbage Measurements

4.2.3.1. Herbage Utilization

Two portable 1.5 x 1.5 m exclosure range cages were randomly set up within each plant community shortly after snow melt on May 10, 2000, prior to livestock entry into the paddocks. Grazing was subsequently carried out in the 1st rotation with 150 yearling heifers for 4 days at a stocking rate of 1.1 AUM/ha (Appendix IV). In the 2nd rotation, six breeding bulls were added to the herd, and grazed for three days at a stocking rate of 0.9 AUM/ha. The herd was granted unrestricted access to each paddock from 6:00 pm on the day prior to the commencement of the scheduled date of grazing in the paddock, until 6:00 pm on the last day of the scheduled grazing period in both grazing rotations. Prior to beginning the 2nd rotation, range cages were randomly repositioned to grazed areas on the same plant communities to take new measurements of available standing crop of herbage (regrowth) available for cattle grazing following the 1st grazing cycle.

At the end of each grazing period, all above-ground herbage within a 40 cm x 80 cm quadrat was clipped to ground level inside each exclosed range cage to determine available herbage yield per unit area in each plant community. Similar clips were made 1 m outside each cage to assess post-grazing herbage phytomass. Each clip sample was sorted into grass and forb components, oven-dried at 30°C for 72 hours, and weighed to determine dry matter (DM) yields per unit area. Clip samples were pooled into grass and forb mean DM production and utilization values per plant community at each topographic position for subsequent analysis. Caged-uncaged comparisons with the paired-plot method (Cook and Stubbendieck 1986) were used to quantify the "absolute" herbage utilization per unit area in each community. In addition, "relative" herbage utilization was computed as the proportion of DM yield utilized in each community, expressed as a percentage. Bork and Werner (1999) suggest that information on absolute and relative utilization may both be important, particularly when assessing grazing impacts from the perspectives of the grazing animal and plant community, respectively.

4.2.3.2. Herbage Quality

Grass components of the oven-dried herbage samples were analyzed for herbage quality. Samples were ground through a 1 mm screen using a Wiley Mill to facilitate laboratory determination of percent crude protein (CP) and neutral detergent fibre (NDF) during the 1st and 2nd grazing rotations. Crude protein (that is, Nitrogen content of the sample multiplied by 6.25) was analyzed by the Dumas method using the LECO FP-428 analyzer (Sweeney and Rexroad 1987, Jacob et al. 1995, Simonne et al. 1995, Lee et al. 1996). Crude protein yield (CPY) and crude protein utilized (CPU) were respectively computed as the CP fraction of grass DM yield and grass DM utilized by the heifers, using the relationship (CP/100)*DM in g/m^2. The ANKOM filter bag technique (Komarek 1993, Safigueroa et al. 1999) was used to analyze NDF.

4.2.3.3. Daily Patterns of Plant Community Utilization

Two 10-metre permanent transects were randomly established within each of the plant communities examined in the three study paddocks prior to introducing cattle. Twenty, 20 cm x 50 cm quadrats were monitored daily for frequency of herbage utilization along each 10-metre transect during each grazing period, in order to capture fine-scale temporal habitat selection activities. The number of quadrats that had experienced one or more cattle bites by 6:00 pm of each day during the four and three day scheduled grazing periods in the 1st and 2nd rotations, respectively, were counted. Frequencies of herbage utilization data were calculated and converted to % utilization for each plant community for subsequent statistical analyses in assessing daily trends in plant community use throughout each grazing period.

4.2.4. Data Analyses

Data from each grazing rotation were analyzed separately, as available herbage phytomass in each rotation was phenologically different in terms of seasonal growth. Herbage available to cattle during the 2nd rotation was essentially regrowth from the 1st rotation.

It was hypothesized that:

i. Absolute and relative herbage utilization levels would not be significantly different among plant communities from the three topographic positions, as well as among dates of sampling within each rotation,

ii. Daily frequency of plant community utilization during each grazing period would not be significantly different across the three topographic positions.

The statistical procedure PROC GLM of SAS (SAS Institute, Inc 1999) was used to perform all data analyses. Prior to statistically testing the study hypotheses, normality tests were performed on the raw field data, with box-plot output indicating the data to be normally distributed. All data were analyzed as a split-plot design, with topographic position blocked within dates of grazing in each rotation. Analysis of Variance (ANOVA) examined the effects of topographic position (riparian meadow, upland grassland, and forest), and dates of grazing /sampling (June 01-04, June 17-20, and July 01-04 in the 1st rotation, and July 16-18, July 29-31, August 12-14 in the 2nd rotation), as well as their interactions on dependent variables, including absolute and relative herbage utilization, as well as daily patterns of herbage utilization. Response variables for absolute herbage utilization were dry matter (DM) of grass and forb utilized. Relative herbage utilization was analyzed as the absolute utilization fraction of herbage yield, expressed as a percentage. Daily patterns of plant community utilization were examined as the frequencies at which cattle utilized the plant communities within each topographic position during each day in a grazing period.

Herbage DM yield and quality variables, including NDF, CP, CPY and CPU of grass samples were also analyzed to help interpret herbage utilization data. Paired t-tests (Zar 1999) were used to compare means of categorical variables, including grass and forb components. Mean comparisons were conducted for all significant treatment effects ($p<0.05$) using the Tukey test procedure (Zar 1999).

4.3. Results and Discussions

4.3.1. Absolute and Relative Herbage Utilization

The utilization of grass, but not forb, varied significantly ($p<0.001$) among topographic positions during the 1st and 2nd grazing rotations (Table 4.1). Furthermore, paired mean comparisons (Table 4.2) showed grass, rather than forb, to be the principal component of both the available and utilized herbage ($p<0.05$). The increased absolute utilization of grasses rather than forbs, particularly in the 2nd rotation (Table 4.2) indicates grass abundance may be a key factor driving cattle grazing behavior (Willms 1998, Vallentine 2001) on native Aspen Parkland rangelands. Both mean herbage DM yield and absolute utilization of grass per unit area were greater on riparian meadows ($p<0.05$) during both grazing rotations (Table 4.2). These results corroborate those of other researchers (e.g., Skovlin 1984, Kauffman and Krueger 1984, Gillen et al. 1985, Willms 1988), and affirm the importance of riparian meadows as foraging sites for livestock. The low overall forb production in either rotation may have influenced the lack of significant absolute forb utilization among the three topographic positions examined (Table 4.2).

Overall grass and forb production per unit area remained similar at all grazing dates within each rotation. Mean production values for each component across the three dates of grazing in the 1st and 2nd rotation were 103.0 and 138.7 g/m^2 respectively for grass, and 10.0 and 5.6 g/m^2 respectively for forb. The lack of an increase in forage production was unexpected, as vegetation generally exhibits appreciable growth with rapid phenological development in spring and early summer. However, it is suspected that the two week grazing interval among the three successive dates of grazing in either rotation may have been inadequate to allow for appreciable changes in herbage production, and consequently, absolute utilization. This observation is consistent with the results in Chapter 3 (Fig. 3.2A), which found no significant change in grass yield among the three initial defoliation dates in spring. Overall, absolute grass utilization was greatest on riparian meadows (Table 4.2). Coupled with the overall high levels of grass production in this location, the results suggest that foraging opportunity could be among the important factors that determine cattle grazing behavior on Aspen Parkland landscapes.

Although date of grazing alone had no significant affect on the absolute utilization of grass, it did interact with topographic position to produce significant effects in both rotations ($p<0.05$) (Table 4.1). Examination of the data indicated that absolute grass utilization in each topographic position varied among dates of grazing in both rotations, but remained consistently greater on riparian meadows (Table 4.3).

Unlike absolute utilization, relative grass and forb utilization levels were similar across all topographic positions examined during both the 1st and 2nd grazing rotations (Table 4.1, 4.2). This suggests that although differential patterns of absolute grass utilization may be typical across various plant communities on native Aspen Parkland rangelands as a result of differences in foraging opportunities in various topographic positions, the use of high intensity-low frequency (HILF) grazing may have continued to ensure relatively even use of the entire landscape. It is important to note that the use of continuous or season-long grazing may have resulted in less uniform use among plant communities than that observed here, as low stocking densities are typicall*y* employed with this grazing system, resulting in maximum patchiness of use across the landscape (Platts 1990). Furthermore, the high availability of forage within riparian meadows may make these areas more susceptible to excessive use under low density season-long grazing.

Relative grass utilization did respond significantly ($p<0.01$) to the date of grazing in the 2nd rotation (Table 4.1), with low utilization (~35%) on July 18 that increased significantly during the last two grazing dates of July 31 and August 14 (Fig 4.1). The reason for this trend remains unclear. However, one possibility is that the abundant July 2000 rainfall (Appendix II) may have caused herbage to become more succulent, and therefore attracted cattle to utilize more herbage (Vallentine 2001) during the last two grazing dates in the 2nd rotation.

Examination of the grass forage quality variables, including CP, CPY, and CPU indicated that apart from CP content in the 2nd rotation, all variables analyzed in each rotation were consistently influenced by topographic position (Table 4.4). Crude protein in both rotations was also significantly influenced by the interaction of date of grazing and topographic position (Table 4.4). Although overall CP content was significantly greater on riparian meadows in the first rotation (Table 4.5), no differences existed among the three plant communities by July 04. Table 4.5 also indicates that although CP generally declined with later dates of grazing in the first rotation, the greatest reduction occurred within riparian meadows (from 20.2 to 9.6%). In contrast, moderate declines were evident within upland grasslands, with relatively minor, non-significant losses on forested areas (Table 4.5).

There was no significant difference in grass CP content across either topographic positions or dates of grazing in the 2nd rotation (Table 4.4). This observation was unexpected, as CP content generally declines with time (Donkor 2001). However, it is suspected that the equal rest period of approximately 6 weeks between the 1st and 2nd grazing cycles probably caused grass regrowth (i.e., available grass in the 2nd rotation) to remain at a similar phenological condition, and therefore accounted for the non-significant temporal change in grass CP content (Table 4.5).

The interaction of topographic position and dates of grazing significantly affected grass CP ($p<0.05$) in both rotations (Tables 4.4). In the 1st rotation, the interaction effects were caused by a high CP level within riparian meadows and upland grasslands on June 04 relative to the other topographic positions and dates of grazing. In the 2nd rotation however, the interaction was due to low grass CP on upland grasslands on July 18, and also on forested sites on July 31 (Table 4.5).

Both CPY and CPU differed significantly ($p<0.05$) among the three topographic positions in both rotations (Table 4.4), with each variable greater on riparian meadows than either of the other two positions (Table 4.5). The significantly greater CPY and CPU within the riparian meadows may have been influenced by the greater grass DM yield and absolute grass utilization respectively, at this location.

Neither topographic position nor date of grazing produced significant effects on grass NDF content, which averaged 68% in both rotations.

Based on these results, it appears that in addition to high grass availability, the high CP content of riparian meadow grass may also have influenced cattle foraging behavior (Bailey et al. 1996, Vallentine 2001), particularly prior to July 04 when forage quality was greater. The lack of differences in forage quality after July 4, however, reinforces the notion that greater absolute utilization of meadow grass after this date was probably due to greater opportunities for cattle to enhance forage intake within riparian meadows.

4.3.2. Daily Frequency of Plant Community Utilization

Date of grazing, topographic position, and their interaction had significant effects ($p<0.05$) on the daily frequencies of herbage utilization in both the 1st and 2nd rotations (Table 4.6). Graphical displays of daily herbage utilization patterns within each grazing period in the two rotations are presented in Fig. 4.2 (A to F). Overall, cattle appeared to utilize herbage on the riparian meadows sooner and more frequently than within the other topographic positions. Sampled quadrats within riparian meadows typically experienced 90% plus utilization by the end of the second grazing day within a grazing period in either rotation (Fig. 4.2). This herbage utilization pattern is probably due to the ready availability of abundant high quality grass within the riparian meadows relative to the other topographic positions, which may have attracted cattle into these sites (Marlow and Pogacnik 1986, Willms 1988, Bailey et al. 1996, Vallentine 2001). In addition, high levels of soil moisture may have ensured that riparian meadows remained productive and encouraged cattle utilization. In June 2000, precipitation was slightly below normal (Appendix II) and may have limited plant growth within upland grassland and forested sites. This situation may further account for the affinity cattle demonstrated for riparian meadows over the upland grassland and forested sites in early July (Fig. 4.2C).

The upland grasslands, on average, were less frequently utilized compared to the adjacent forested slopes during the 1st rotation (Fig. 4.2; A, B and C). During the 2nd rotation, however, this pattern appeared to reverse, with upland grasslands more frequently utilized than forested sites (Fig. 4.2; D, E and F). Upland grassland productivity, unlike that of other plant communities, is heavily dependent on growing season precipitation (Marlow and Pogacnik 1986, Bork et al. 2001). Thus, the herbage utilization patterns observed in this study may be at least partly due to precipitation patterns. In particular, low spring soil moisture on south-facing grasslands may have limited herbage growth and foraging opportunities on upland grasslands in the 1st rotation, particularly in early June (Fig. 4.2; A, B and C). However, high rainfall in July (Appendix II) probably resulted in enhanced upland grassland productivity, as well as increased growth of warm season herbage, encouraging cattle to utilize these areas more heavily in the 2nd rotation (Fig. 4.2; D, E and F). It is also possible that the abundant July 2000 rainfall caused cattle to avoid humid forested sites in favor of relatively drier upland grasslands.

Forested sites received greater utilization relative to upland grasslands during the 1st rotation (Fig. 4.2; A, B, and C). It is likely that the forested sites had available succulent herbage in spring (Vallentine 2001), as these locations may have benefited from snow accumulation the previous winter, enhancing succulent spring herbage growth compared to upland grasslands with little snow and spring drought. In addition to herbage, shrub and aspen succulence may have attracted cattle to mostly utilize forested sites in spring compared to upland grasslands (Alexander and Bailey 1992, Alexander 1995, Dockrill 2001). Conversely, cattle avoidance of forested sites during the 2nd rotation (Fig. 4.2; D, E, and F) was probably the result of shrub and aspen becoming lignified and less palatable (Dockrill 2001). It is also likely that cattle sacrificed thermal comfort and avoided the forested sites because of the presence of high abundance of insects during mid-late summer, particularly following the heavy July 2000 rainfall.

4.4. Summaries and Conclusions

Herbage utilization patterns by heifers using a high intensity-low frequency grazing system were documented across three topographic positions on a native Aspen Parkland rangeland in central Alberta, including riparian meadows, upland grasslands, and north-facing forests, under both early and mid-to-late growing season conditions. Results indicated grass to be the principal herbage component utilized across all topographic positions. Riparian meadows consistently experienced the greatest phytomass removal (absolute utilization) per unit area, highlighting their importance for commercial beef production. In addition, the grass component of riparian meadows was greatest in CP prior to July, and in both CPY and CPU throughout the study. The results suggest that although forage quality may influence cattle grazing behavior early in the year, intake opportunities ultimately regulate where cattle graze within Aspen Parkland landscapes. That is, greater grass abundance probably attracted cattle to utilize riparian meadows more heavily.

Unlike absolute utilization, relative use did not differ among positions, indicating that cattle grazed all topographic positions in proportion to available herbage. This implies that, with an appropriate grazing system such as the high intensity-low frequency grazing system used in this study, ranchers can make optimum use of the abundant foraging opportunities on riparian meadows, and simultaneously ensure uniform use of the entire landscape. However, further research is needed on how these patterns of use may vary under different gazing systems, including continuous, short-duration and more simplistic forms of rotational grazing.

Riparian meadows also received the highest daily frequencies of plant community utilization. Cattle appeared to concentrate on riparian meadows before moving onto the other topographic positions during both the 1st and 2nd rotations, probably as a result of the readily available foraging opportunities at this location.

Forested sites were more frequently utilized than upland grasslands during the 1st rotation from June to early July. This was probably due to limited herbage growth on uplands as opposed to herbage availability on forested sites. The pattern reversed in August with forested sites being avoided in favor of uplands. This may have been caused by the high precipitation in July 2000, which probably influenced upland herbage growth to increase forage availability for cattle. As well, advancing plant phenology (maturation, senescence and aspen lignification) and high insect density in forested sites may have caused cattle to avoid these sites in favor of upland grasslands later in the season.

Table 4.1: Effects of date of grazing (D), topographic position (P), and their interaction on absolute and relative herbage utilization by yearling heifers on a native Aspen Parkland rangeland in central Alberta during 2000 (N=36).

			Absolute herbage utilization (g/m^2)				Relative herbage utilization (%)			
			Grass		Forb		Grass		Forb	
Rotation	Source	DF	Mean Sq.	F Value[a]	Mean Sq.	F Value[a]	Mean Sq.	F Value[a]	Mean Sq.	F Value[a]
1st Rotation	Date of grazing (D)	2	1426.5	0.1	597.6	0.6	88.6	0.4	2983.5	0.5
	Error A - "Rep (D)"	3	13134.4		984.7		466.2		2861.4	
	Topographic position (P)	2	66667.2	**20.6*** **	293.1	0.7	340.2	1.4	8130.4	1.4
	D x P	4	10298.2	**3.2***	513.4	1.2	589.0	2.5	4938.4	0.8
	Error B - Residual	24	3244.7		440.4		237.5		5972.2	
2nd Rotation	Date of grazing (D)	2	8097.5	4.1	11.8	0.1	1330.7	**7.4****	7165.3	1.7
	Error A - "Rep (D)"	3	1973.6		83.8		520.1		3174.4	
	Topographic position (P)	2	58762.3	**33.5*** **	19.3	0.3	232.0	1.3	576.1	0.1
	D x P	4	8985.4	**5.1****	58.4	1	456.3	2.5	5211.5	1.2
	Error B - Residual	24	1751.9		58.5		180.5		4220.5	

[a] - *, **, and *** indicate significant effects at $p<0.05$, $p<0.01$, and $p<0.001$, respectively.

Table 4.2: Mean herbage DM yield and utilization within three topographic positions during each of two grazing rotations on a native Aspen Parkland rangeland in central Alberta during 2000. Within a herbage type and rotation in each response variable, treatment (topographic position) means with different lowercase letters differ significantly ($p<0.05$). Within response variables and rotation, grand means of herbage types (grass and forb) with different uppercase letters differ significantly ($p<0.05$).

		Available Herbage DM Yield (g/m^2)		Absolute Utilization (g/m^2)		Relative Utilization (%)	
Herbage type	Topographic Position	1st Rotation	2nd Rotation	1st Rotation	2nd Rotation	1st Rotation	2nd Rotation
Grass	Upland grasslands	124.8 a	192.6 a	76.2 a	104.1 a	61.1	54.0
	Riparian meadows	353.4 b	479.4 b	206.3 b	211.4 b	58.4	44.1
	N-facing forests	136.9 a	159.5 a	78.2 a	80.0 a	57.1	50.1
	Mean (± s.e.)	**205.0(74.3) A**	**277.2(101.6) A**	**120.2(43.0) A**	**131.8(40.4) A**	**58.9(1.2) A**	**49.4(2.9) A**
Forb	Upland grasslands	13.3	13.6	4.5	2.7	33.6	19.9
	Riparian meadows	20.6	6.8	9.9	1.8	47.9	26.4
	N-facing forests	26.4	13.9	14.3	5.0	54.3	36.2
	Mean (± s.e.)	**20.1(3.8) B**	**11.4(2.3) B**	**9.6(2.8) B**	**3.1(1.0) B**	**45.3(6.1) A**	**27.5(4.7) B**
Total herbage	Upland grasslands	138.1 a	206.2 a	80.7 a	106.8 a	58.4	51.8
	Riparian meadows	374.0 b	486.2 b	216.2 b	213.2 b	57.8	43.2
	N-facing forests	163.3 a	173.4 a	92.5 a	83.1 a	56.6	47.9
	Mean (± s.e.)	**225.1(74.7)**	**288.6(99.3)**	**129.8(43.3)**	**134.4(40.0)**	**57.6(0.5)**	**47.6(2.5)**

Table 4.3: Mean absolute grass utilization within three topographic positions across three dates of grazing during each of two rotations on a native Aspen Parkland rangeland in central Alberta during 2000. Within each rotation, means of position x date interaction with different lowercase letters differ significantly ($p<0.05$).

Rotation	Date of Grazing	Topographic Position		
		Upland Grassland (g/m^2)	Riparian Meadow (g/m^2)	N-facing Forest (g/m^2)
1st Rotation	4-Jun	85.6 b	190.1 c	100.8 b
	20-Jun	61.0 ab	157.0 c	105.1 b
	4-Jul	82.0 b	271.8 d	28.6 a
2nd Rotation	18-Jul	80.9 b	163.6 d	79.3 b
	31-Jul	156.6 cd	201.7 e	120.4 c
	14-Aug	74.8 b	269.0 f	40.3 a

Table 4.4: Effects of date of grazing (D), topographic position (P), and their interaction on grass crude protein (CP), crude protein yield (CPY), and crude protein utilized (CPU) by yearling heifers on a native Aspen Parkland rangeland in central Alberta during 2000 (N=18).

			CP (%)		CPY (g/m^2)		CPU (g/m^2)	
Rotation	Source	DF	Mean Sq.	F Value[a]	Mean Sq.	F Value[a]	Mean Sq.	F Value[a]
1[st] Rotation (Early growing season)	Date of grazing (D)	2	68.9	**51.2***	488.9	2.2	141.4	1.2
	Error A - "Rep (D)"	3	1.3		226.2		116.0	
	Topographic position (P)	2	42.1	**32.0****	3135.7	**36.3****	929.8	**21.0***
	D x P	4	9.0	**6.8***	152.9	1.8	24.2	0.6
	Error B - Residual	6	1.3		86.5		44.3	
2[nd] Rotation (Mid - Late growing season)	Date of grazing (D)	2	25.2	8.7	33.8	0.7	72.5	10.1
	Error A - "Rep (D)"	3	2.9	1.71	50.0		7.2	
	Topographic position (P)	2	2.6	1.54	2817.6	**62.0*****	384.2	**14.6***
	D x P	4	10.5	**6.2***	91.7	2.0	46.0	1.8
	Error B - Residual	6	1.7		45.4		26.3	

[a] - *, **, and *** indicate significant effects at $p<0.05$, $p<0.01$, and $p<0.001$, respectively.

Table 4.5: Mean grass crude protein (CP), crude protein yield (CPY), and crude protein utilized (CPU) by yearling heifers at three topographic positions during each of two grazing rotations on a native Aspen Parkland rangeland in central Alberta during 2000. Within a rotation and forage quality variable, means (topographic position x date of grazing interaction) with different lowercase letters differ significantly ($p<0.05$). Within a response variable, grand means with different uppercase letters differ significantly ($p<0.05$).

		CP (%)				CPY (g/m^2)				CPU (g/m^2)			
Rotation	Date of Grazing	Upland Grassland	Riparian Meadow	N-facing Forest	Mean (±s.e)	Upland Grassland	Riparian Meadow	N-facing Forest	Mean (±s.e)	Upland Grassland	Riparian Meadow	N-facing Forest	Mean (±s.e)
1st	4-Jun	15.2 b	20.2 a	11.8 bc	15.7(2.4) B	19	72.5	16.8	36.1(18.2)	13.2	38.5	11.2	21.0(8.8)
	20-Jun	10.6 c	14.8 b	8.0 c	11.1(2.0) A	11.5	51.9	16.0	24.5(12.8)	6.5	23.3	8.5	12.8(5.3)
	4-Jul	8.8 c	9.6 c	9.1 c	9.2(0.2) A	12.5	35.3	6.4	18.1(8.8)	7.2	27.4	2.7	12.4(7.6)
	Mean (± s.e.)	11.5(1.9) A	14.7(5.1) B	9.6(1.1) A		14.3(2.4) A	53.2(10.8) B	13.1(3.3) A		9.0(2.1) A	29.7(4.5) B	7.4(2.5) A	
	Pooled s.e.		(1.3)				(7.4)				(3.9)		
2nd	18-Jul	9.5 a	11.4 b	10.5 ab	10.5(0.5)	17.6	62.4	20.2	33.4(14.5)	7.7	18.2	8.3	11.4(3.4)
	31-Jul	10.9 ab	11.3 b	8.7 a	10.3(0.8)	24.8	47.8	18.4	30.3(8.9)	17.0	22.8	10.4	16.7(3.6)
	14-Aug	12.2 b	12.2 b	10.4 ab	13.9(1.7)	21.2	56.8	8.3	28.8(14.5)	9.4	32.7	11.7	17.9(7.4)
	Mean (± s.e.)	10.9(0.8)	11.6(0.3)	12.2(2.7)		21.2(2.1) A	55.7(4.2) B	15.6(3.7) A		11.4(2.9) A	24.6(4.3) B	10.1(1.0) A	
	Pooled s.e.		(0.8)				(6.5)				(2.8)		

Table 4.6: Effects of date of grazing (D), topographic position (P), and their interaction on the daily frequency of plant community utilization on a native Aspen Parkland rangeland in central Alberta during 2000 (N=144 and 108 respectively, during 1st and 2nd rotations).

Rotation	Source	DF	Mean Sq.	F Value[a]
1st Rotation	Date of grazing (D)	2	297.7	**15.7***
	Error A - "Rep (D)"	9	19.0	
	Topographic position (P)	2	988.2	**30.8*****
	D x P	4	251.4	**7.8*****
	Error B - Residual	126	32.1	
2nd Rotation	Date of grazing (D)	2	208.8	**8.6***
	Error A - "Rep (D)"	9	23.9	
	Topographic position (P)	2	432.7	**14.5*****
	D x P	4	140.3	**4.71***
	Error B - Residual	90	29.8	

[a] - *, **, and *** indicate significant effects at $p<0.05$, $p<0.01$, and $p<0.001$, respectively.

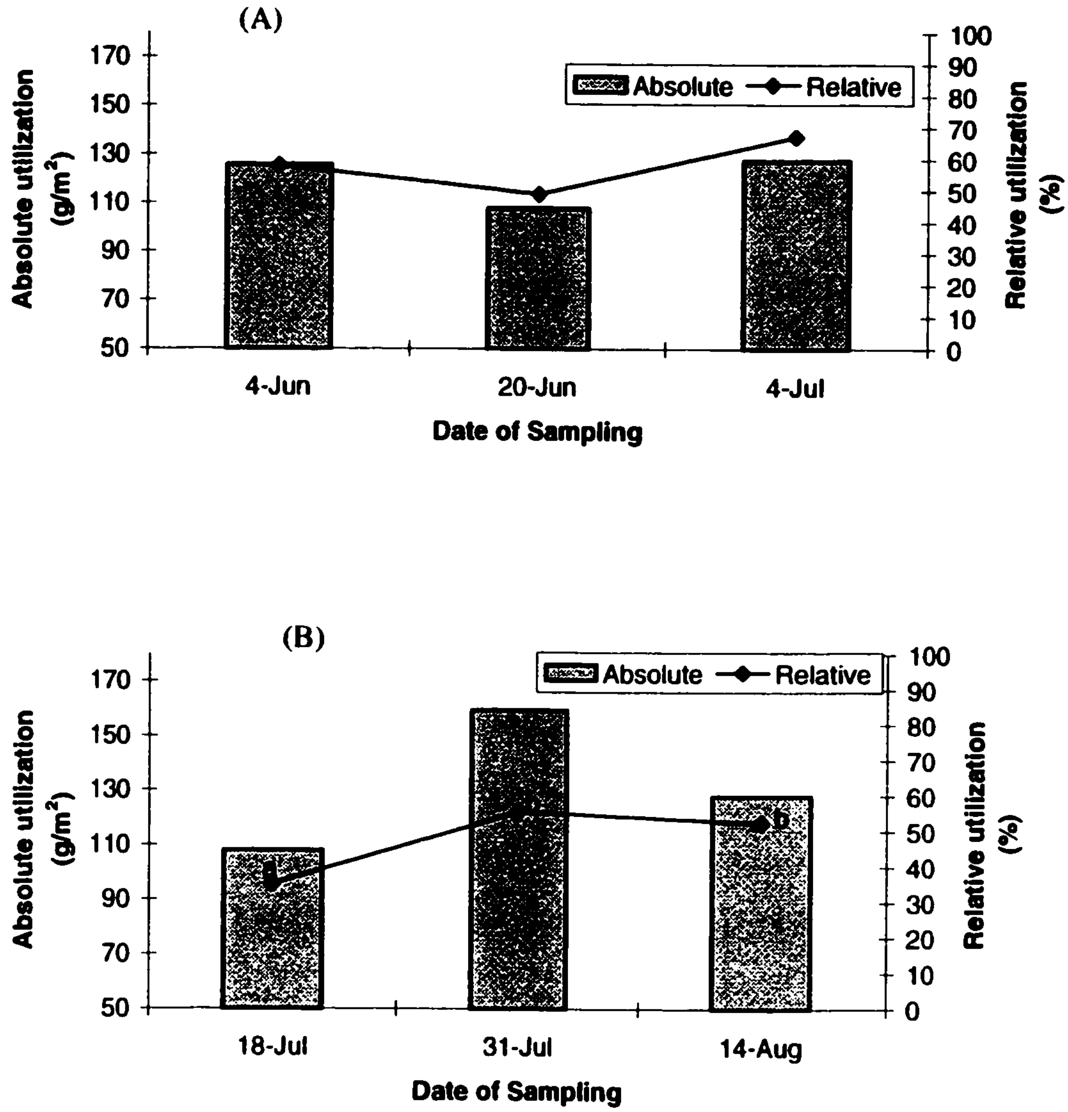

Fig. 4.1: Mean absolute and relative herbage utilization at three dates of grazing in (A) 1st rotation and (B) 2nd rotation on a native Aspen Parkland rangeland in central Alberta during 2000. Within a rotation, relative utilization means among different dates of grazing with different lowercase letters differ significantly ($p<0.05$).

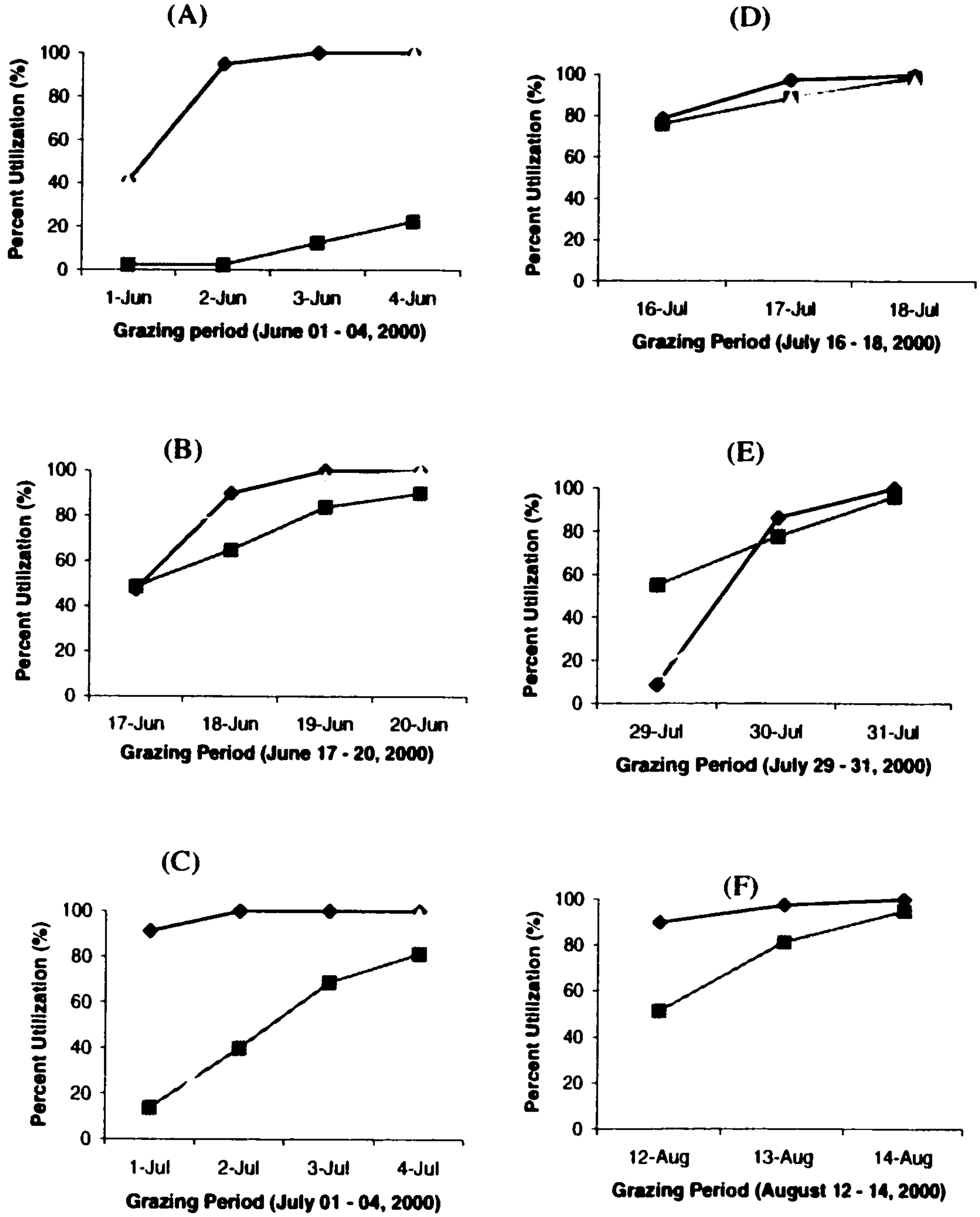

Fig. 4.2: Percent daily frequencies of plant community utilization by yearling heifers in three topographic positions [upland grasslands (■), riparian meadows (♦), and north-facing forests (▲)] during consecutive days of high intensity low-frequency grazing in the 1st rotation (early season A - C) and 2nd rotation (mid-late season D-F) on a native Aspen Parkland rangeland in central Alberta during 2000. Data is grouped according to the three paddocks examined (A & D; B & E; and C & F).

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CHAPTER 5

SYNTHESIS

5.1. Sustaining Native Rangeland Management and Utilization

Sustainable utilization of rangeland resources in the Aspen Parkland of Central Alberta is an issue of critical concern to all stakeholders, including livestock (cattle) farmers, rangeland managers, environmental conservationists, recreationists, private land owners, and both provincial and federal governments. As an important livestock production zone in Western Canada, the Aspen Parkland ecoregion has few (~5%) remnant native rangelands that must be managed to satisfy the needs and concerns of all stakeholders. Conventional livestock grazing capacities have often been estimated based on the herbage productivity of the most abundant range type, typically the upland grasslands. However, uneven use of the landscape may result in over-utilization of riparian zones. Cattle grazing capacity estimations should take into account herbage in all plant communities, including the relative preference of cattle to utilize various plant communities. Assessment of range condition may also have to consider the variations in plant community composition, yield, structure, and diversity across the entire native range landscape.

Due to inherent variability in plant communities across the complex landscapes of the Aspen Parkland, it is necessary to quantify growing season herbage yields and quality among these plant communities, particularly as these variables influence the opportunities for livestock grazing. Furthermore, long-term conservation of these communities depends on livestock grazing patterns across the landscape, necessitating an understanding of cattle utilization within these communities. This information will provide documentation of the differential foraging opportunities among various native plant communities within the Aspen Parkland, and facilitate the implementation of effective livestock grazing systems and other management practices to ensure sustainable utilization and conservation of the spatially interspersed riparian meadow, upland grassland and north-facing aspen forest landscapes typical of the region.

Results from Chapter 3 showed riparian meadows as the most important topographic position in providing abundant, high quality season-long herbage on Aspen Parkland rangelands. This may have resulted from high soil moisture availability within riparian meadows, which probably ensured that there was continuous vigorous growth of abundant high quality herbage. Total season-long accumulated grass yield remained constant in each topographic position regardless of varying the initial defoliation date from May to September. These results suggest that in the absence of severe moisture stress, grass regrowth can compensate for a single defoliation event, irrespective of the timing of initial defoliation. Furthermore, it appears livestock grazing can be carried out on riparian meadows or other topographic positions at any time during the growing season, provided ample time is allowed for plant recovery following initial defoliation. However, other critical issues to consider may be the frequency, intensity and duration of livestock grazing, as these factors may influence plant vigor, regrowth potential, amount of litter cover, and range condition.

Chapter 3 also documented that grass crude protein and crude protein yield were generally greater on riparian meadows. As expected, crude protein content declined temporally from May to September as a result of plant maturation and senescence. Grass crude protein yield, however, increased temporally from May to September, indicating that the large increase in grass yield was able to more than offset any temporal reduction in crude protein concentration. It is important to note that declining seasonal crude protein with advancing grass growth may be traded off by increasing crude protein yields, provided the crude protein concentration during the late season meets the minimum requirement of the individual grazing animal. Thus, riparian meadows provide high quantities of readily available crude protein within native Aspen Parkland rangelands, and livestock may preferentially consume more riparian herbage in order to obtain greater levels of crude protein intake.

Riparian meadows also provided the greatest quantities of accumulated (initial + regrowth) grass crude protein yield all season-long, with no apparent seasonal difference prior to late July. Under the conditions of this research, deferring livestock grazing on native Aspen Parkland rangelands until mid July (i.e., under a Ducks Unlimited Canada Conservation Agreement) for the purpose of conserving critical waterfowl habitat, did not cause over-maturation of riparian herbage and an overall reduction in livestock production potential. This suggests that it is possible to defer grazing and still maximize season-long foraging opportunities for livestock, provided grazing is carried out before August, and a sufficient rest period is allowed to sustain herbage regrowth and plant vigor. However, a timely resumption of livestock grazing after the deferment period is also important since a significant reduction in crude protein yield occurred at the beginning of August.

Chapter 4 documented the grazing patterns of yearling heifers in relation to different topographic positions. Results indicated that grass availability rather than quality likely influenced cattle grazing behavior on native Aspen Parkland rangelands. Cattle removed more grass (and grass-like) plant phytomass in riparian meadows relative to those in other topographic positions. However, relative levels of forage removal among the various positions were similar, indicating that the entire landscape was "evenly" utilized under the high intensity-low frequency grazing system that was implemented. The greater absolute use within riparian meadows is likely a result of greater forage abundance or intake opportunities available to cattle.

Cattle appeared to utilize herbage in riparian meadows more frequently within each grazing period throughout the study. Secondary utilization patterns, however, switched between upland grasslands and forests in June and August. Upland grasslands were less frequently utilized in June in favor of forests. This was probably due to limited soil moisture to facilitate upland herbage growth during spring, and also the enhanced foraging opportunities in forested sites due to moisture availability from snow accumulation the previous winter. Cattle switched from utilizing forests in June to upland grasslands in August, potentially because summer precipitation enhanced upland grassland herbage production. In addition, senesced and lignified shrub and aspen growth later in the growing season probably encouraged cattle to avoid forests in August.

5.2. Grazing Strategies for Enhancing Sustainability

Given that season-long foraging opportunities were greatest on riparian meadows and these areas represent a small fraction of the landscape, there may be greater potential for over-utilizing riparian herbage to the detriment of riparian ecosystems. Thus, livestock grazing systems used on native Aspen Parkland rangelands should be those that effectively and sustainably utilize the herbage resources and also conserve the landscape. Among the numerous grazing systems available, continuous grazing may not be very appropriate for the Aspen Parkland. According to Platts (1990), this system may result in patchiness of use on the landscape and over-utilization of riparian meadows. Furthermore, fencing and resting riparian meadows from grazing may result in abundant litter accumulation that may be inhibitory (negative feedback) to subsequent herbage growth, and enhance the growth of woody species (Platts 1990). Extensive litter accumulation may also increase the risk of catastrophic fires that destroy riparian herbage and lead to a loss of suitable wildlife habitats and the invasion of undesirable species. Fencing of riparian zones in a landscape such as the Aspen Parkland is also economically and physically impractical, as they are highly interspersed throughout a matrix of upland vegetation.

Results of this study indicated that riparian meadows may be grazed at any time during the growing season. It was also evident that riparian meadows provided abundant high quality foraging opportunities for livestock, provided they are initially grazed prior to August. Thus, the deferred grazing strategy (until mid July), which has been widely used to graze landscapes important to waterfowl as nesting sites (under

Conservation Agreements with Ducks Unlimited Canada), appears to be compatible with the results of this study. However, while grazing deferment is in place, ranchers may have to seek alternative foraging sources on tame pastures, which can be operationally more expensive than grazing native rangelands.

Cattle grazing behavior on native Aspen Parkland rangelands also appeared to be influenced by foraging opportunities, with absolute utilization greatest on the more productive riparian meadows. However, the entire landscape appeared to be evenly utilized under the high intensity-low frequency (HILF) grazing system implemented in this study. It remains unknown whether similar responses would have been observed if a different grazing system had been used. Secondly, it is unknown whether the results of this study apply to rangelands converted from native to tame pastures. Accordingly, further research is recommended in these areas.

5.3. Reference

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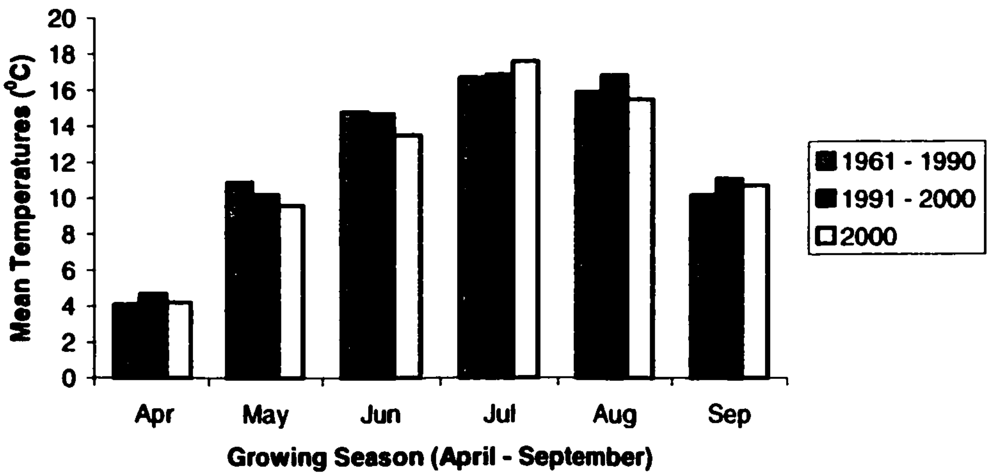
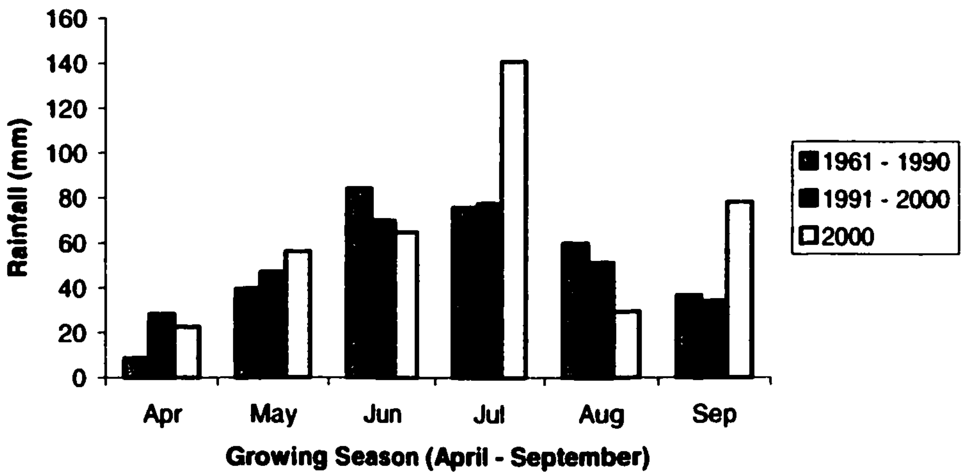
APPENDICES

Appendix I: Mean monthly growing season temperatures for Kinsella Ranch in the Aspen Parkland ecoregion of central Alberta.



Source: Environment Canada, 2000

Appendix II: Mean monthly growing season precipitation for Kinsella Ranch in the Aspen Parkland ecoregion of central Alberta.



Source: Environment Canada, 2000

Appendix III: Grass and forb species composition and % cover in three plant communities of a native Aspen Parkland rangeland at Kinsella in 2000.

Riparian meadows		Upland grasslands		North-facing forests	
Grass	**Cover (%)**	**Grass**	**Cover (%)**	**Grass**	**Cover (%)**
Beckmannia syzigachne	3.6	Agropyron pectiniforme	2.0	Bromus inermis	22.3
Carex aquatilis	19.3	A. trachycaulum var. trachycaulum	1.0	Calamagrostis sp.	10.0
Carex praegracilis	13.1	A. trachycaulum var. unilaterale	3.1	Carex curta	1.0
Carex rostrata	60.3	Bromus inermis	25.4	Festuca idahoensis	3.5
Glyceria grandis	4.0	Carex obtusata	16.8	Poa palustris	17.5
Phleum pratense	2.0	Festuca hallii	17.2	Poa pratensis	25.6
Poa palustris	14.8	Koeleria macrantha	1.0	Schizachne purpurascens	5.0
Poa pratensis	27.8	Poa pratensis	19.6		
		Stipa comata	10.0		
		Stipa curtiseta	13.2		
		Stipa viridula	5.0		
Forbs	**Cover (%)**	**Forbs**	**Cover (%)**	**Forbs**	**Cover (%)**
Achillea millefolium	3.0	Achillea millefolium	15.8	Achillea millefolium	1.0
Cirsium sp.	5.0	Androsace septrionalis	1.5	Aster laevis	4.0
Cruciferae sp.	3.3	Antennaria parvifolia	2.0	Cruciferae sp.	1.5
Galium boreale	1.0	Artemisia cana	6.5	Dactylis glomerata	20.0
Gutierezia sarothrae	10.0	Artemisia ludoviciana	6.5	Elaeagnus commutata*	1.0
Mentha sp.	3.5	Aster laevis	1.7	Fragaria virginiana	4.7
Polygonum sp.	2.7	Astragalus bisulcatus	1.8	Galium boreale	8.0
Populus tremuloides*	1.0	Astragalus sp.	5.3	Geranium sp	6.3
Potentilla hippiana*	27.0	Cruciferae sp.	3.0	Mentha sp.	1.0
Potentilla sp.*	8.1	Dactylis glomerata	1.0	Populus balsamifera*	5.0
Taraxacum officinale	13.6	Draba aurea	1.0	Populus tremuloides*	12.6
		Elaeagnus commutata*	1.5	Potentilla sp.*	9.0
		Erigeron philadelphicus	3.0	Rosa arkansana*	8.0
		Fragaria virginiana	7.1	Smilacina stellata	5.0
		Galium boreale	10.3	Symphoricarpos occidentalis*	16.7
		Geum triflorum	1.0	Taraxacum officinale	4.6
		Gutierezia sarothrae	3.0	Thalictrum venulosum	14.7
		Melilotus officinale	35.0	Vicia americana	1.0
		Penstemon sp.	2.3		
		Populus tremuloides*	3.0		
		Potentilla sp.*	1.3		
		Rosa arkansana*	3.1		
		Stellaria sp.	1.0		
		Symphoricarpos occidentalis*	15.8		
		Taraxacum officinale	1.7		
		Thermopsis rhombifolia	12.6		
		Trifolium repense	2.0		
		Vicia americana	1.0		

* Low growing shrubs or saplings

Appendix IV: Calculation of stocking rate (AUM/ha) from herd size and animal equivalence based on metabolic weight (Body Weight $^{0.75}$)

$$AUM/ha = \frac{\text{AUM equiv.} \times N \times Gp\ (\text{days})}{A\ (\text{ha}) \times 30\ (\text{days})}$$

Where:

AUM equivalence of Heifers = 0.8, Mature Cows = 1.0, and Bulls = 1.5

N = number of specific category of grazing animal

Gp = Grazing period

A = Size of paddock in hectares