Cattle herbage utilization patterns under high-density rotational grazing in the Aspen Parkland

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Received 22 November 2002, accepted 2 May 2003.

Asamoah, S. A., Bork, E. W., Irving, B. D., Price, M. A. and Hudson, R. J. 2003. **Cattle herbage utilization patterns under high-density rotational grazing in the Aspen Parkland.** Can. J. Anim. Sci. **83**: 541–550. Native Aspen Parkland landscapes consist of a complex mosaic of plant communities, including riparian meadows, upland grasslands, and forests. Sustainable livestock production in this environment depends on an understanding of livestock grazing behavior among communities, particularly under contemporary, intensive management rotational grazing systems. This study examined seasonal patterns of absolute ($kg \cdot ha^{-1}$) and relative (%) herbage utilization, as well as plant community visitation, across a Parkland landscape by 150 heifers in two rotations of a high-intensity, low-frequency grazing system. Graminoids constituted more than 92% of the total herbage utilized. Absolute graminoid utilization within each grazing period was greater ($P < 0.05$) throughout the growing season from riparian meadows (2003 to 2114 $kg \cdot ha^{-1}$) than from upland grasslands (762 to 1041 $kg \cdot ha^{-1}$) or forests (782 to 800 $kg \cdot ha^{-1}$). In contrast, relative graminoid utilization remained similar ($P > 0.05$) among communities in either rotation, suggesting heifers grazed in proportion to graminoid availability (57–61% in first rotation, 44–54% in second rotation). Although riparian meadows represented a small fraction of the landscape (~ 4%), and provided up to 9.5% of the total forage used, the majority of herbage removal at the paddock level continued to originate from upland grasslands and forests. Patterns of visitation indicated heifers initially visited riparian meadows more often within each 3–4 day grazing period, regardless of entry date. While upland grasslands were least visited in June, forests were least visited in August. Based on these utilization and visitation patterns, we discuss the implications of using high-density, rotational livestock grazing for the sustainable management of Aspen Parkland rangelands.

Key words: Aspen forest, cattle grazing, forage quality, herbage utilization, riparian meadow, rotational grazing, upland grassland

Asamoah, S. A., Bork, E. W., Irving, B. D., Price, M. A. et Hudson, R. J. 2003. **Utilisation des herbages par les bovins dans les prairies-parcs de trembles soumises à un régime de paissance par rotation à forte densité**. Can. J. Anim. Sci. **83**: 541–550. Les prairies-parcs de trembles naturelles consistent en une mosaïque complexe de peuplements végétaux comprenant des prés riverains, des prairies sèches et des forêts. Élever du bétail de façon durable dans un tel environnement exige une solide connaissance du comportement des animaux qui se nourrissent des divers peuplements végétaux, surtout avec les régimes contemporains de gestion intensive des pâturages par rotation. L'étude portait sur des programmes saisonniers d'utilisation absolue (kg par hectare) ou relative (%) d'herbages et sur la fréquentation des écotypes par 150 génisses dans une région de prairies-parcs, en deux rotations, dans le cadre d'un régime de paissance à faible fréquence et à densité élevée. Les graminoïdes représentaient plus de 92 % des herbages consommés. Pendant la période végétative, les animaux ont consommé une plus grande quantité absolue ($P < 0{,}05$) de graminoïdes dans les prés riverains (de 2 003 à 2 114 kg par hectare) que dans les prairies sèches (de 762 à 1 041 kg par hectare) ou les forêts (de 782 à 800 kg par hectare) durant chaque période de paissance. La consommation relative est toutefois demeurée la même ($P > 0{,}05$) dans les différents écotypes lors des deux rotations, signe que les animaux paissent en fonction des graminoïdes disponibles (de 57 à 61 % pour la première rotation; de 44 à 54 % pour la seconde). Bien que les prés riverains ne constituent qu'une petite partie du relief (~ 4 %) et fournissent jusqu'à 9,5 % des fourrages consommés, la plupart des herbages broutés sur place émanent toujours des prairies sèches et des forêts. Les habitudes de fréquentation indiquent que les génisses visitent souvent les prés riverains au début de chaque période de paissance de 3 ou 4 jours, quelle que soit la date de leur mise à l'herbe. Si les prairies sèches sont moins fréquentées en juin, il en va autant des forêts en août. Les auteurs se fondent sur ces observations pour discuter des répercussions d'un régime de paissance par rotation à haute densité sur l'exploitation durable des grands parcours dans les prairies-parcs de trembles.

Mots clés: Forêt de trembles, paissance, qualité des fourrages, consommation d'herbages, prés riverains, paissance par rotation, prairies sèches

Heterogeneous patterns of herbage productivity and quality across the landscape influence livestock grazing behavior (Coughenour 1991; Bailey et al. 1996; Willms and Rode 1998). Although uniformity of use can be improved by reducing the size of individual pastures (Hart et al. 1993),

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Abbreviations: **AUM**, animal unit month; **CP**, crude protein; **CPU**, crude protein utilized; **CPY**, crude protein yield; **DM**, dry matter

this option may not be practical in complex landscapes containing a high degree of heterogeneity. Alternatively, the development of specialized grazing systems through grazing trials may improve the uniformity of pasture use (e.g., Popolizio et al. 1994). Because no single system is likely to be sufficient for all land areas due to inherent variability in climatic, landscape, and associated vegetation and edaphic characteristics (Platts 1990), testing of these systems under various conditions is important.

Considerable research exists demonstrating cattle distribution on rangeland is influenced by vegetation type (Smith et al. 1992), forage availability (Bryant 1982; Willms 1988), and quality (Cook 1966; Kie and Boroski 1996), as well as topography (Mueggler 1965; Pinchak et al. 1991) and water availability (Irving et al. 1995; Willms 1990). Cattle typically congregate on lowlands relative to adjacent uplands (Willms 1988; Philips et al. 1999), presumably due to the inhibitory effect of steep slopes (Mueggler 1965) and the ready availability of abundant, high quality forage (Senft et al. 1987).

Concentrated livestock use of riparian lowlands is often a concern for rangeland managers (Platts 1990; Holochek et al. 1998). Localized overuse can significantly affect plant community composition (Kauffman and Krueger 1984), in turn affecting other rangeland values including wildlife habitat (Schulz and Leininger 1990). Despite their importance, riparian zones have often been overlooked because of their small size relative to the entire landscape (Gillen et al. 1985), and accordingly, are more likely to be overgrazed, particularly under season-long grazing systems (Platts 1990).

In some jurisdictions, exclusion of livestock grazing has been advocated to protect riparian vegetation (North American Waterfowl Management Plan 1986). This recommendation appears to assume that grazing is incompatible with the safe utilization and long-term conservation of riparian vegetation. Other evidence exists, however, suggesting riparian productivity and soil properties can be maintained or improved under appropriate livestock grazing strategies (e.g., Kauffman and Krueger 1984; Elmore 1992; Kie and Boroski 1996). For instance, rotational grazing may promote more uniform distribution of grazing pressure across the landscape (Platts 1990).

The Aspen Parkland is an important livestock production zone in western Canada (McCartney 1993), and is characterized by distinctly undulating topography known as "knob and kettle" terrain. This variable topography strongly affects soils (Acton 1965) and resulting vegetation (Wheeler 1976), including the formation of numerous riparian meadows within lowlands. Meadows provide forage for livestock as well as wildlife habitat. In order to prevent the over-utilization of riparian zones, conservation initiatives are often employed such as deferring livestock grazing until mid-July to enable waterfowl to complete the breeding cycle (North American Waterfowl Management Plan 1986). The successful implementation of this initiative, particularly on private lands, requires cooperation from producers who are increasingly adopting management intensive (i.e., rotational) grazing systems in order to increase the efficiency of cattle production. Ranchers are therefore faced with the challenge of balancing the conservation of riparian vegetation with optimizing livestock production.

In central Alberta, distance from water interacts with topography to influence herbage utilization patterns by cattle in the Mixed Prairie-Aspen Parkland transition (Irving et al. 1995). Where water is less limiting, topography and vegetation are likely the most influential factors. Using animal observation data, Arthur (1984) found cattle preferred to spend their time foraging within upland grasslands and shrublands of the Parkland, but avoided both forested and riparian sites, regardless of time of year. Additionally, heavier stocking rates were associated with greater time spent in upland grasslands (Arthur 1984). Working in the Fescue Prairie under conditions of greater topographic relief (e.g., >50 m), Willms (1988) found the greatest relative use of lowlands by cattle during spring and early summer, which then declined later in the growing season. Marlow and Pogacnik (1986) found cattle used foothill uplands rather than riparian meadows following abundant spring precipitation, with the opposite pattern after low spring precipitation.

In order to sustain livestock production and conserve riparian habitats within complex Aspen Parkland landscapes, an understanding of cattle behavior under management intensive, rotational grazing is needed, particularly as more ranchers adopt these grazing systems. This study documented early and late season herbage utilization patterns among three plant community types by yearling heifers in a high density, rotational grazing system, within native Aspen Parkland rangeland in central Alberta. We hypothesized that if cattle exhibited similar preferences for different plant communities, observed levels of actual herbage removal (i.e., absolute utilization) would be uniform among communities.

MATERIALS AND METHODS

Study Area

The study was conducted at the 3100-ha University of Alberta Kinsella Research Station (53°01′N, 111°34′W), a ranch located 150 km southeast of Edmonton, Alberta, within the Aspen Parkland ecoregion (Strong 1992). The area experiences a continental climate, with average monthly growing season temperatures from 1960 to 2000 ranging from 10.9°C in May to 16.7°C in July (Environment Canada, unpublished data). Average annual (January to December) and growing season (May to August) precipitation are 428 and 259 mm, respectively, peaking at 85 mm in June. During 2000, growing season rainfall was 291 mm, 12% above the long-term average.

The landform across the ranch is hummocky moraine consisting of calcareous parent material deposited over underlying marine shales (Gravenor and Kupsch 1959). There are strong effects of topography and aspect on soils across the landscape. Soils under well-drained upland grasslands are Dark Brown, Eluviated Black, or Black Chernozems, while poorly drained lowlands are Gleysols (Wheeler 1976). Dark Gray or Gray Luvisols are associated with forested, north-facing slopes.

Vegetation includes native grasslands interspersed with deciduous shrub and forest communities that are influenced

by topography (Wheeler 1976; Scheffler 1976), as well as disturbances such as livestock grazing and burning (Bailey et al. 1990). Upland grasslands are representative of the Fescue Association (Coupland 1961), and include the *Stipa-Agropyron* and *Festuca-Stipa* faciations (Wheeler 1976; Scheffler 1976).

This study utilized an area of the ranch known as the "wagon-wheel" grazing system. This area consists of 10 paddocks with a central water source that had been grazed annually for more than 5 yr prior to this study using a high-density, rotational grazing regime at a moderate stocking rate (~2 AUM·ha^{-1}). For the present study, 3 of the 10 paddocks were selected on the basis of their uniformity in size (15 ha each) and vegetation (i.e., similar proportions of grassland and forest), as well as the availability of two suitable riparian meadows in proximity to adjacent native upland grasslands and aspen forests. Within individual paddocks, riparian meadows constituted 0.6 ± 0.1 ha (~4%) of the land base, while upland grassland and forest communities were 7.8 ± 1.2 and 6.6 ± 0.9 ha, respectively. The average composition of each vegetation type examined is shown in Table 1. When data collection was initiated (22 May 2000), all communities including riparian meadows were free of standing water.

Table 1. Summary of dominant plant species ground cover (minimum 3% cover) found within the riparian meadows, upland grasslands, and upland forests sampled

Species	Riparian meadow	Upland grassland	Upland forest
		(% cover)	
Grasses			
Agropyron trachycaulum (Link) Malte		4.1	
Bechmannia syzigachne (Steud.) Fern.	3.6		
Bromus inermis Leyss.		25.4	22.3
Calamagrostis canadensis (Michx.) Beauv.			10.0
Carex aquatilis Wahlenb.	19.3		
Carex obtusata Lilj.		16.8	
Carex praegracilis W. Boott	13.1		
Carex rostrata Stokes	60.3		
Dactylis glomerata L.			20.0
Festuca idahoensis Elmer			3.5
Festuca hallii (Harms) Vasey		17.2	
Glyceria grandis S. Wats. ex A. Gray	4.0		
Poa palustris L.	14.8		17.5
Poa pratensis L.	27.8	19.6	25.6
Schizachne purpurascens (Torr.) Swallen			5.0
Stipa comata Trin. & Rupr.		10.0	
Stipa curtiseta (A.S. Hitchc.) Barkworth		13.2	
Stipa viridula Trin.		5.0	
Forbs			
Achillea millefolium L.	3.0	15.8	
Artemisia ludoviciana Nutt.		6.5	
Artemisia frigida Willd.		6.5	
Aster laevis L			4.0
Astragalus spp. L.		7.1	
Cirsium spp. Mill.	5.0		
Erigeron philadelphicus L.		3.0	
Fragaria virginiana Duchesne		7.1	4.7
Galium boreale L.		10.3	8.0
Geranium richardsonii Fisch. & Trautv.			6.3
Gutierezia sarothrae (Pursh) Britt. & Rusby	10.0	3.0	
Melilotus officinale (L.) Lam.		35.0	
Mentha arvensis L.	3.5		
Potentilla spp. L.	35.1		9.0
Smilacina stellata (L.) Desf.			5.0
Taraxacum officinale Weber	13.6		4.6
Thalictrum venulosum Trel.			14.7
Thermopsis rhombifolia (Nutt.) Richards.		12.6	
Shrubs and trees			
Populus balsamifera L.			5.0
Populus tremuloides Michx.		3.0	12.6
Rosa arkansana Porter		3.1	
Rosa woodsii Lindl.			8.0
Symphoricarpos occidentalis Hook.		15.8	16.7

Study Design

Herbage utilization by cattle among vegetation types in the three grazing paddocks was tested with a split-plot design (Zar 1999). In each paddock, two replicate blocks of three plant communities were sampled. Replicate blocks consisted of three adjacent plant communities across the landscape catena, including an upland grassland, riparian meadow, and aspen forest community. Grazing was implemented in two separate rotations over the same paddocks and replicate blocks in order to make early and late-season observations on the same plant communities. Grazing dates and associated sampling in the first rotation were 1–4 June, 17–20 June, and 1–4 July, while those in the second rotation were 16–18 July, 29–31 July, and 12–14 August. Duplicate subsampling was conducted in each plant community within a block.

Grazing was carried out in the first rotation with 150 commercial British-Continental crossbred yearling heifers (each 0.7 animal units) for 4 d at a stocking rate of 1.1 animal unit months (AUM) ha^{-1}. In the second rotation, six breeding bulls were added for a total stocking rate of 0.9 AUM ha^{-1} over 3 d. The herd was granted unrestricted access to each paddock from 1800 on the day prior to the commencement of the scheduled date of grazing, until 1800 on the last day of the grazing period. All animals had ready access to water, and coupled with the small size of the paddocks, water availability was assumed to impose no restriction on foraging behavior.

Measurements

Herbage Utilization

Herbage utilization in each community was quantified using caged-uncaged comparisons as per the paired-plot method (Cook and Stubbendieck 1986). Two, portable 1.5 × 1.5 m range cages were randomly set up within each plant community shortly after snow melt on 10 May 2000, prior to livestock entry. At the end of each grazing period within a paddock, all aboveground current annual growth within a 40 cm × 80 cm quadrat was clipped to ground level in each cage to quantify available herbage per plant community. Similar clips were made 1 m outside each cage to assess post-grazing residual herbage biomass (excluding litter). All samples were sorted to graminoid and forb components, oven-dried at 30°C for 72 h, and weighed to determine dry matter (DM) yields per unit area. Duplicate clip subsamples for each plant community were averaged to determine mean graminoid and forb DM production as well as absolute utilization (kg ha^{-1}) within each plant community. Relative uti-

lization (%) was calculated as the proportion of DM yield removed in each community. Bork and Werner (1999) suggest information on both absolute and relative utilization are important, as these parameters emphasize grazing impacts from the perspective of the grazing animal and plant community, respectively.

Prior to beginning the second rotation, range cages were randomly repositioned to grazed areas on the same plant communities in order to take new measurements of the standing herbage available to cattle following the first rotation.

Herbage Quality

Graminoid clip samples were ground through a 1-mm screen using a Wiley Mill and analyzed for crude protein (CP) using the Dumas method and a LECO FP-428 analyzer (Lee et al. 1996). Crude protein yield (CPY) and crude protein utilized (CPU) were computed as the CP fraction of graminoid total DM yield and DM removed, respectively. Crude protein yield was determined using the relationship (%CP/100) × DM. Forbs were not analyzed for quality because they represented a minor component (i.e., < 10%) of total biomass.

Daily Plant Community Visitation

To evaluate fine-scale temporal selection of plant communities by heifers within each grazing period, herbage utilization data were augmented with daily visitation frequency data in each plant community. Two, 10-m permanent transects were randomly established within each community prior to grazing. Twenty, 0.1-m^2 quadrats were then monitored daily during each grazing period along each transect for evidence of cattle visitation (i.e., herbage defoliation). Monitoring consisted of counting the number of additional quadrats that had experienced one or more cattle bites by 1800 of each day. Accumulated daily frequencies of visitation were calculated and converted to percentages by plant community for subsequent analyses. Grazing periods in the first and second rotation were 4 and 3 d, respectively.

Analyses

All analyses were done using Proc GLM of SAS (SAS Institute, Inc. 1999). Prior to testing the study hypotheses, data were checked for normality. Data from each grazing rotation were analyzed separately, as available herbage biomass in each rotation was phenologically different in terms of seasonal growth; herbage available during the second rotation was essentially regrowth from the first rotation.

All data were analyzed as a split-plot design, with topographic positions blocked within dates of grazing at each location. Replicate blocks (plant community combinations) were considered random. Analysis of variance (ANOVA) was used to examine the effects of plant community (riparian meadow, upland grassland, and forest), and date of grazing, as well as their interactions, on absolute (kg ha^{-1}) and relative (%) herbage utilization, as well as daily frequencies of community visitation. Within a rotation, date of grazing was tested against its interaction with replicate block. Plant community and community by date of grazing effects were tested against the community by date by block interaction. Multiple mean comparisons were conducted for all significant treatment effects ($P < 0.05$) using Tukey's test (Zar 1999).

Herbage DM yield and quality variables, including CP concentration, CPY, and CPU of graminoid samples, were also analyzed to help interpret the associated utilization data. Paired t-tests (Zar 1999) compared yield and quality values between graminoid and forb components.

RESULTS

Herbage Availability

Paired mean comparisons (Table 2) indicate graminoid biomass rather than forb was the main component (i.e., > 90%) of available herbage in both rotations ($P < 0.05$). Although no differences in herbage availability were evident among different grazing dates within a rotation ($P > 0.05$), available graminoid biomass was 35% greater in the second rotation (Table 2). Additionally, differences in graminoid biomass were evident among plant communities ($P < 0.05$). Riparian meadows produced a minimum of 61 and 59% more graminoids in the first and second rotation, respectively, compared to the other two communities (Table 2).

Herbage Removal

The absolute utilization of graminoids, but not forbs, varied significantly ($P < 0.001$) among plant communities during the first and second rotations. Absolute graminoid removal per unit area was consistently greatest from riparian meadows ($P < 0.05$), regardless of rotation (Table 2), but was also affected by an interaction with date of grazing ($P < 0.05$). Within each rotation, absolute graminoid utilization within the meadows increased ($P < 0.05$) with each successively later grazing period (Table 3), a trend not consistently apparent in the other community types. Additionally, graminoid use within forested communities was lower ($P < 0.05$) during the final date of grazing in each rotation compared to both adjacent upland grasslands, as well as forested areas grazed at other dates (Table 3). Grazing during the 31 July period resulted in the greatest absolute graminoid use (Table 3).

Unlike absolute utilization, the relative use of both graminoids and forbs remained similar ($P > 0.05$) among plant communities during both rotations (Table 2). Utilization of graminoids ranged from 57 to 61% in the first rotation, and from 44 to 54% in the second. Although relative levels of graminoid and forb use did not differ from one another in the first rotation ($P > 0.05$), graminoids did receive 22% greater relative use than forbs ($P < 0.05$) in the second rotation (Table 2).

Graminoid levels of CP concentration, CPY and CPU were all affected ($P < 0.05$) by plant community in the first rotation, with the greatest values ($P < 0.05$) of each parameter apparent within riparian meadows (Table 4). This pattern was repeated in the second rotation with the exception of CP concentration (Table 4). Graminoid crude protein in both rotations was also significantly affected ($P < 0.05$) by the interaction of grazing date and plant community. Although CP generally declined with later dates of grazing in the first rotation (Table 4), the greatest reduction occurred within riparian meadows (from 20.2 to 9.6%). In contrast, a more

Table 2. Mean herbage dry matter (DM) yield and utilization on a native Aspen Parkland landscape in central Alberta

Herbage type	Plant community	Available herbage DM yield (kg·ha^{-1})		Absolute utilization (kg·ha^{-1})		Relative utilization (%)	
		First rotation	Second rotation	First rotation	Second rotation	First rotation	Second rotation
Graminoid	Upland grassland	1248*b*	1926*b*	762*b*	1041*b*	61.1	54.0
	Riparian meadow	3534*a*	4794*a*	2063*a*	2114*a*	58.4	44.1
	Aspen forest	1369*b*	1595*b*	782*b*	800*b*	57.1	50.1
	Mean (±SE)	2050 (743)*A*	2772 (1016)*A*	1202 (430)*A*	1318 (404)*A*	58.9(1.2)*A*	49.4(2.9)*A*
Forb	Upland grassland	133	136	45	27	33.6	19.9
	Riparian meadow	206	68	99	18	47.9	26.4
	Aspen forest	264	139	143	50	54.3	36.2
	Mean (±SE)	201 (38)*B*	114 (23)*B*	96 (28)*B*	31 (10)*B*	45.3(6.1)*A*	27.5(4.7)*B*
Total Herbage	Upland grassland	1381*b*	2062*b*	807*b*	1068*b*	58.4	51.8
	Riparian meadow	3740*a*	4862*a*	2162*a*	2132*a*	57.8	43.2
	Aspen forest	1633*b*	1734*b*	925*b*	831*b*	56.6	47.9
	Mean (±SE)	2251 (747)	2886 (993)	1298 (433)	1344 (400)	57.6(0.5)	47.6(2.5)

a, b Within a herbage type and rotation in each response variable, community means with different lowercase letters differ significantly ($P < 0.05$).
A, B Within each response variable and rotation, grand means of herbage types with different uppercase letters differ significantly ($P < 0.05$).

Table 3. Mean absolute graminoid utilization within plant communities and grazing rotations on a native Aspen Parkland rangeland in central Alberta

Rotation	Grazing date	Plant community: Upland grassland (kg·ha^{-1})	Riparian meadow (kg·ha^{-1})	Aspen forest (kg·ha^{-1})
First rotation	4 June	856*c*	1901*b*	1008*c*
	20 June	610*cd*	1570*b*	1051*c*
	4 July	820*c*	2718*a*	286*d*
	SE	(7.7)	(34.1)	(24.8)
Second rotation	18 July	809*e*	1636*c*	793*e*
	31 July	1566*cd*	2017*b*	1204*d*
	14 August	748*e*	2690*a*	403*f*
	SE	(26.3)	(30.8)	(23.1)

a–f Within each rotation, means with different lowercase letters differ significantly ($P < 0.05$).

moderate decrease was evident within upland grasslands, with non-significant ($P > 0.05$) declines on forested areas. By 4 July, no significant differences ($P > 0.05$) existed in graminoid CP among the three communities. In the second rotation, differences in CP concentration among plant communities appeared to be relatively small (i.e., < 2%), but remained significant ($P < 0.05$) during the first two dates of grazing (Table 4).

Daily Plant Community Visitation

Date of grazing, plant community type, and their interaction had significant effects ($P < 0.05$) on the daily frequencies of community visitation in both rotations. Frequencies of visitation by grazing period in the two rotations are presented in Fig. 1 (A to F). Overall, cattle visibly defoliated herbage within the riparian meadows sooner and more frequently than either of the other two community types. Sampled quadrats within riparian meadows typically experienced a visitation frequency greater than 90% by the end of the second day within each grazing period in either rotation (Fig. 1).

On average, upland grasslands were less frequently visited compared to the adjacent forested communities in the first rotation (Fig. 1 A, B and C). During the second rotation, however, this pattern reversed, with upland grassland utilized more frequently than forests, particularly early in each grazing period (Fig. 1 D, E and F).

DISCUSSION

Total absolute levels of herbage removal within the two rotations (1298 and 1344 kg·ha^{-1}) and their associated relative utilization (57 and 47%), are consistent with those expected for the Aspen Parkland based on the moderate stocking rates used in this study (0.9 and 1.1 AUM ha^{-1}, respectively, for each rotation).

Results of this study indicate greater absolute graminoid use occurred within riparian meadows compared to the other communities, thereby rejecting our hypothesis that heifers utilize each community similarly. Greater absolute biomass removal from riparian meadows corroborates results from other studies (e.g., Kauffman and Krueger 1984; Gillen et al. 1985; Willms 1988) on the importance of riparian meadows as foraging sites for livestock. Given that cattle tend to be more selective at the beginning of a rotational grazing period (Walker et al. 1989), the visitation frequency data documented here tend to support the notion that livestock occupy riparian meadows immediately upon initiation of the grazing period. This trend may have contributed to the removal of more biomass on a localized (i.e., unit area) basis throughout each grazing period. Notably, these results appear to contradict those of Arthur (1984) who found cattle favored upland grasslands over other communities during June. That investigation, however, did not quantify actual levels of herbage removal, but rather the time cattle spent within individual areas. Differences in the method of data collection may account for this difference.

Prompt entry of cattle into riparian meadows in the present investigation is probably due to the availability of abun-

Table 4. Mean graminoid crude protein (CP), crude protein yield (CPY), and crude protein utilized (CPU) by yearling heifers within three plant communities on a native Aspen Parkland rangeland in central Alberta

Rotation	Grazing Date	CP (%) Upland grassland	CP (%) Riparian meadow	CP (%) Aspen forest	CP (%) Mean (±SE)	CPY ($kg \cdot ha^{-1}$) Upland grassland	CPY Riparian meadow	CPY Aspen forest	CPY Mean (±SE)	CPU ($kg \cdot ha^{-1}$) Upland grassland	CPU Riparian meadow	CPU Aspen forest	CPU Mean (±SE)
First	4 June	15.2*b*	20.2*a*	11.8*bc*	15.7(2.4)*A*	190	725	168	361(182)	132	385	112	210(88)
	20 June	10.6*c*	14.8*b*	8.0*c*	11.1(2.0)*B*	115	519	160	245(128)	65	233	85	128(53)
	4 July	8.8*c*	9.6*c*	9.1*c*	9.2(0.2)*B*	125	353	64	181(88)	72	274	27	124(76)
	Mean (±SE)	11.5(1.9)*B*	14.7(5.1)*A*	9.6(1.1)*B*		143(24)*B*	532(108)*A*	131(33)*B*		90 (21)*B*	297(45)*A*	74(25)*B*	
	Pooled SE		(1.3)				(74)				(39)		
Second	18 July	9.5*a*	11.4*b*	10.5*ab*	10.5(0.5)	176	624	202	334 (145)	77	182	83	114(34)
	31 July	10.9*ab*	11.3*b*	8.7*a*	10.3(0.8)	248	478	184	303(89)	170	228	104	167(36)
	14 August	12.2 *b*	12.2*b*	10.4*ab*	11.6(0.3)	212	568	83	288(145)	94	327	117	179(74)
	Mean (±SE)	10.9(0.8)	11.6(0.3)	9.9(0.3)		212(21)*B*	557(42)*A*	156(37)*B*		114 (29)*B*	246(43)*A*	101 (10)*B*	
	Pooled SE		(0.8)				(65)				(28)		

a–c Within a rotation and response variable, means with different lowercase letters differ significantly ($P < 0.05$).
A, B Within a rotation and response variable, grand means among grazing dates or plant communities with different uppercase letters differ significantly ($P < 0.05$).

dant, high-quality forage relative to the other plant communities, as these factors have the potential to attract cattle into the area for foraging (Marlow and Pogacnik 1986; Willms 1988; Bailey et al. 1996). Large herbivores spend increased time in plant communities that offer greater forage resources in order to maximize intake (Senft et al. 1987). In addition, riparian communities maintained greater soil moisture compared to uplands throughout the summer (Asamoah 2002), which may have ensured herbage in riparian meadows remained vegetative and palatable. June precipitation was slightly below average (93% of mean) and would have helped maintain the affinity cattle demonstrated for riparian meadows, as was apparent in the visitation data in early July (Fig. 1C).

Results of the forage quality analysis provided another potential mechanism to account for the increased absolute utilization within riparian meadows. Crude protein concentrations remained greater in meadows than other areas prior to 4 July, as were the associated levels of CPY and CPU. For example, CPY and CPU were 2.2 to 4.0 times greater in riparian meadows compared to the other communities in both the first and second rotations. Based on these results, it appears the high CP concentration of graminoids within riparian meadows prior to 4 July may have complemented the high graminoid availability in influencing cattle foraging behavior across the landscape. However, it should also be noted that the greater absolute graminoid biomass utilization from riparian meadows continued after this date as well, despite similar observed graminoid CP concentrations. The latter finding suggests the ultimate factor accounting for the greater absolute use was probably enhanced opportunities to maximize forage intake, as suggested by Senft et al. (1987), at least early in each grazing period.

It is also important to note that with the exception of the first grazing period (1 June), visitation of upland grasslands generally increased to levels near that of meadows late in each grazing period. Moreover, this occurred despite a continued abundance of available biomass within the meadows. The increasing visitation of upland grasslands within individual grazing periods may be due to progressive depletion of the higher quality meadow forage, thereby encouraging switching of habitats. Cattle have been found to be less selective at the end of grazing periods (Walker et al. 1989).

The lack of a significant response in CP concentration to date of grazing in the second rotation was unexpected, as CP generally declines with time, particularly late in the growing season (e.g., Donkor 2001). High rainfall during the second rotation in July (181% of mean), may have facilitated favorable regrowth within all plant communities, resulting in the relatively stable CP concentrations among dates.

The lower absolute utilization and less frequent visitation patterns within upland grasslands compared to riparian meadows could partly arise from precipitation levels, moisture redistribution in the landscape, and differences in plant growth and associated foraging opportunities. Upland herbage production is more heavily dependent on growing season precipitation than lowlands (Bork et al. 2001). Low spring soil moisture on south-facing upland grasslands in 2000 may have been responsible for limiting overall

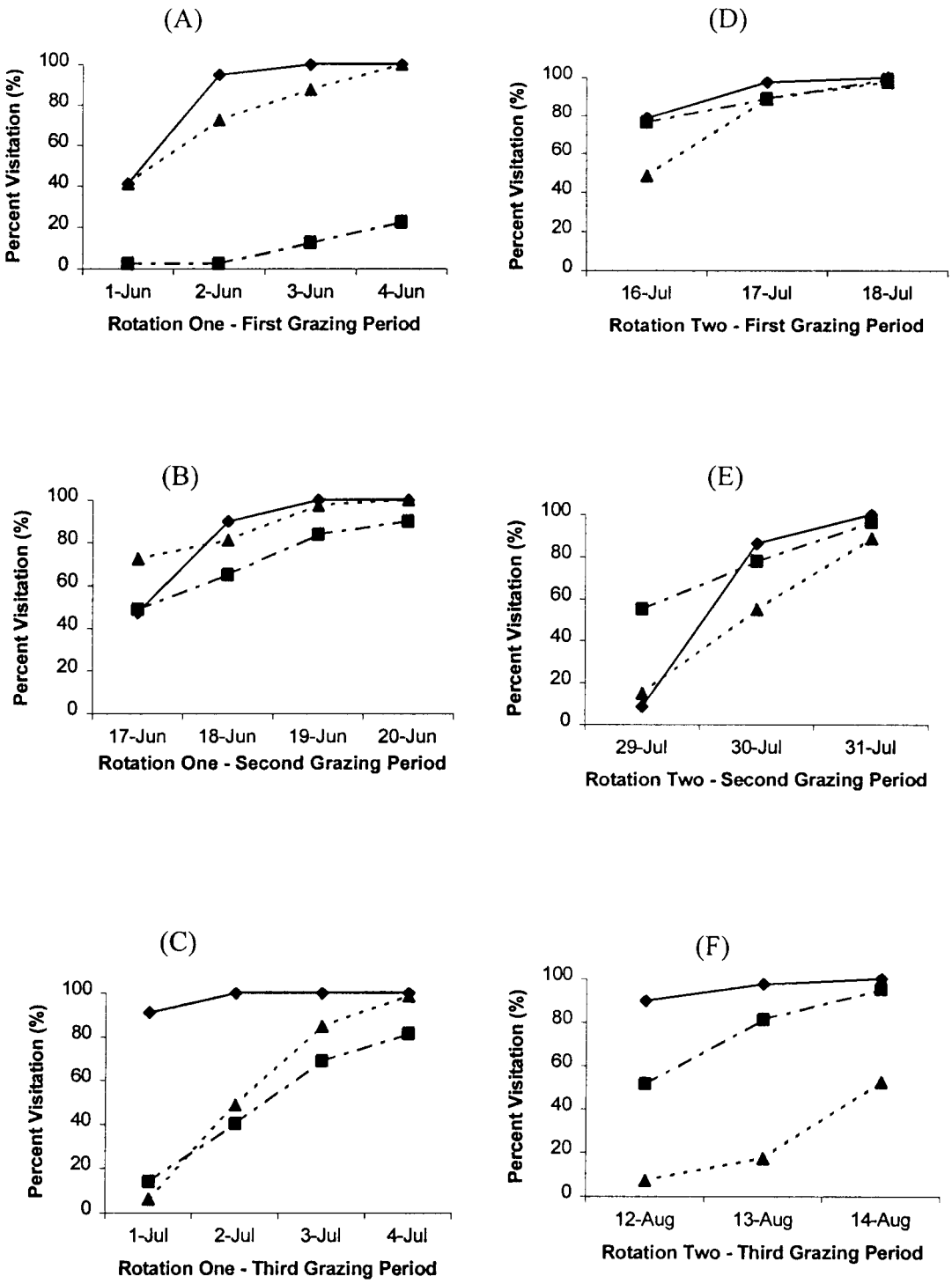

Fig. 1. Daily accumulated visitation frequency data of yearling heifers within three plant communities [upland grasslands (■), riparian meadows (◆), and aspen forests (▲)] during consecutive days of the first rotation (early season A–C) and second rotation (mid to late season D–F) of a high density, rotational grazing system on a native Aspen Parkland rangeland in central Alberta during 2000. Data are grouped according to the three paddocks examined (A and D; B and E; and C and F).

herbage growth and associated foraging opportunities relative to meadows in the first rotation, leading to the reduced visitation frequencies. However, favorable July rainfall could have enhanced vegetation regrowth on uplands, thereby encouraging cattle to enter these areas sooner during the second rotation. High soil moisture and enhanced regrowth

of all communities may help account for the particularly high absolute graminoid utilization levels observed in mid July.

Given that the relative proportion of upland grassland and aspen forest habitats were similar among paddocks, differences in absolute graminoid use between these two plant communities in the last grazing period may reflect differences in vegetation structure or composition. This is supported by the finding that the reduced graminoid removal from forests occurred in the last date of grazing in both rotations, and therefore, was not limited to either initial or regrowth herbage. Factors such as forest age, the amount of coarse, woody debris, and subsequent accessibility to cattle, are all likely to influence levels of utilization at the plant community level.

The greater visitation frequencies found within forested communities relative to upland grassland during the first rotation may arise from forests benefiting from greater snow retention the previous winter, and subsequent enhanced spring growth. In addition, new shrub and aspen growth has been shown to be palatable early in the growing season and attract cattle use (Dockrill 2001). Reduced visitation to forest communities during the second rotation may be attributed to increasing lignification of current year's growth in late summer (Dockrill 2001). Other factors, however, such as thermoregulation and insect avoidance may also be important in reducing forest use late in the year. In a previous study, Arthur (1984) found cattle spent the least amount of time within forested sites and riparian areas during mid to late summer, at both low and high stocking rates. Results from the second rotation in the present study indicate that while forested areas were avoided at that time, meadows were preferred.

Although absolute graminoid utilization was greater in riparian meadows, relative levels of utilization remained similar among community types. This indicates that despite the unequal absolute utilization levels, heifers removed a similar proportion of herbage from each plant community. The similar relative use levels achieved in this study may be partly due to the high density, rotational grazing system employed. Although not explicitly tested here, season-long grazing may have resulted in less uniform use among plant communities, as low animal densities are typically employed with this grazing system, resulting in maximum patchiness of animal use across the landscape (Platts 1990).

Contrasting patterns of absolute and relative graminoid utilization among plant communities has implications for the management of paddocks containing diverse vegetation. Bork and Werner (1999) suggested that the absolute and relative methods of assessing herbage use have implications for the grazing animal and plant community, respectively. For example, absolute levels of herbage removal provide an indication of the contribution of each community type to livestock production. In this study, the average area of upland grassland and forest communities per paddock were similar to each other (7.8 ± 1.2 and 6.6 ± 0.9 ha, respectively), but greater than that of the riparian meadows (0.6 ± 0.1 ha). As a result, although riparian areas comprised an average of only 4% of each grazed paddock by area, these communities provided a greater proportion of total available herbage production and removal than suggested by their area alone (i.e., 9.5 and 8.5% of absolute herbage use in the first and second rotations, respectively). Conversely, because riparian areas occupied only 4% of the landscape in this study, the majority of absolute forage biomass removed (i.e., > 90%) continued to be provided by upland grassland and forest communities.

Despite the apparent minor contribution of riparian meadows to livestock production at the overall landscape level, the conservation of these areas remains an important land-use objective. The results found here suggest that the use of high density, rotational grazing systems have the potential to generate uniform levels of relative use among diverse plant communities. This finding is important because it indicates that despite the greater absolute use within riparian meadows, all plant communities appear to be grazed to similar proportions near accepted "safe use levels" under this grazing system. Examined from the perspective of conserving individual plant communities, sufficient residual plant material appears to have been left across the landscape under the rotational grazing system employed here, thereby ensuring the conservation of each plant community type. Although this study did not look at different stocking rates, it should be noted that the use of greater stocking levels than those used in this study may lead to accelerating forage removal within riparian areas where foraging opportunities are greater, thereby increasing their susceptibility to eventual over-use and degradation (Platts 1990).

CONCLUSIONS

This study documented patterns of herbage use by yearling heifers grazing within a high-density, rotational grazing system, in an Aspen Parkland landscape of central Alberta. Heifers consistently removed the greatest absolute amount of graminoids from riparian meadows rather than upland grasslands and forests throughout the growing season. This supports the importance of riparian meadows in providing foraging opportunities (on a unit area basis) under this grazing system. In contrast, relative graminoid utilization among all three plant communities were similar, and indicated all plant communities were used at acceptable levels to ensure their long-term conservation. Riparian meadows also had greater concentrations of CP prior to 4 July, leading to greater levels of CP yield and CP utilized. Frequency of community visitation data corroborated the absolute utilization data, and indicated heifers visited riparian meadows sooner than the other community types, regardless of the date of grazing. In spring, heifers visited forest areas rather than upland grasslands, while the reverse was true later in the summer.

Collectively, these results indicate that although cattle foraged across the landscape in proportion to graminoid availability, they did remove greater biomass from meadows when rotationally grazed, highlighting their importance for commercial beef production in the Aspen Parkland. Results of this study also indicate riparian graminoid availability and quality both appear to be important variables influencing cattle grazing behavior within this environment.

Further research is recommended to assess the patterns of plant community use under different grazing systems, including other forms of rotational grazing and season-long grazing, as well as the impact of different stocking rates. Ultimately, this information can facilitate the development of more effective grazing management systems to simultaneously optimize livestock production and conserve important, grazing-sensitive habitats within the Aspen Parkland.

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