Vegetation response to seven grazing treatments in the Northern Great Plains

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Abstract

Grazing systems may alter botanical composition and productivity of grasslands through differential use in time, space, or intensity. Seven simulated grazing treatments were applied six years in eastern Montana, USA to determine effects on plant community composition and standing crop. Treatments were moderate stocking (28.8 AUD ha^{-1} year^{-1}) of cattle using 3-pasture summer rotation, season-long, high-intensity low-frequency, short-duration, 3-pasture winter rotation, and spring calving systems. The final treatment was severe growing-season grazing (108.2 AUD ha^{-1} year^{-1}). Treatments were randomly assigned to 14, 6.1-ha pastures. Post-treatment grass and total standing crops were 54 and 58% of their pre-treatment measures because of extended drought. No single grazing system affected standing crop of any herbage component. Standing crops of *Pascopyrum smithii* Rydb. (Love) (674 $\pm$ 186 kg ha^{-1}; $P > 0.69$), other perennial C$_3$ grasses (102 $\pm$ 156 kg ha^{-1}; $P > 0.77$), perennial C$_4$ grasses (178 $\pm$ 111 kg ha^{-1}; $P > 0.22$), and shrubs (13 $\pm$ 34 kg ha^{-1}; $P > 0.57$) were similar across grazing treatments. Severe grazing produced more forbs (142 $\pm$ 16 kg ha^{-1}; $P < 0.01$) than moderate stocking (67 $\pm$ 16 kg ha^{-1}). Annual C$_3$ grasses increased ($P < 0.01$) from 131 $\pm$ 55 kg ha^{-1} on pastures grazed after May to 362 $\pm$ 55 kg ha^{-1} on pastures grazed before June. Cacti also increased ($P < 0.03$) from 47 to 187 $\pm$ 52 kg ha^{-1} on early-grazed pastures. Greater total standing crop on pastures grazed before June ($P < 0.03$) was accounted for by increases in annual C$_3$ grasses and cacti. Rotational and continuous grazing strategies produced similar effects on all vegetation components. Grazing systems were not effective in altering standing crop or functional group composition one year after six years of treatment. Standing crop changes over time and limited shifts in forbs, cacti, and annual C$_3$ grasses indicate northern mixed prairie is most responsive to weather, with stocking rate and timing of grazing contributing minor influences.
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1. Introduction

Plant species composition and associated biomass of natural plant communities are controlled by a multitude of factors of which climate, soils, and herbivory are primary. Among these, herbivory is the single factor that management controls directly on grasslands. This control is achieved by managing forage demand through the manipulation of number and kind of animals over both time and space (Heitschmidt and Taylor, 1991). Number of animals is most often considered to be the primary factor because it is highly correlated with the frequency and severity of individual plant defoliation (Heitschmidt and Walker, 1996). Grazing systems, on the other hand, are strategically designed to control time of grazing (Vallentine, 1990).

Individual grazing systems are often promoted as a cure for perceived grassland management problems. However, studies of grazing systems over long periods are limited and those directly comparing more than a few grazing systems at a time are quite limited (Hart et al., 1988; Manley et al., 1997).

Among the grazing systems most commonly compared are year-long or growing-season-long continuous grazing, high-intensity low-frequency grazing, short-duration grazing, and various deferred-rotation systems. Previous research comparing two or three of these systems at similar stocking rates has generally shown that all grazing systems impact herbaceous standing crop and species composition in a similar manner (e.g., Hart et al., 1988; Thurow et al., 1988; Manley et al., 1997; Gillen et al., 1998) although some exceptions have been documented (Owensby et al., 1973; Taylor et al., 1993).

A fifth type of grazing commonly employed is repeated seasonal use, in which the same pasture is grazed annually at the same time of the year. Such use is often applied in conjunction with calving or lambing events. Although repeated seasonal use is often done to simplify animal management, such use may be expected to alter productivity and species composition because of seasonal differences in plant response to herbivory and subsequent effects on competitive plant interactions (Briske and Richards, 1994; Pieper, 1994). This is particularly so if use is severe, which is often the case.

Verifying the effectiveness of management strategies is crucial in achieving objectives and improving grassland resources. Although excellent reviews of grazing systems have been conducted (Vallentine, 1990), few have been able to directly compare a large number of grazing systems applied concurrently at the same stocking rate and on the same site. Grazing systems selected for study represented a continuum of high-utilization grazing and high-performance grazing tactics commonly applied, ranging from a multi-pasture, 1-herd, high-intensity, low-frequency grazing system (high-utilization tactics, HUG) to a 1-pasture, 1-herd continuous grazing system (high-performance tactics, HPG) (Booysen and Tainton, 1978). The primary objective of this study was to determine the impacts of six different grazing treatments, all stocked at the same moderate rate, on standing crop and functional group composition of a northern mixed prairie. Additional objectives were to contrast the impacts of severe grazing intensity and moderate stocking, and to assess the effects of season of grazing and pasture rotation on these grasslands to determine whether key general grazing management strategies could be identified across grazing systems. A very high stocking rate treatment was also included in the study to evaluate the stability of these grasslands as discussed by Archer and Smeins (1991). Perennial C_3 grasses dominate the region and are generally less tolerant of herbivory than the most common perennial C_4 grasses. Therefore, greatest potential for and magnitude of grazing effects are likely to exist within the perennial C_3 grasses. Our fundamental hypotheses were: (1) high-utilization systems would tend to impact plant biomass and functional group composition to a greater extent than high-performance systems; and (2) severe stocking would reduce herbaceous standing crop through the reduction of perennial C_3 grasses and exceed the effects of grazing system.

2. Materials and methods

2.1. Study area

Research was conducted in southeastern Montana, USA at the Fort Keogh Livestock and Range Research Laboratory, near Miles City (latitude 46°22′N, longitude 105°5′W, elev. 720 m). The region consists of rolling hills and broken badlands with broad river valleys. Vegetation is northern mixed prairie of the grama–needlegrass–wheat-grass potential vegetation type (Küchler, 1964). Long-term (1937–2004) mean annual precipitation is 340 mm, with about 65% occurring as rain during the mid-April to mid-September growing season (Western Regional Climate Center, 2004). Mean monthly temperatures range from −14 °C in January to 32 °C in July. Daily temperatures can exceed 38 °C during summer and be colder than −40 °C in winter.

Treatments were imposed across a contiguous 85-ha area with level to gently sloping (<2%) topography. Soils on the site were dominated by Sonnett loams (FOA: Calcic Luvisols; USDA: fine, smectitic, frigid Aridic Haplustalfs) and included a complex of Kobase silty clay loams (fine, smectitic, frigid Torrertic Haplustepts) and Gerdrum clay loams (fine, smectitic, frigid Torrertic Natrustalfs) on about 15% of the area. All soils were deep, well-drained, and formed from alluvium. The study site was used in the early 1980s as part of a rangeland improvement study. Original treatments were established in 1982 and consisted of: (1) soil tilling with a Range Improvement Machine (RIM); (2) drill seeding of alfalfa (*Medicago sativa* L.) after RIM tilling; (3) aerial seeding of alfalfa after RIM tilling; (4) contour furrowing; (5) nitrogen fertilization; and (6) mechanical brush shredding. Studies of the effects of these treatments on herbage standing crop and plant species composition between 1983 and 1990 revealed no treatment effects (Haferkamp et al., 1993).

During the eight years of this study (1996–2003), perennial grasses dominated the study pastures, with the most abundant being western wheatgrass (*Pascopyrum smithii* Rydb. [Love]) and blue grama (*Bouteloua gracilis* [H.B.K.] Lag. ex Griffiths). Sub-dominant perennial grasses were needle-and-thread (*Hesperostipa comata* [Trin. & Rupr.] Barkworth) and buffalograss (*Buchloe dactyloides* [Nutt.] Engelm.). The dominant annual grass was Japanese brome (*Bromus japonicus* Thunb.) with sub-dominants of cheatgrass (*Bromus tectorum* L.) and six-weeks fescue (*Vulpia octoflora* [Walt.] Rydb.). Needleleaf sedge (*Carex duriuscula* C.A. Mey.) and threadleaf sedge (*Carex filifolia* Nutt.) were the most abundant grass-like plants, but neither were large contributors to standing crop. Western salsify (*Tragopogon dubius* Scop.), dandelion (*Taraxacum officinale* Webber), and scarlet globemallow (*Sphaeralcea coccinea* [Pursh.] Rydb.) were the most common forbs, but all forbs combined were generally less than 6% of the herbaceous species composition by weight. The primary

succulent and shrub were plains prickly pear (*Opuntia polycantha* Haw.) and Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young).

2.2. Treatments

Seven grazing treatments were selected for study, six stocked at an identical moderate rate of 28.8 animal unit days (AUD) ha^{-1} year^{-1} (Table 1) and one stocked at the severe rate of 108.2 AUD ha^{-1} year^{-1}. Natural Resource Conservation Service recommended stocking rates for this site with 1000–1400 kg ha^{-1} forage production are 20–28 AUD ha^{-1} year^{-1} (NRCS, 2006). Moderately stocked treatments were: (1) 3-pasture, 1-herd, 15- and 30-day graze, twice-over summer rotation (3PR); (2) 1-pasture, 1-herd, season-long (SL); (3) 12-pasture, 1-herd, 24-day graze, 706-day rest, high-intensity low-frequency (HILF); (4) 15-pasture, 1-herd, 3-day graze, 42-day rest, short-duration grazing (SDG); (5) 3-pasture, 1-herd, winter rotation (3PRw); and (6) 1-pasture, 1-herd, spring calving pasture (SpC). There were three criteria governing the selection of these six treatments for study. First, we wanted treatments that would span Booysen and Tainton (1978) HUG-HPG continuum. In this study, the treatments representing the end points of this continuum are the HILF (HUG) and SL (HPG), with the four other treatments intermediate. Second, we wanted treatments that would, in varying combinations, simulate a year-long grazing regime. This was accomplished by applying all treatments, except the 3PRw and SpC, during the period from 1 June to 15 October. The 3PRw treatment was applied from 15 October to 20 March, which approximates the predominant period of weaning to calving in this region, and the SpC treatment was applied from 21 March to 31 May, which approximates the most common time of calving to branding in this region. The third criterion was that the treatments needed to be representative of systems applied in the northern mixed prairie. The seventh treatment was a severely grazed treatment in which high numbers of cattle grazed pastures intensively anytime forage availability exceeded scarce, with an average stocking rate of 108.2 AUD ha^{-1} year^{-1}. Severe grazing was included to evaluate the stability of these grasslands.

All treatments were twice-replicated and randomly applied to 14 adjacent pastures measuring 6.1 ha each. Multi-pasture rotational grazing treatments were simulated as a single pasture in the rotation. Treatments were temporally applied so as to simulate season-long grazing. Stocking rate for HILF was double that of other systems during grazed years, such that the average in a full cycle (two years) was equal to the moderate stocking rate, 28.8 AUD ha^{-1} year^{-1}.

Treatments were applied for six years from 1997 through 2002, allowing two cycles for 3PR, three cycles for HILF, 1.5 cycles for 3PRw, and six cycles for all other treatments (Table 1). The 3PRw treatment was not applied during the last period of the second cycle (December 6, 2002 through January 27, 2003). Depending on the year, pastures were grazed by either 454-kg cows or 350-kg steers. Animal breed varied slightly over the period, but all animals were moderately-framed crossbreds with at least 50% British breeding. A single source of water and standard loose mineral mix (12% Ca, 12% P, 27% salt, fortified with Cu, Zn, and vitamins A, B, and E) were provided in each pasture. Animal performance data were not collected because rotational treatments were simulated using put-and-take stocking procedures. A put-and-take procedure was also used to create the severely grazed treatment because animals could not maintain themselves for extended periods at that stocking rate (108.2 AUD ha^{-1} year^{-1}).

2.3. Sampling

A vegetation sampling area measuring 50 m × 50 m was selected within each pasture and permanently marked with steel posts at the beginning of the study such that all sites were similar in initial composition. Pre-treatment standing crops were estimated in July 1996 by clipping vegetation from 10 randomly located, circular 0.25-m^2 quadrats in each sample area. Standing crop was also measured from 10 quadrats per sample area between late June and mid-July during grazing treatment (1997–2002). Post-treatment estimates were derived from 20, 0.25-m^2 quadrats clipped in July 2003. Time since last grazed varied among treatments because of inherent differences in grazing schedules, but no grazing occurred on any pastures during

Table 1
Schedules of grazing systems applied from 1997 to 2002 on Fort Keogh Livestock and Range Research Laboratory near Miles City, Montana

Grazing system	Year(s)	Grazing dates
3-Pasture summer rotation	1997, 2000	1–15 June, 15 July–15 August
	1998, 2001	1–15 July, 15 September–15 October
	1999, 2002	16–30 June, 15 August–15 September
Season-long	1997–2002	1 June–15 October
High-intensity low-frequency	1997, 1999, 2001	4–27 June
Short-duration	1997–2002	1–3 June, 15–17 July, 28–30 August
3-Pasture winter rotation	1997, 2001	15 October–6 December
	1998–1999	6 December–27 January
	2000	27 January–20 March
Spring calving	1997–2002	21 March–31 May

2003. All herbage and cacti rooted within quadrats were clipped to ground level. Shrub leaves within the vertical projection of quadrats were collected to estimate shrub leaf standing crop. Vegetation was harvested by functional groups (i.e., grasses and grass-likes, forbs and half shrubs, cacti, and shrubs). Additionally, composition of the grass component was assessed using a dry-weight-rank (Gillen and Smith, 1986) and weighted based on sample standing crop of the grass component. Ranked composition components were western wheatgrass, other perennial C_3 grasses, perennial C_4 grasses, and annual C_3 grasses. Sedges were included with other perennial C_3 grasses. Because of the extended time required to dry cacti, the relationship between field and dry weights was determined early in the study and cactus dry weight thereafter was estimated as 20% of field weight. All other vegetation components were oven-dried to a constant weight at 60 °C and weighed to the nearest 0.01 g.

Precipitation was monitored on site from April through mid-November with a 0.2-mm graduated all-weather rain gauge (Productive Alternatives, Fergus Falls, MN). On-site, cold weather precipitation was assumed to be equal to that at the Miles City airport located 11.7 km from the study area (Western Regional Climate Center, 2004).

2.4. Statistical analyses

Data were tested for outliers using the maximum normal residual (Snedecor and Cochran, 1989) and summarized by replicate pasture. Pasture means were statistically analyzed as a completely randomized design using analysis of covariance and the GLM procedure of SAS with pre-treatment data as a covariate (SAS Institute Inc., 1989). The covariable was not significant for any of the tests and pre-treatment data were removed from the models. Analysis of variance using the MIXED procedure of SAS (Littell et al., 1996) was applied to pre- and post-treatment data to assess vegetation change over the study period and post-treatment data were analyzed alone to assess grazing treatment effects. Standing crop data from the treatment period were analyzed with analysis of variance to quantify differences in unused herbage between moderately and severely stocked pastures during treatment. Grazing systems were not compared using treatment period data because of differences in grazing schedules. Grazing treatments were analyzed as individual systems and as combinations of systems to allow comparisons between general management strategies controlling stocking rates, seasons of grazing, or pasture rotation *versus* continuous use. The six moderately stocked treatments were combined and compared against the severely grazed treatment to assess stocking rate effects. To contrast pre-June and post-May grazing effects, the 3PRw and SpC treatments were contrasted against the 3PR, HILF, SDG, and SL treatments. The 3PR, HILF, SDG, and 3PRw treatments were contrasted against the SL and SpC treatments to compare multi-pasture, rotational grazing treatments against single pasture, continuous grazing

treatments. Grass standing crop from 1996 through 2003 was modeled with April–May precipitation and grazing treatment as predictor variables and partial sums of squares were analyzed to assess relative contributions of precipitation and grazing treatment in explaining variation in standing crop. Significant differences were declared at $P < 0.05$ for all tests. Individual grazing system treatment means were separated with a protected LSD test.

3. Results

3.1. Growing conditions

Average growing conditions during the study tended to be droughty, particularly with respect to April–May precipitation (Fig. 1). However, precipitation was adequate for average or above-average plant growth during the pre- and post-treatment years of 1996 and 2003. During the six treatment years, annual precipitation was near-average three years and well below average three years, with spring precipitation average one year and below to well below average the other five years.

3.2. Standing crop

Grass standing crop decreased ($P < 0.01$) from 2097 ± 120 kg ha^{-1} to 1139 ± 120 kg ha^{-1} between 1996 and 2003 and total standing crop decreased ($P < 0.01$) from 2248 ± 104 kg ha^{-1} to 1309 ± 104 kg ha^{-1} in the same period. Forbs, cacti, and shrubs were each similar between years ($P > 0.19$). Changes in standing crop were primarily weather-related and not believed to be grazing effects as regression of total standing crop on April–May precipitation and grazing treatment indicated a partial r^2 of 0.50 for precipitation and a partial r^2 of 0.02 for grazing treatment. April–May precipitation explained 84% of the variation in mean annual standing crop across grazing treatments throughout the study period (Fig. 2).
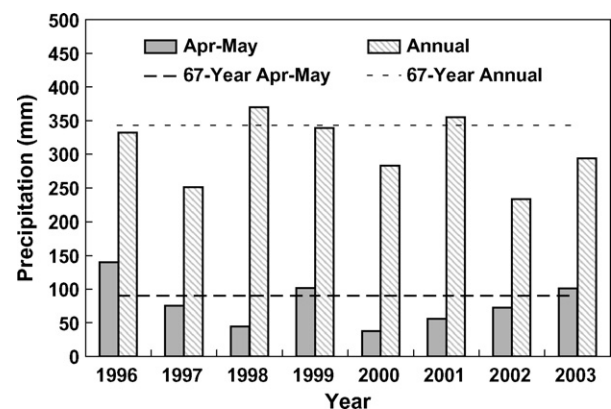

Fig. 1. Long-term (1937–2004) average annual and April–May precipitation totals at Miles City, Montana (Western Regional Climatic Center 2004) and study site precipitation from 1996 through 2003.
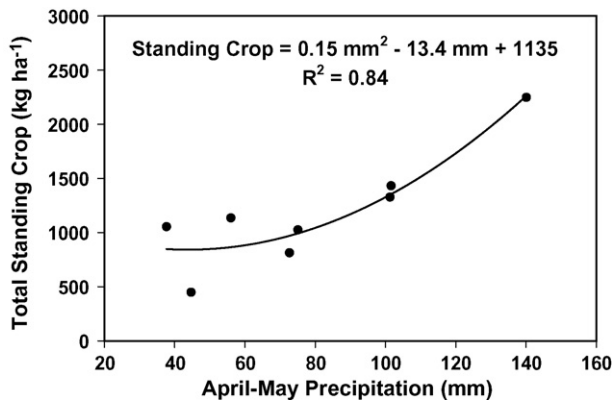
Fig. 2. Relationship between total standing crop across grazing strategies and April–May precipitation from 1996 through 2003 at Fort Keogh Livestock and Range Research Laboratory near Miles City, Montana.

Post-treatment standing crops were similar ($P > 0.05$) among individual grazing treatments for all but the forb component, which was greater ($P < 0.04$) with severe grazing than other treatments (Table 2). Although June grass standing crop was greater ($P < 0.01$) in moderately-grazed pastures (964 ± 87 kg ha^{-1}) than severely-grazed pastures (398 ± 87 kg ha^{-1}) during the treatment years of 1997–2002, post-treatment stocking rate effects were limited. Forb standing crop was more than two times greater ($P < 0.01$) in severely-grazed than moderately-stocked pastures (Table 3). Standing crops of the other vegetation components were similar ($P > 0.14$) between moderately and severely grazed pastures one year after six years of treatment. Despite the increase in forbs and lack of effect on other components, total standing crop trended ($P < 0.09$) toward a reduction in severely grazed pastures.

Forb and shrub standing crop were each similar between pre-June and post-May grazing treatments ($P > 0.16$; Table 3). Pastures grazed after May had 75% less cactus ($P < 0.03$) and 64% less annual C$_3$ grass standing crop than early-grazed pastures ($P < 0.01$). Standing crops were similar between pre-June and post-May grazing treatments for western wheatgrass ($P > 0.22$), other perennial C$_3$ grasses ($P > 0.53$), and perennial C$_4$ grasses ($P > 0.15$). Pastures grazed before June had greater total standing crop ($P < 0.04$), largely because of greater cactus and annual C$_3$ grass standing crop. However, grass standing crop was similar ($P > 0.25$) between treatments. No differences in standing crop were observed between rotational and continuous grazing treatments for any vegetation component ($P > 0.12$; Table 3).

3.3. Functional group composition

The relative contributions to total standing crop for western wheatgrass (51 ± 9%; $P > 0.44$), other perennial C$_3$ grasses (9 ± 12%; $P > 0.81$), perennial C$_4$ grasses (15 ± 10%; $P > 0.24$), cacti (4 ± 4%; $P > 0.29$), and shrubs (1 ± 3%; $P > 0.58$) were similar across grazing treatments. Forbs were

6 ± 2% of the standing crop in moderately-grazed pastures and increased ($P < 0.01$) to 12 ± 2% in severely-grazed pastures (Fig. 3). Trends existed for annual C$_3$ grasses to be a smaller percentage of the standing crop ($P < 0.08$) in severely-grazed (3 ± 6%) than moderately-stocked pastures (15 ± 6%) and for shrubs to be a larger component ($P < 0.06$) in severely-grazed (4 ± 2%) than moderately-stocked pastures (1 ± 2%). Annual C$_3$ grasses were more dominant ($P < 0.02$) on pastures grazed before June (22 ± 4%) than those grazed after May (11 ± 4%; Fig. 3). Similarly, cacti comprised 9 and 3 ± 3% of the total standing crop in pre-June and post-May grazed pastures ($P < 0.05$). Perennial C$_4$ grasses trended ($P < 0.07$) toward a lesser portion of the total standing crop in pastures grazed before June (6 ± 6%) than those grazed after May (19 ± 6%). Rotational and continuous grazing treatments produced similar contributions from western wheatgrass (49 ± 5%; $P > 0.17$), other perennial C$_3$ grasses (9 ± 7%; $P > 0.77$), perennial C$_4$ grasses (15 ± 7%; $P > 0.90$), annual C$_3$ grasses (15 ± 5%; $P > 0.91$), shrubs (1 ± 1%; $P > 0.17$), forbs (7 ± 2%; $P > 0.37$), and cacti (5 ± 3%; $P > 0.64$).

4. Discussion

Results indicate that standing crop and functional group composition in northern mixed prairie were responsive to stocking rate and season of grazing, but resistant to grazing system. Similar plant responses among grazing systems led to a rejection of our first hypothesis, that high-utilization systems would affect standing crops and functional group composition to a greater extent than high-performance systems. Results were partially supportive of our second hypothesis in that stocking rate effects exceeded those of grazing system, but severe grazing did not reduce perennial C$_3$ grasses as we predicted. Conditions potentially affecting these results include the site examined, climatic conditions during the study, and the duration of treatments. The low productivity of arid and semiarid regions limits response capacity and reduces the potential accumulation of dead material contributing to standing crop. Generally droughty conditions (Fig. 1) during the six years of treatment also could have limited response capacity, but should not be viewed as exceptional because drought is a defining characteristic of arid and semiarid grasslands. Although results clearly indicate standing crop and functional group composition were resistant to grazing system, the limits of that resistance were not identified and grazing-induced changes in plant communities may occur with more than six years of exposure to the grazing systems examined.

Standing crop reductions observed between 1996 and 2003 were primarily related to differing climatic conditions, particularly April–May precipitation (Fig. 1). April–May precipitation was abundant in 1996 and generally lacking thereafter. Heitschmidt and Vermeire (2005) and others have shown annual herbage production in this region is closely

Table 2

Mean standing crop and standard errors by vegetation component and grazing treatment one year after grazing (1997–2002) at Fort Keogh Livestock and Range Research Laboratory near Miles City, Montana

Vegetation component	Grazing treatment							S.E. (kg ha^{-1})
	Season-long (kg ha^{-1})	Spring calving (kg ha^{-1})	3-Pasture winter rotation (kg ha^{-1})	High-intensity, low-frequency (kg ha^{-1})	Short-duration (kg ha^{-1})	3-Pasture summer rotation (kg ha^{-1})	Severe grazing (kg ha^{-1})	
Pascopyrum smithii	534	717	796	599	591	810	672	186
Perennial C$_3$ grass	90	131	15	194	212	33	41	156
Perennial C$_4$ grass	242	123	79	379	162	78	180	111
Annual C$_3$ grasses	88	383	341	84	179	176	44	97
All grass	954	1354	1231	1256	1143	1097	937	269
Forbs	66 b[a]	64 b	77 b	92 b	53 b	52 b	142 a	21
Cacti	105	215	159	3	16	63	0	89
Shrubs	0	54	0	0	0	0	35	34
Total	1125	1687	1467	1351	1212	1212	1113	273

[a] Grazing treatment means followed by different letters within a vegetation component differ ($P < 0.05$).

Table 3

Mean standing crop and standard errors by vegetation component and grazing strategy comparing moderate vs. severe stocking, pre-June vs. post-May grazing, and rotational vs. continuous seasonal stocking in 2003

Vegetation component	Grazing strategy								
	Stocking rate			Season of grazing			Rotation strategy		
	Moderate (kg ha^{-1})	Severe (kg ha^{-1})	S.E. (kg ha^{-1})	Pre-June (kg ha^{-1})	Post-May (kg ha^{-1})	S.E. (kg ha^{-1})	Rotation (kg ha^{-1})	Continuous (kg ha^{-1})	S.E. (kg ha^{-1})
Pascopyrum smithii	674	673	135	756	634	96	699	626	101
Perennial C$_3$ grass	113	41	107	73	132	92	113	111	94
Perennial C$_4$ grass	177	179	104	101	215	74	175	182	82
Annual C$_3$ grasses	208	44	105	362 a[a]	131 b	55	195	235	90
All grass	1172	937	185	1292	1112	149	1182	1154	159
Forbs	67 b	142 a	16	70	65	10	68	65	10
Cacti	94	1	78	187 a	47 b	52	60	160	61
Shrubs	9	36	25	27	0	18	0	27	18
Total	1360	1005	188	1577 a	1224 b	144	1310	1406	180

Grazing strategies were applied from 1997 to 2002 on Fort Keogh Livestock and Range Research Laboratory near Miles City, Montana.

[a] Stocking rate, season of grazing, or rotation strategy means followed by different letters within a vegetation component differ ($P < 0.05$).
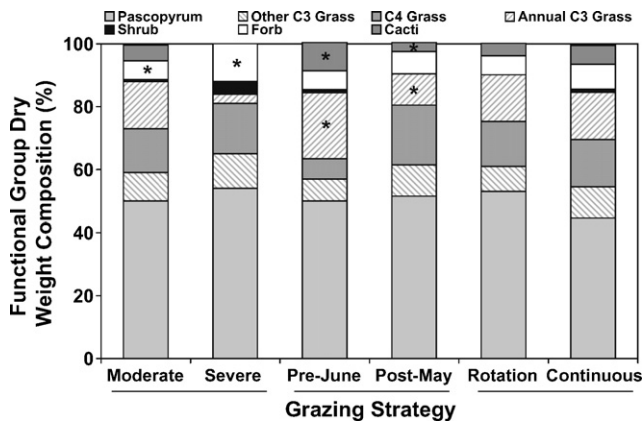
Fig. 3. Percent dry weight composition based on functional group standing crop comparing moderate vs. severe stocking, pre-June vs. post-May grazing, and rotational vs. continuous seasonal stocking 1 year after grazing (1997–2002) on Fort Keogh Livestock and Range Research Laboratory near Miles City, Montana. Functional group means marked with asterisks differ within a stocking rate, season of grazing, or rotation strategy ($P < 0.05$).

and positively related to April–May precipitation. In addition, annual monitoring of early summer standing crops (i.e., near time of peak standing crop) inside and outside Fort Keogh livestock exclosures reflected similar reductions in standing crop during the same period (file data).

The absence of stocking rate effects on graminoid functional groups was somewhat unexpected in that western wheatgrass typically decreases with severe use (Reed and Peterson, 1961; Everson, 1966; Launchbaugh, 1967; Manley et al., 1997). The similarity between stocking rates does not definitively rule out the possibility that western wheatgrass decreased with severe use during treatment years (i.e., 1997–2002); rather it may simply indicate recovery was rapid with the release from grazing coinciding with near-average spring precipitation. Previous work at Fort Keogh showed that western wheatgrass recovered rapidly following periods of drought and grazing (Eneboe et al., 2002). The absence of a warm-season grass response was not surprising in that blue grama, the dominant warm-season grass, is known to tolerate grazing (Milchunas et al., 1990; Manley et al., 1997; Hart and Ashby, 1998). Annual brome biomass and seed production may be expected to decrease with severe defoliation during growth (Hulbert, 1955; Haferkamp and Karl, 1999). Although this effect was not realized in annual C_3 grass biomass or percent composition, the trends toward reductions in each indicated severe use has the potential to reduce annual C_3 grasses over time. Japanese brome is reduced by low autumn precipitation and reduced litter cover (Whisenant and Uresk, 1990; Haferkamp et al., 1993). Generally dry conditions during the grazing period and the dry autumn preceding the post-treatment year were not conducive for annual brome production and could have dampened any stocking rate effect on that component.

Stocking rate is commonly considered a primary, if not the most significant, factor affecting plant community

response to herbivory. Moderate stocking would be expected to result in greater standing crop than severe stocking during the grazing period (Heitschmidt et al., 1989). That shifts in standing crop and functional group composition were limited to forbs, which remained a small component, indicates the plant community was resistant to stocking rate effects, or it was quite resilient, with recovery within a single growing season. This position is further supported by the fact that the sole component responding to stocking rate, forbs, was not more abundant in HILF pastures, which were grazed at double the moderate rate and completely rested in alternating years. Two factors could have contributed to the response to stocking rate. Drought conditions for five of the six treatment years (Fig. 1) and reduced standing crop may have moderated the stocking rate effect by making utilization relatively high for both stocking rates. Secondly, previous years' biomass comprises only 10–25% of the standing crop in grazed grasslands of the northern mixed prairie (Singh et al., 1983). Therefore, only a fraction of differences between stocking rates via previous years' standing dead material would have directly influenced post-treatment standing crop. These findings are in agreement with those of Gillen et al. (2000) who also reported minimal stocking rate effects over a seven-year period in southern mixed prairie. However, increased forb standing crop and apparent trends toward greater reductions in total standing crop indicate longer exposure to severe grazing may cause larger shifts in standing crop and functional group composition. With longer exposure, basal cover at the site (Olson et al., 1985) and forage production in shortgrass steppe (Milchunas et al., 1994) were responsive to stocking rate as it interacted with precipitation.

The greater total standing crop in early-grazed pastures does not appear to support a general supposition that grazing before June is detrimental to these grasslands (Table 3). However, increased biomass on early-grazed pastures was accounted for almost to the kilogram by annual C_3 grasses and cacti. Although precise grazing prescriptions have not been developed for annual brome control (Haferkamp and Karl, 1999), increased annual C_3 grass standing crop could be expected on pastures grazed before June. Annual bromes would have received little or no grazing pressure during growth with 3PRw. Bromes were probably grazed during growth on SpC pastures, but cattle were removed at the end of May, leaving a few weeks of the primary brome growing season for recovery. Reduced standing crops of other species during late spring could favor prickly pear propagation and growth because it is during late spring and early summer that prickly pear seeds germinate and pad growth is most rapid (Turner and Costello, 1942). Weather and associated microclimates have generally been shown to play a major role in cactus abundance (Turner and Costello, 1942; Reed and Peterson, 1961; Houston, 1963; Bement, 1968; Hart, 2001).

Similarities between rotational and continuous grazing system effects support results from southern mixed prairie

(McIlvain and Savage, 1951), northern mixed prairie (Manley et al., 1997), and tallgrass prairie (Owensby et al., 1973; Gillen et al., 1991, 1998) that also observed weak vegetation responses to rotational systems. Although one of the intended benefits of rotational grazing is to allow plant growth and recovery between defoliation events, the frequency of defoliation may not be affected by livestock rotation (Hart et al., 1993). Opportunities for plants to respond to rest periods were limited by dry conditions throughout much of the study. However, the majority of plant growth is normally restricted by climate to mid- and late spring in the northern mixed prairie (Heitschmidt et al., 1995; Haferkamp and Karl, 1999) and drought is not uncommon. Considerable spring rest periods were afforded SDG and neither HILF pastures nor 3PRw pastures were utilized during the growing season. Given the general absence of any post-treatment shifts in composition, it appears that these grazing systems either did not affect plant functional group composition appreciably, or the changes lasted less than a year.

5. Conclusions

Grazing systems are often proclaimed to be viable options for enhancing the productivity and ecological condition of grasslands. However, no individual grazing system investigated in this study effectively altered standing crop or functional group composition relative to other grazing systems. The greatest changes in standing crop were climate-related. Therefore, selection of grazing strategies should not be based primarily on the premise that a particular system or the implementation of pasture rotations will hasten alterations in standing crop or plant community composition.

The greatest opportunity for affecting the plant community appears to be through controlled timing of spring grazing and stocking rate. The increased prominence of annual C_3 grasses and cacti indicate considerable potential exists for shifting species composition with annual grazing before June. Standing crop and functional group composition were similar between stocking rates one year post-treatment, with the exception of forbs. However, severe use reduced grass standing crop during treatment and drought reduced differences in forage use between stocking rates during the driest years. Therefore, results of this study should not be interpreted as condoning a general application of severe grazing, or suggesting community structure and productivity would remain unchanged over longer periods or across environmental conditions.

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